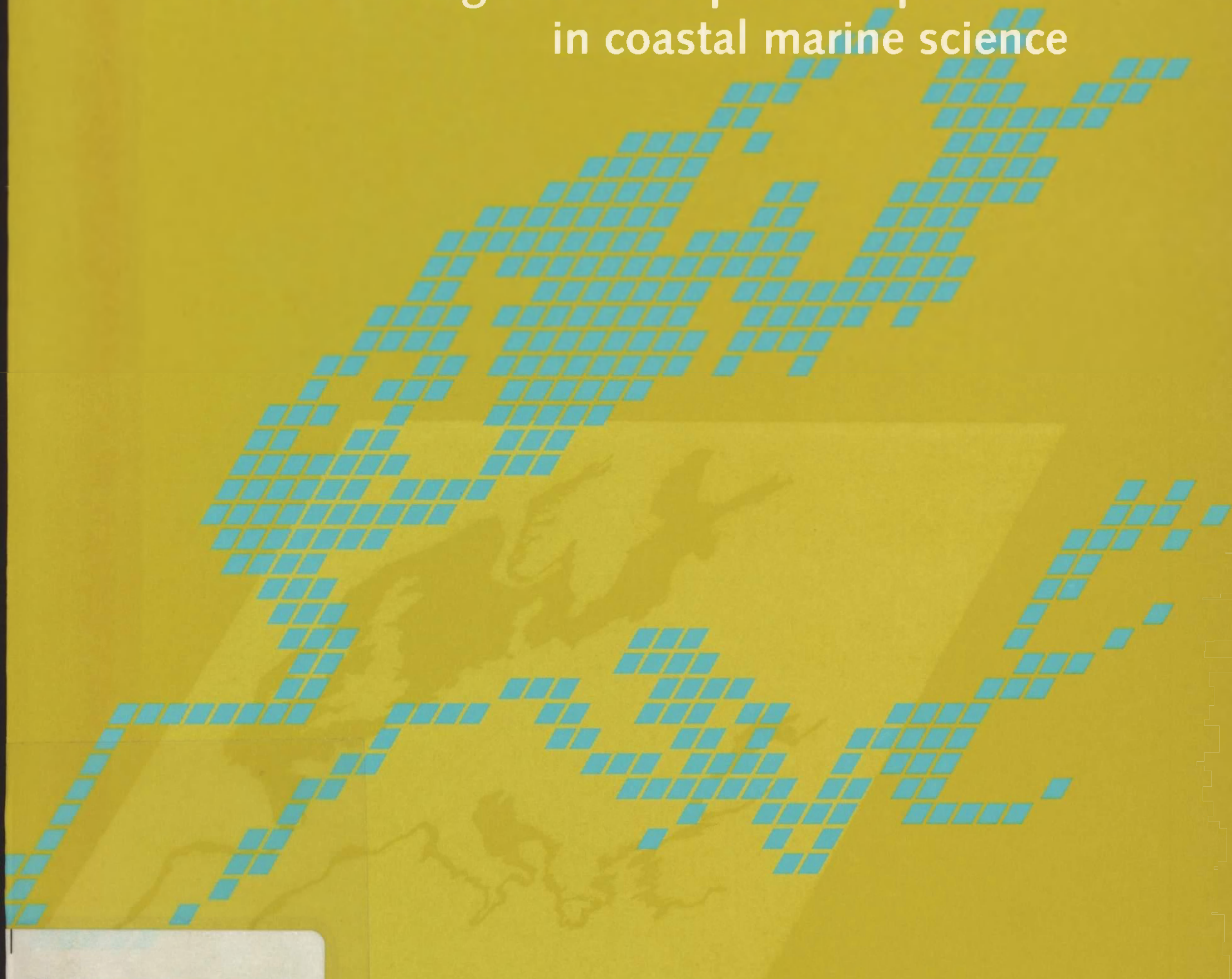
Prediction of Change in Coastal Seas

Grand challenges for european cooperation in coastal marine science



Outcome of the ECOPS-Euroconference

Prediction of Change in Coastal Seas

grand challenges for european cooperation in coastal marine science

Outcome of the ECOPS Euroconference held in Port d'Albret, France
19-24 June 1993

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Executive summary

The long-term response of the coastal zone to human intervention and to changing external factors cannot be predicted within the present state of knowledge.

An increase in human activities affecting the coastal zone is occurring, not only on the European shelves, but also on a global scale. Expanding population centres, especially those situated around the deltas of major world rivers, have particular impact. Additional stress will be put on coastal zones by climate change and sea level rise. Important social and economical interests are at stake.

It is therefore necessary and timely to start a coherent research programme aimed at developing shelf sea prediction systems. This represents a major challenge requiring a dedicated strategy for investigating change in the coastal zone at an international level.

The key elements of such a strategy were identified during the European Conference on "Prediction of Change in Coastal Seas", held in France from 19 to 24 June 1993. These elements are:

- Identification and investigation of relevant physical, chemical and biological processes and their interactions, in particular those involving feedback effects in coastal systems,

- Integrated modelling of these processes over a wide range of scales and including their complex and non-linear interactions, aiming at long-term predictive capability,

- Long-term observation programmes in the coastal zone and large-scale experiments of limited duration; the development of required observation techniques.

The Conference brought forward recommendations highlighting specific technical and scientific challenges. For instance:

- Process studies should in particular address the zones where there is greatest dynamic interaction between physical, chemical and biological processes: the interface zones between water and sediment and between sea and air and the frontal zones between different water masses.

- The development of observational technologies for long-term and large-scale observations should be actively promoted; consideration should be given to the launch of satellite systems specifically designed for coastal zone observation.

- In order to identify contaminants and other stresses on the ecosystem, molecular biological and biochemical methods should be further developed. Serious attention is necessary for the genetic adaptation of species, the dispersal of genetically modified organisms and the consequences for the marine ecosystem.

The above lines of research and development should not be pursued in isolation. The integration of various advanced observation and prediction techniques would greatly improve their contribution to long-term predictibility.
Based on this consideration, the Conference formulated the following "Grand Challenge" for future coastal marine science:

to create a predictive generic framework in which advanced observation techniques, infrastructure for large-scale experiments, dynamic description of key processes, integrated modelling, data-assimilation and data management techniques are brought together, further developed and funded.

Such a framework would be an important instrument for research planning, coastal monitoring and prediction and coastal zone management. It would provide the scientific basis for national, regional or global coastal observation and information systems and should provide the design premises for the further development of the technologies specifically needed for the coastal zone.

Elaboration of the strategic objectives formulated at the Conference should take into account both the national research programmes of the European states and wider international activities such as GOOS, IGBP (in particular LOICZ) and IPCC. A clearly identified European contribution to these programmes will improve research cooperation within Europe and worldwide.

The coastal marine science and technology community should be actively involved in the search for adequate solutions to the high development and pollution stresses imposed on the coastal zone and to the impacts of climate change. A second Grand Challenge has therefore been formulated:

to create mechanisms to improve the communication with socio-economic experts, with management authorities and with users of coastal marine systems.

This is an essential requirement for successful management of the great changes expected to occur over the coming decades on the national, European and global scale.

The conference excursion took the participants to the dune de Pyla, the highest dune along the European coast, situated at the entrance of the Baie d'Arcachon. This remarkable coastal feature illustrates the limitations of present predictive capabilities; the morphodynamic processes responsible for its development during the past centuries are not yet well understood.

Contents

Introduction

The Euroconference on "Prediction of Change in Coastal Seas" took place in Port d'Albret (France) from 19 to 24 June 1993.
The objective of the Euroconference was:

> "to identify grand challenges for European cooperation in coastal marine science leading to significant progress in predictive modelling of coastal seas".

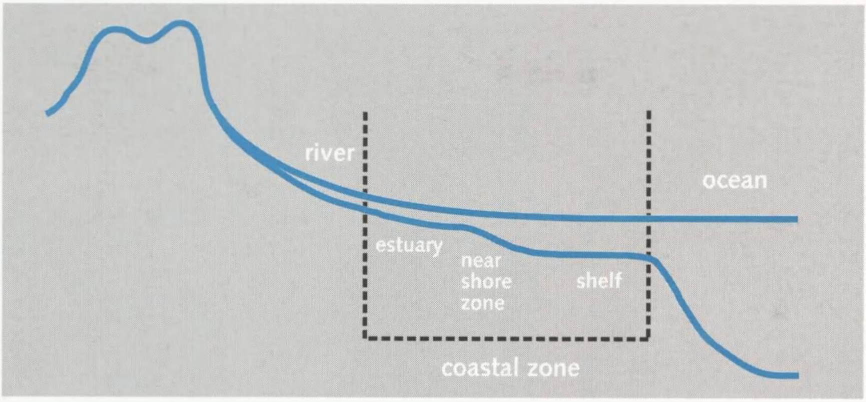
This objective is situated in the context of the great changes expected to occur in the coastal marine environment over coming decades on the local, regional and global scale. New instruments will be required for the comprehensive management of these changes and for the identification of sustainable policy options. The achievement of an adequate response will be heavily dependent on innovative thinking and the development of appropriate technologies.

The European Committee on Ocean and Polar Science (ECOPS) has assigned the Coastal Zone Steering Group (CZSG) the task of advising on a future research strategy, reflecting the views of the European coastal marine science and technology community. Members of the CZSG are:

J. Dronkers	(NL, chairman),
J.M. Martin	(FR, vice-chairman),
G.M. Bozzo	(IT),
B.S. McCartney	(GB),
P. Chardy	(FR),
C. Heip	(NL),
P. Holligan	(GB),
L.P. Roed	(NO),
W.P.M. de Ruijter	(NL),
A. Sànchez-Arcilla	(ES),
M.B.A.M. Scheffers	(NL, secretary),
J. Sündermann	(DE).

The present report has been produced by the CZSG, based on the outcomes of the Euroconference.

At the Conference leading researchers were asked to present their views on major shortcomings in the present state of knowledge with respect to the prediction of change in coastal seas over decadal time scales. They were also asked to indicate existing barriers limiting present predictive capabilities. The presenters then joined young scientists to discuss these views in groups, each dealing with a different sub-theme. The task of these groups was to propose grand challenges for future European cooperation in coastal marine science. The group reports, which were prepared during the Conference, are reproduced in the next sections.



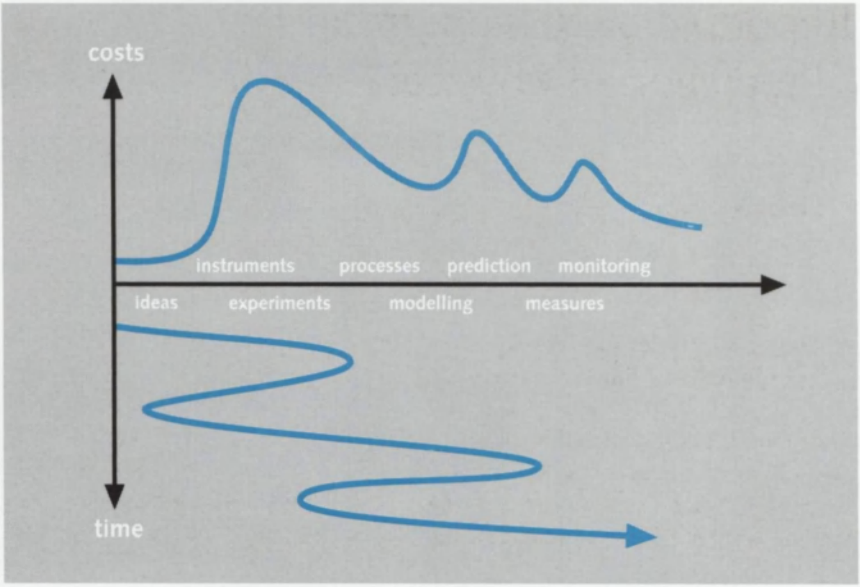
The coastal seas considered at the Euroconference cover the marine environment from shelf break up to estuary.

The group reports reflect the major conclusions reached by each group. The subjects assigned to each group represent different approaches to the Conference theme:

- prediction of physical change
- prediction of ecological change
- integrated prediction
- sustainable development
- research instrumentation and infrastructure

The sub-themes cover broad and partially overlapping fields of research. Any complete coverage of all scientific aspects would exceed the ambitions of the Conference. However, due to their different approaches, the keynote presentations and the group discussions together present a view of the Conference theme from many different angles.

For the identification of "grand challenges" a step-by-step approach is adopted. The first step consists of a general survey of coastal change: potential threats to and opportunities for the development of the coastal marine environment. If the trends of the last decades continue or accelerate, a tremendous change in the structure and use of the coastal zone will result. Averting this risk demands the development of a pertinent and timely response strategy.



The evolution of a research theme in general does not follow a straight path from first recognition to final solution and implementation. In the course of research new discoveries may force to reconsider previous assumptions and to iterate earlier research steps. At several stages of the research process important investments may be required to prepare the next step, for example, for the development of an experimentation programme, for the development of a modelling system or for the development of a monitoring programme. If such investments exceed national capabilities, then a challenge arises for international cooperation.

The second step consists of defining the particular contribution that coastal marine science may be able to make to the elaboration of such a strategy and to its implementation. Predicting the status of the coastal zone in 2030 can be considered as a conceptual experiment to test our capacity to describe the basic processes and to integrate them in a predictive system. This experiment should reveal major shortcomings in data and knowledge, relating to basic processes, their interactions and forcing functions.

The third step is to identify current barriers to the acquisition of relevant knowledge and instruments. The removal of these barriers requires specific research initiatives in possession of the necessary facilities. If the provision of resources for such research initiatives exceeds the capacity of individual nation states, then this constitutes a challenge for European cooperation.

Report of discussion group on "Prediction of Physical Change"

1. Introduction

The group discussions have been focused on

- physical variables and processes of coastal seas
- possibilities and limitations of prediction on time scales of a few decades

The group is being aware, that physical processes are only one part of the coastal system and that interactions with chemistry, biology, socio-economic issues can not be neglected in many cases. There are nevertheless grand challenges in predicting the coastal future which are related mainly to physics.

Looking ahead to 2030 does not necessarily mean that short-term and small-scale phenomena are not relevant. They must be investigated as far as their understanding is crucial for long-term prediction.

2. Physical changes to be considered

- **Climate forcing**
  The coastal seas are externally forced by the atmosphere and the adjacent waters of the shelf and the ocean. These boundary conditions are underlying climatological changes themselves (e.g. sea level rise).

- **General circulation parameters**
  Water motion (currents, tides, waves), temperature, salinity, density, transparency, ice

- **Atmospheric parameters**
  Air pressure, wind, precipitation

- **Morphology**
  Sediment transport, erosion and deposition, shoreline motion

3. Nature of changes and predictability

It is obvious from observations that physical parameters vary on several time scales. One relevant scale is the long-term change which is of the order of a few decades. But it is not known to what extent the changes are due to the statistical variability of the system, due to climate change or due to direct impact of man (which presumable have the greatest influence).

The climate changes and the human interventions are external conditions, controlling the coastal system, but both are unpredictable. What can be done, is the execution of scenario studies of possible future changes.

The challenges are

- to develop methods of long-term prediction of physical parameters as a function of the external conditions;

- to study the applicability of linear and non-linear prediction techniques for the physical environment;

- to consider scenarios which demonstrate the range of possible developments of the coastal seas.

4. Individual views of group members

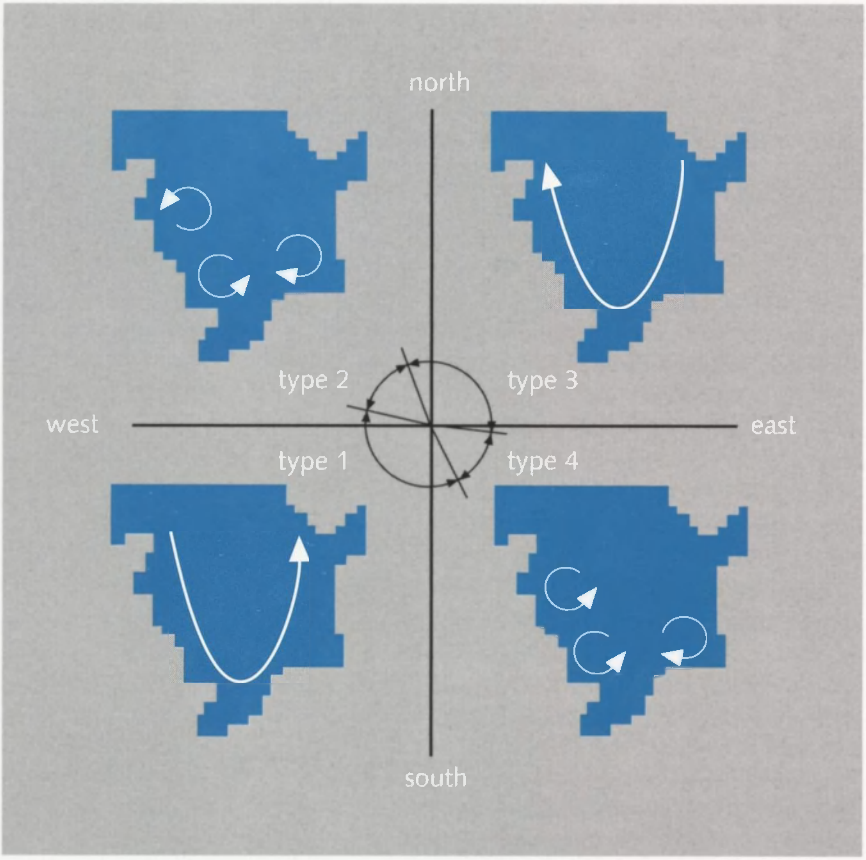
Being aware of the aforementioned background the participants specified a number of challenges based on their personal views:

Boundary conditions

- the impact of climate change on the coast (natural climate variability and direct man-made influence)
- better representation of the regional climate
- interaction of shelf seas and coastal waters
- impact of man-made structures on coastal dynamics
- coupling of atmospheric and ocean model on a regional scale

Processes in morphology

- physical understanding of larger scale geomorphological entities (open coast, tidal basins, estuaries, deltas) by using theory, modelling and observation (in situ, remote sensing, geology)
- morphodynamics of intermediate scale entities (longshore bars)
- sediment transport processes (better experimental data sets, improved models)
- development of long time series of morphological phenomena and analysis of underlying dynamics
- sediment transport models with topography
- impact of extreme events



Circulation patterns in the North Sea depend on the wind direction. Presently the cyclonic circulation (TYPE 1) with short flushing times is dominating. A climate change can rapidly lead to more blocking situations (eg. TYPE 2) affecting the North Sea ecosystem. Better insight in climate variability is essential for the prediction and assessment of long term change in coastal systems. Present global climate models are not yet capable to provide the necessary regional climate information.

Hydrodynamic processes

- flow stratification in extreme events (modelling and experiments)
- nonlinear interactions of currents and waves over topography
- dynamics of the wave breaking zone
- benthic and pelagic processes (interaction of physics and biology)

General approach

- stepping back to 1900: prediction until 1995

5. Main barriers

On the basis of the preceding discussion the group identified the following main barriers for a long-term prediction of physical changes in coastal seas.

- The missing coupling of water motion, sediment transport and morphology on time scales of a few decades.
  Separate models of hydrodynamics, sediment transport and morphodynamics in coastal seas are existing, but no integrated approach with a predictive capability in the range of decades.

- The lack of appropriate field data for the formulation, testing and verification of such a coupled model.
  The major processes must be identified, parameterized for the needs of a predictive model in the long-term range. The model then must be tested and verified against field data. Required are a better resolution in time and space, synoptic data sets and monitoring programs supporting parallel model developments and runs. Furthermore a data base forming a reference state of coastal waters is necessary for scenario calculations.

- The unavailability of forcing functions for the regional scale from climate change scenarios.
  The respective climate models do not resolve the coastal waters.
  Downscaling techniques providing regional information from global models must be developed and applied.

6. A major challenge

Considering the individual views and the specified main barriers the group summarizes that all required research efforts can be grouped under one major challenge:

> **Integrated modelling of water motion, sediment transport and morphology aimed at a prediction of coastal evolution in the decadal range**

This theme includes the investigation of all relevant scales, the establishment of an appropriate data base and the necessary improvement of models. For a clearer specification the following "subchallenges" are identified (adding a few keywords).

- Improvement of models
  (scales, processes, coupling, parameterisation, upscaling)
- Role of biology in morphodynamics
  (biogeomorphic processes, biogenic sediment supply, particle size, cohesiveness, filtering organisms)
- Comprehensive field experiments
  (high resolution, synoptic, new instruments,reference state)
- Operational nowcast of coastal dynamics
  (monitoring, satellites, data-assimilation)
- Relative importance of the causes to change:
  direct man-made, anthropogenic climate change, natural climate variability, internal dynamics of coastal seas
  (including role of extreme events)
- Downscaling of climate model results to get the forcing for predictive regional models
- Boundary conditions of the coastal system
  (interaction with the deep ocean, adjacent shelf seas, rivers, land)
- Stepping back to 1900:
  Prediction of coastal changes until 1995

Participants in group discussions:

D.J.R. van den Eynde (BE, rapporteur), H. Howa (FR), J. Lanckneus (BE), I. McCave (GB), J. Murphy (IR), T. Pohlmann (DE), H.L. Rouse (GB), M.B.A.M. Scheffers (NL), M. Stive (NL), H. von Storch (DE), J. Sündermann (DE, chairman), H. de Swart (NL), F.F.M. Veloso Gomes (ES).

Report of discussion group on "Prediction of Ecological Change"

Major challenge:
To predict the effects of change in climate and man's impact on coastal ecosystems

1. What are the limitations?

- Inherent unpredictability
  Many states and processes in systems are of limited predictability. It is mostly unknown what the limits of predictability of ecological processes are and how to deal with phenomena that are unpredictable
- Lack of adequate concepts
  The scientific basis for determining ecosystem characteristics applicable in the management and restoration of marine systems, eg. sustainability, stability, resilience, stress is not yet strong enough.
- Lack of fundamental knowledge
  In many areas of marine ecology a lack of knowledge still exists of basic processes. A few examples are given to illustrate this.

First example:
To predict the effects of eutrophication on coastal systems we need to develop predictive operational models of the response to qualitative and quantitative changes in nutrient inputs. For this we need e.g.:

- study of the energy allocation characteristics of phytoplankton and benthic populations as a function of increasing nutrient and food availability
- data and models on nutrient delivery by river systems to the coastal seas as influenced by economic activity, changes in land use and biogeochemical processes in the river basin and the estuaries
- historical studies of eutrophicated systems
- studies of sedimentation of phytoplankton blooms and their effect on benthic structure and metabolism

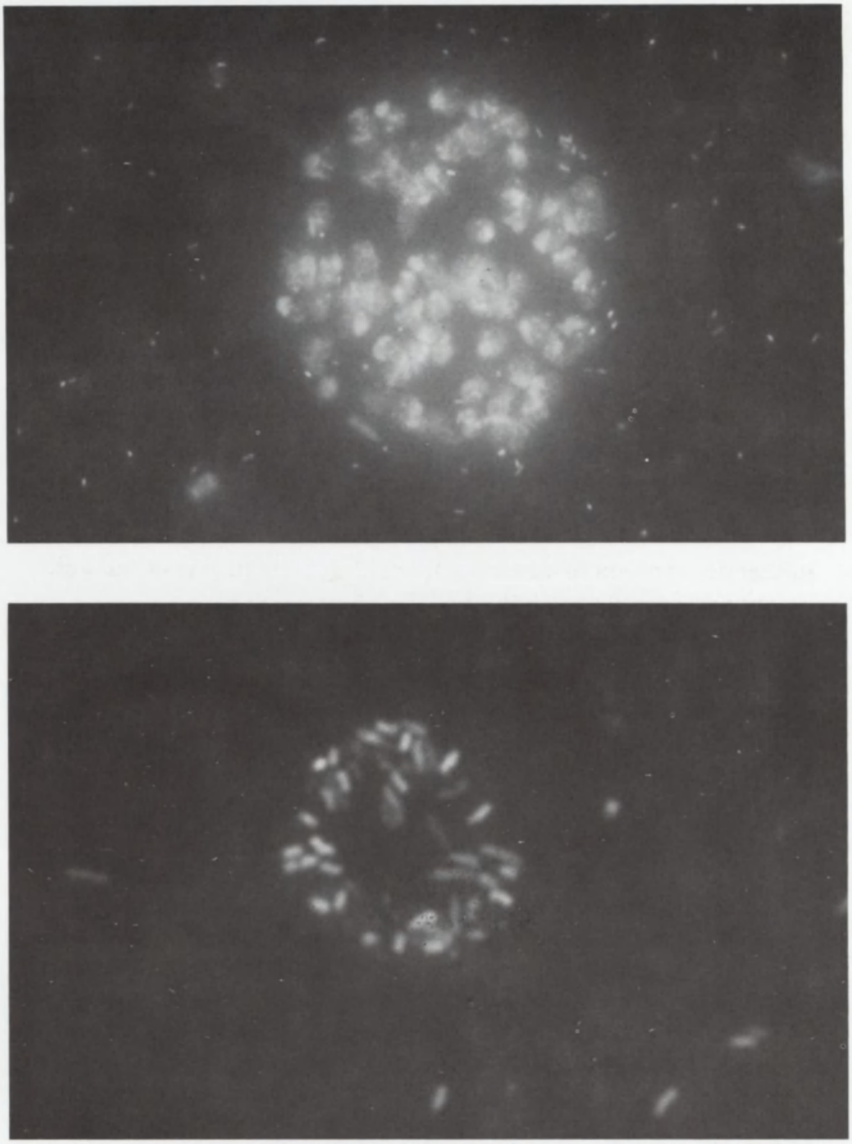
Second example:
Ecological models necessarily have to reduce the biological complexity of the system. In order to do so properly we need:

- to determine the level of discrimination which is acceptable for predictive purposes

- to determine the relationships between biological types and functions
- to simplify diversity of communities to a small number of functional units chosen to be able to reflect the change in biological diversity while still describing the variety of geochemical processes in the system (taxonomy of functional types)
- to determine factors that can cause major shifts in population distribution and abundance of key species in communities
- to examine the potential of species to adapt to and to compensate for changes in coastal environment, particularly at genetic, physiological, population and community levels.

Third example:
In order to understand how ecosystems function we need to understand the interactions between biological, chemical and physical processes. For this it is necessary:
- to understand the characteristic spatial and temporal dimensions of important biological phenomena and to establish coherence between biological and physical scales
- to describe spatial heterogeneity and patchiness
- to identify functional biological types in relation to homogeneous units describing the physical environment
- to document and understand the functional aspects of biodiversity
- to understand relationships between chemical and physical perturbations and biological feed-backs: what are the selective pressures and what is the phenotypic plasticity of marine organisms; what is the relationship between benthic biology and sediment chemistry and physics; what are the relationships between phytoplankton blooms and atmospheric chemistry; what is the influence of extreme and stochastic events?

To the lack of fundamental knowledge on processes in many areas of marine ecology we need to add the lack of even basic knowledge in certain other areas:
- marine microbiology (how many bacterial metabolic types exist?)
- effects of diseases (viruses, bacteria, protozoans) on population dynamics.
- detection and effect studies of xenobiotics, especially organic products such as antibiotics, mutagenic substances, solvents etc.
- consequences of natural selection and evolutionary adaptation to the changing environment and of the introduction of genetically modified or invading new species



Bacteria and fungi are extremely abundant in the marine environment. Their most crucial role is the reduction of organic matter. The photo above shows a Phaeocystis colony surrounded by marine bacteria (scale 1/200). In a later stage the senescent Phaeocystis colony is colonized and reduced by the bacteria (photo under, scale 1/1000). Bacteria also rule many other processes in the marine environment. Examples are the secretion of extracellular polymeric substances influencing erosion and sedimentation and the modification of genetic properties of marine organisms. Predictive models including all these processes do not yet exist.

2. Opportunities

Existing ideas and technology from other areas of science and management can be better exploited and applied to problems of marine ecology:

- application of molecular biological and biochemical methods, including gene probes, biosensors and biomarkers
- use of acoustic methodologies to map relationships between sediment type and transport and benthic biology, patchiness in plankton, density of euphausiids, mysids, fish etc.
- better application of aircraft and satellite remote sensing techniques
- use of developments in computer sciences such as neural networks, supercomputers
- further development of mesocosm technology, introduction of adequate experimental techniques in the field (field flumes, landers)
- large scale field experiments, using management of lagoons, estuaries, fjords, fisheries and aquaculture
- exploration and use of historical data sets

3. Strategies

The necessary improvement in marine ecological theory and working methodology can be promoted by several action lines:

- insist on rigorous hypothesis testing approaches within ecology by educating scientists, scientific organisations and journals
- develop well-chosen collaborative multi-disciplinary research experiments and projects on representative and model sites, especially by making use of common platforms and facilities
- development of models in advance of this research as a means of communication, structuring research and hypothesis generation.
- development of improved methodologies to access and analyze large data sets

- development of methodology for rigorous calculation of scenarios of environmental change

- further development of networking and exchange of especially young scientists
- strengthening of links between scientific research and other users of the seas:
  * military facilities
  * oil industry e.g. to provide platforms and ROV's
  * government agencies responsible for monitoring and adequate description of the state of the sea

- development of interactions between environmental scientists, social scientists, historians and economists

- development of tools to facilitate education and the timely transfer of knowledge to public, environmental managers and decision makers, e.g to facilitate Europe-wide accessibility of expertise to these groups

- improvement of financial support of marine science by one order of magnitude through the formulation of strategic research questions and grand challenges.

Participants of group discussions:

J. Baretta (NL), B. Bayne (GB), G. Billen (BE), P.J. Hansen (DK), C. Heip (NL, chairman), K. Hostens (BE), A. Malmgren-Hansen (DK), R. Riegman (NL), V. Smetacek (DE), R. Willows (GB), J.J.G. Zwolsman (NL).

Report of discussion group on "Integrated Prediction"

1. Rationale

Changing climate and population growth will have major impacts on the global environment during the next century. These changes will particularly alter estuaries and coastal seas. Change in climate as well as the reduction of most river discharge of water and sediments will induce noticeable changes in coastal dynamics, sediment storage, coastal geomorphology and coastal ecosystems. Increased population may lead on the one hand to increased nutrient input to coastal seas and to their subsequent eutrophication, on the other hand to a larger quantity of industrial waste prone to adversely affect coastal ecosystems. The working group recognized the urgent need of improving our capability to predict the consequences of natural and man-made changes upon the water quality and the structure of coastal ecosystems.

2. Aims

The long term objective of future research activities is the understanding and prediction of the response of the coastal ecosystem consecutive to natural or anthropogenic changes of the forcing variables. Hydrodynamical research needs to be developed with particular emphasis on the translation of global changes into regional hydrographical changes, such as altered sea levels, changes in flow patterns, stratification, waves, sediment dynamics and changes in geomorphology etc. Similarly, the changes in distributions of nutrients and contaminants consecutive to changes in socio-economic organization and land use should be better understood. In order to reach these objectives the implementation of an integrated system approach is needed. The output of such a system should be produced for research purposes in the first place. However, special effort should be devoted to assist decision makers and managers to implement the appropriate policies needed to allow a sustainable development of the coastal environment.

3. Recommendations

Although significant progress has recently been achieved with the implementation of an "integrated system approach", the working group identified some further requirements to be considered in relation with the european specificity.

Europe has world-leading capabilities in coastal marine science which could provide the basis for an integrated coastal model. This should take advantage of the uniqueness and wide diversity of European coastal seas. The integrated coastal model must be conceived as a suite of coupled sub-models describing the basic processes in a general ecosystem model. The success of such a model depends upon the improvement of some critical steps at 3 levels of integration, that are presented below.

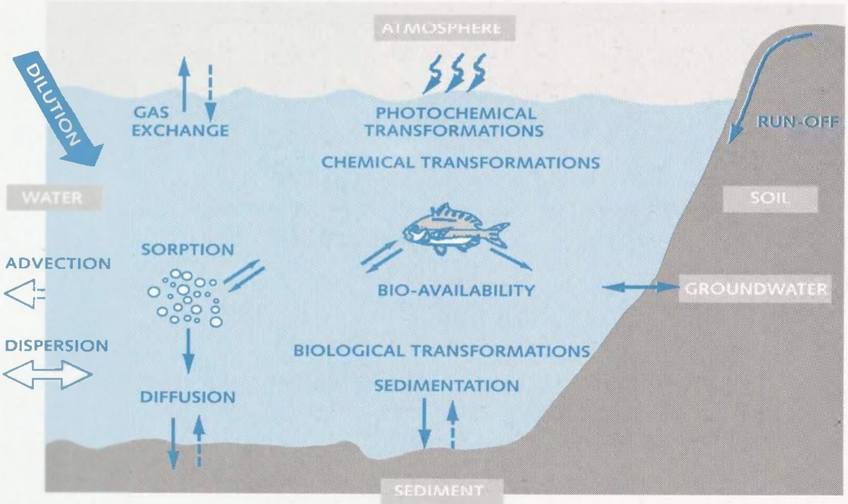
3.1 Integration

A. Basic Science: Fundamental processes and their integration in the model
Further understanding is required of many physical, biological and chemical processes in the coastal environment. Studies of basic processes in contrasted coastal environments are required to provide the models with the essential equations and parameters.

Processes that require special attention include: i) species succession and dominance in plankton and benthic communities, ii) role of behaviour in ecological functioning, iii) biogeochemical exchanges between water and sediments, iv) fate and accumulation of key pollutants in estuarine and coastal systems, v) fine-grained sediment dynamics and vi) role of trace elements in biological interactions.

B. Geographical integration
The coastal model should be conceived in a broad sense and incorporate the main geographical entities influencing the functioning of the coastal seas. Of special relevance are changes in drainage basins, in land-uses and human practices which could lead to drastic changes in the rates of contaminants and nutrients discharged to coastal seas. This may have catastrophic impact on living resources and amenities. Shelf-edge exchange processes have been recently recognized as one of the driving mechanisms needed to sustain coastal production. Atmospheric inputs which represent the main source of matter for many elements and compounds should also be integrated.

C. Interdisciplinarity and coordination
Hydrodynamical, sedimentological, ecological and chemical as well as socio-economical submodels should be better integrated.



The integrated coastal model must be conceived as a suite of coupled sub-models describing the physical, chemical and biological key processes into a general ecosystem model. Studies of these processes in contrasted coastal environments should provide the models with the essential equations and parameters. Feed-back effects need to be properly incorporated to predict the response of the coastal ecosystem to natural or anthropogenic changes of the forcing variables. The specification of inputs by runoff, by the atmosphere and by shelf-edge exchange requires great attention.

In particular, the reciprocal interactions between the ecological submodel and the chemical one's describing the fate and effects of contaminants in coastal seas is largely needed. Similarly, a better coupling between socio-economical and ecological models must be achieved. Co-operation is needed between the social scientists, economists, politicians, legislators and scientists. Decision makers need to make informed decisions. It is the job of the scientist to inform them. Dialogue is difficult at present due to understanding barriers and these need to be eroded.

At present, many researchers are independently producing data which could potentially be used by modellers elsewhere. A programme is clearly needed. In addition, the co-ordination of future programmes, at an early stage, would improve the temporal and spatial data available and minimise duplication and the better integration of the various disciplines.

Modellers also need to liaise with experimenters to ensure that the right data will be collected.

3.2 Validation

The validation of the models should take advantage of the wide diversity of european coastal seas. In any case the transferability and the robustness of the models should be tested by applying them to sites distinct from those used locally in model development.

3.3 Training

In the same vein as the ECOPS conferences, specific problem orientated workshops and discussion groups should be instigated in order to improve the basic knowledge of coastal processes. The topic of "non-linear interactions" has been identified as requiring such attention. Examples of this would be species recruitment, increased stratification due to global warming in shallow bays which can trigger rapid chemical reactions (chemical "time bombs") etc. The workshops and courses should allow the mixing of young and older scientists as well as other authorities with responsibilities in coastal seas to identify specific problems and share knowledge and ideas. It has been shown that a Euroconference is an ideal setting for such exchanges.

3.4 Global programmes

The working group considered that the research topics described here should represent an European contribution to LOICZ.

Participants of group discussions:

J. Backhaus (DE), G. Crispi (IT), S. Djenidi (BE), P. Herman (NL), C. Lancelot (BE), J-M. Martin (FR, chairman), A. Moriki (GR), J-M. Mouchel (FR), S.M. Mudge (GB, rapporteur), D. Prandle (GB), S. Righetto (IT), C. Ramasco (IT), J.H.M. Schobben (NL), M-H. Tusseau (FR)

Report of discusion group on "Sustainable Development"

1. Objective:

To establish and apply a more rigorous scientific basis for the management and sustainable development of coastal systems over the next 50 years.

In this context it is envisaged that further attempts will be made to manipulate coastal systems in order to maintain and, if possible, increase the supply of renewable resources for future human generations without interruption or loss of quality and quantity, and at low cost in terms of the use of non-renewable materials. The maximum potential yields of such resources remain uncertain.

2. Recommended research actions

The main environmental problems in the future are likely to concern continuing physical, chemical (e.g. releases of inorganic nutrients and of xenobiotics) and biological disturbance of coastal ecosystems, the effects of increasing demands for fresh water and energy, and the development of large scale mariculture practices and recreational facilities.

The goal of sustainable development will require the following actions:

a. Develop an integrated systems approach, involving both the natural and socio-economic sciences, for studies of the dynamic properties of coastal systems and of the ways in which they are being altered by human activities and by climate and sea level change.

b. Build realistic scenarios of change in the coastal zone over the next 20-50 years, based on specific hypotheses concerning population growth, the regional impacts of human activities, and climatic factors and including consideration of likely technological developments for the exploitation of coastal resources.

c. Conduct comparative case studies of the use and management of coastal systems, with special attention to regional cultural differences, resource use structures and past and present demographic changes. Case studies address the need to protect cultural heritage (including small coastal and island communities), the need to present and mitigate conflicts between coastal uses, stimulate proper coastal zoning, and the need to guarantee social equity between present and future generations.

d. Educate scientists, the public (especially young people), decision makers and environmental managers with respect to the overall implications of coastal change and the uncertainties about how yields of living resources will be affected.

e. Encourage the application of new scientific knowledge in the management of the coastal zone, and provide objective advice about the levels of investment in research and technology that will be required to maintain particular levels of renewable resource yields and of environmental quality.

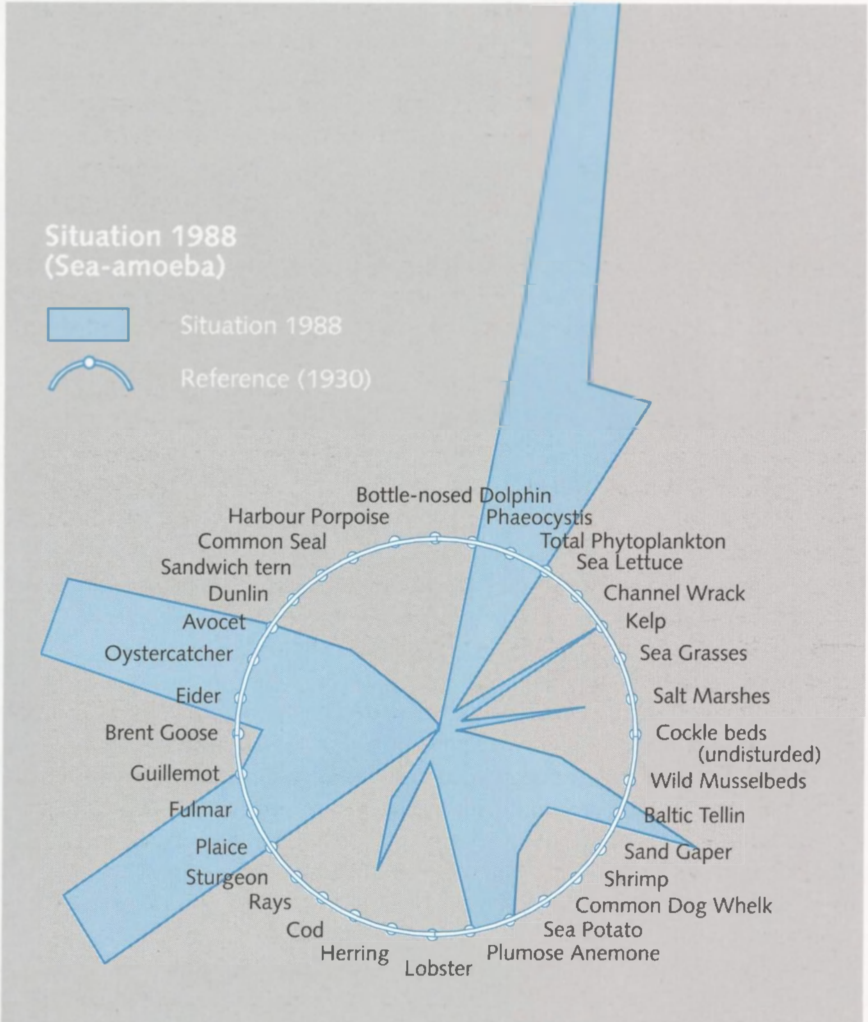
The undertaking of such actions must be a fully iterative procedure, so that the results of work in any one area should be fed into and affect the progress and prioritization of work in another area. It will also be vital to involve skilled and innovative scientists in order that integration between different disciplines is as effective as possible and that accurate information about the potential and uncertainties of management options (environmental and economic) is provided to the users of coastal resources. It will be important to use new technologies for providing information products on the state of coastal environments, perhaps largely based on the development of GIS systems for the coastal zone.

3. The need of a system approach for coastal management

The main requirement for improving the scientific basis of coastal management is a more holistic and integrated framework in which to demonstrate the applicability of the results of ongoing and new research. It is best met by adopting an approach to the study of coastal systems that allows different types of investigation to be linked with the common aims of improving knowledge about ecosystems functions and of developing the capability to predict responses to external forcing (e.g. as a result of changes in land use, climate, human exploitation). The following elements are needed:

- better observations especially of fluxes of materials between land, coastal seas and oceans (including, as appropriate, atmospheric transport), of chemical transformation processes, and of marine benthic primary productivity so that the accuracy of budgets for suspended sediment, organic matter, pollutants etc. in the coastal zone can be improved.

- long term (decadal) measurements of selected properties of coastal systems, in particular to distinguish natural variability from trends in response to environmental change. Automated techniques for data collection, transmission and exchange should be employed as far as possible, and support should be provided for the maintenance of existing programmes of long term observations.



Radar-plot "Amoeba": present biomasses of a number of target species in the Southern North Sea are plotted against biomasses in a more or less undisturbed reference situation (1930). The apparent dislocation of the present marine ecosystem is mainly caused by the release of nutrients and chemicals and by intensive fishery. The scientific base for determining ecosystem characteristics applicable in the management and restoration of marine systems, eg. sustainability, stability, resilience, stress, is not yet strong enough.

- experimental testing of hypotheses relating to the responses of coastal systems to external forcing, especially at large scales over which the interactions between subsystems must be taken into account.

- development of simple, coupled models to examine the dynamics of land-coastal and sea-ocean interactions, with special attention to biological feedbacks, to transient and metastable ecosystem states, to the need for sensitivity analyses as well as model validation over a range of prediction intervals, and to various scaling problems including relating global climate change and local (but intense) human activities to regional impacts in the coastal zone.

Attention also should be given to the need for an improved understanding of the concept of ecosystem integrity or health in the contexts of sustainable yields of renewable resources and of biodiversity in relation to habitat restoration.

4. The next steps

Three priorities were identified:

1. Procedures for integrating the natural and socio-economic sciences could not be discussed in the absence of representatives of the latter group. However, this topic should be examined as soon as possible at a small workshop of experts with access to carefully prepared background documents, particularly with respect to comparing the environmental, social and economic constructs for assessing coastal systems.

2. Initiate new research on future scenarios and case studies of coastal systems, building upon work that has already been done for the Baltic and Mediterranean regions, and applying the results from recent climate and sea level models, observational and theoretical studies of ecosystem dynamics, and up-to-date economic and demographic forecasts.

3. Initiate new educational programmes to inform people at all levels of the implications for sustainable development of continuing environmental degradation in the coastal zone.

Participants of group discussions:

J.W. Dippner (DE), J.S. Gray (NO), P.M. Holligan (GB, chairman), S. Jelgersma (NL), A. Mexa (GR), T. McMahon (IR), V. Rivas (ES), A. Sanchez-Arcilla (ES), A. Vallega (IT)

Report of discussion group on "Research Instrumentation and Infrastructure"

1. Introduction

To achieve the scientific objectives and further benefits of the challenges presented in this report, it is necessary to recognise the need for certain infrastructures to support the research. These infrastructures consist of technologies, software, facilities and networking to allow scientists achieve their objectives in a cost-effective manner. They require resources and may need to be provided or developed by specialists other than the researchers themselves. It is essential however that the priorities of the science define them and that they are identified and specified at the beginning of the programme.

We recognise the need for technologies, both those drawn and adapted from other scientific areas (technology push) and those developed specifically for coastal science (science pull). We also see the need for some new organisational structures to make the most cost effective progress. Whilst these are described in generic forms, we also concluded that certain more specific recommendations can be identified clearly now.

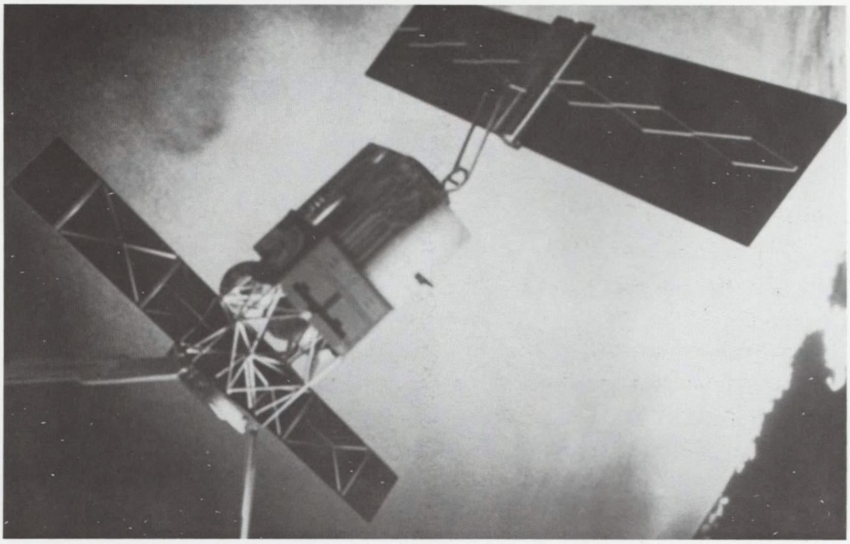
2. Technologies to support coastal marine sciences and observations

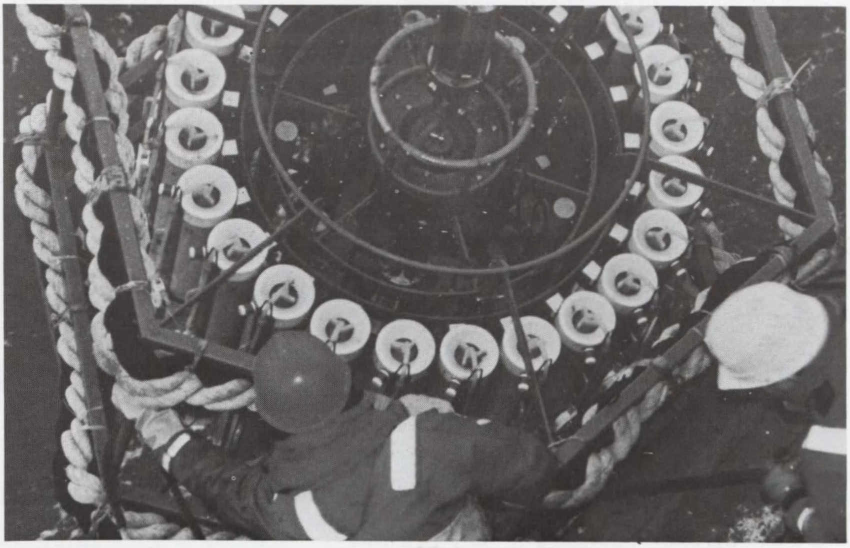
2.1 Sampling Strategies

Owing to the advances in information technology, models of coastal processes now have generally surpassed the availability of observational data with which to initialise, force and test them. The lack of data limits improvements in process understanding and inhibits the further development of models.

Whilst it will not be possible to provide data on all time and space scales, both for resource and technological limitations, there has to be a coherent sampling strategy to provide improved observations and for new variables to be measured. Recently techniques from the laboratory have been transferred in-situ, to provide time-series measurements of some chemical and biological variables. Synoptic coverage of a limited set of variables can come from satellite and airborne remote sensing, and more recently from land based radars, whilst moored stations provide time series at a limited number of sites for a different set of variables. Ships and buoys provide mobile platforms for the lagrangian view. There is a trend towards increased autonomy, both of platforms with sensors and for benthic laboratories undertaking in-situ experiments. Research

Photo ESA





At present synoptic coverage of a limited set of variables is provided by satellite and airborne remote-sensing. For information on most other variables and, in particular, for information on depth structure and for ground truth in-situ sampling is necessary.
Lack of data limits improvements in process understanding and inhibits the further development of models. Progress in measuring technologies therefore should be strongly supported. Promising technologies are, for example, satellite systems optimised for coastal zone observation and in-situ sensors providing time-series measurements of chemical and biological variables.

ships will continue to provide sample collection and analysis facilities which cannot be undertaken any other way. Developments in all these technologies need to be selected for coastal relevance. There continues to be a place for cheap, sometimes expendable, instruments that can be used in quantity.

2.2 Observational Synergies

Simultaneous cover by remote sensing and in-situ sensors enhance the value of both, giving detailed spatial details of the surface on one hand, whilst continuity at limited positions and depth structure comes from the other. The large number of interactive processes in the coastal zone demands accurate local calibration of remote sensors. When carefully applied interpretations over larger distances are possible. These are especially valuable for comparisons with numerical model results.

2.3 Hostility of the coastal zone

The dynamic coastal zone is a fascinating environment but a hostile one for instrumentation, and this presents a considerable challenge to ingenuity for robustness and protection. It is in many respects more hostile than space or the deep ocean, but is on the other hand more accessible. Also some small scale processes can be studied in laboratory facilities such as wave tanks, flumes, rotating tables and aquaria, whilst others can take place in protected waters, such as mesocosms. Proper design, fault tolerance and maintainability criteria need to be applied to assure long, efficient observations in the coastal zone.

2.4 Coastal Information Systems

The power of modern information technologies needs to be applied to the development of flexible Coastal Information Systems (CIS), to integrate multidisciplinary data, including historical, remote and in-situ, with numerical models, with GIS, and with multimedia visualisation facilities. These will provide the scientists with diagnostic capacity as well as improving the transfer of information to the wider community of coastal users and policy makers.

3. Organisational Structures

3.1 Coastal GOOS

At present there is no European-wide monitoring strategy, though a few national networks exist mainly for local or regional impacts and ICES has a regional co-ordination role in a fisheries and pollution context. The proposed introduction of the Global Ocean Observing System (GOOS) is an important opportunity to provide an umbrella organisation for the introduction and coordination of long term monitoring in the coastal zone. It is essential that coastal scientists advise on what limited set of variables should be observed to test, and assimilate into the long term predictive models of the coastal seas and ecosystems. GOOS is also important in providing the outer boundary conditions for coastal models via ocean models.

A European monitoring strategy should be developed for the detection of trends in the condition of coastal systems, for the assessment of sustainable development and for the estimation of possible risks from short term events and long term evolution. These applied needs for data are not incompatible with the scientific needs if the latter are to add understanding to the observations.

3.2 Large Scale Experiments

In so far as GOOS provides a framework for long term experiments, and model validation, there is a parallel need for large scale experiments of limited duration. In this context large refers both to spatial coverage and to the number of observations, such as are beyond the capacity of one national team or laboratory. European collaboration is needed to bring separate teams together, as presently supported in some MAST and ENVIRONMENT projects.

3.3 Networking

Computer based communications are already widely used by scientists. The coastal community need to be supported for this, and for workshops and conferences. Networking people and data will integrate otherwise isolated process studies, so essential to address long term prediction of the coastal system. Both on-line data networks and offline database dissemination should be facilitated without any artificial price barriers. A major disappointment has been the slow delivery of satellite data to users (eg ERS1).

Special laboratory facilities exist across Europe and it makes sense to share those that are not fully occupied, to prevent undue duplication of capital spending. Coastal scientists should be encouraged to use mechanisms that exist to facilitate such sharing.
Sharing of specialised marine equipment is often prevented by the risk of loss, therefore some scheme which insures the lender is worth promoting. An informal network of research ship operators is in place, and could be expanded to keep an inventory of major sea-going equipments available for loan.

3.4 National research programmes

National programmes in coastal marine sciences added together far exceed the support provided through EC funding. It would be naive to believe that there are no duplications in these, nor that with the right encouragement more collaborations would not make for more efficiency overall. Some overlap and competition is necessary to avoid gaps and ensure scientific quality. At present one of the major obstacles to such co-operation is the disparity of procedures for charging for research ship time.

3.5 Education

To develop the new technologies discussed earlier it is necessary to encourage the education and training of creative technologists, as well a new generation of scientists working across the traditional discipline boundaries.

4. Possible recommendations to facilitate the Grand Challenges

4.1 A European Satellite for the Coastal Zone

CZCS, the Coastal Zone Colour Scanner demonstrated a desire to sense the important coastal zone and was useful up to a point. However neither past, present nor any proposed satellites are optimised, either in sensor performance or orbits, for the coastal zone. Serious consideration should be given to a study on what improvements could be obtained, before presenting a case to the space agencies. Coastal scientists must be consulted widely.

4.2 Developments in Autonomous Systems

Support the development of in-situ benthic landers, capable of physical, chemical and biogeochemical experiments over lengthy periods to examine processes at this understudied boundary. Also support the development of reliable autonomous packages that can be installed on co-operating ships of opportunity (eg like the Continuous Plankton Recorder (CPR) Survey).

4.3 Developments in Sensing Techniques

Support the development of new sensing methods, eg: molecular probes; chemical sensors; non-invasive acoustic, optic and electromagnetic systems; biomarkers for environmental stress.

4.4 Coastal GOOS

Define and support the Coastal component of GOOS and implement it for long term monitoring, adding to some components already there.

4.5 Coastal Information System

Develop a Coastal Information System, as discussed above, in particular building on some initial efforts to provide a coherent European approach, capable of contributing to a global coastal integration.

4.6 Transfer of Methodologies

Develop and disseminate user-friendly models of coastal systems (clearly indicating their limitations), with benefits to interdisciplinary scientific objectives, as well as for applications in coastal management.

4.7 Coastal Surveys

Support regular surveys of coastal morphology, to establish a present day baseline, against which future changes can be objectively measured by regular resurveys.

4.8 Optimization of resources

Support the co-ordination and sharing of facilities, instruments and intercalibration exercises, through European initiatives.

Participants of group discussions:

J. Aiken (GB), L. Alberotanza (IT), I.A. Azuz Adeath (ES), M. Capobianco (IT), B.S. McCartney (GB, chairman), K.B. Kristensen (DE), C. Latouche (FR), W.P.M. de Ruijter (NL), P. Thorne (GB), G. Voulgaris (GR)

Conclusions

The discussion groups were free to choose their own working process: no strict format was imposed on the structure of the discussions and the reports. The group reports are reproduced as they stand; rewriting them in a standard form would introduce the risk of information loss. In this concluding chapter the major considerations and findings of the groups are brought together to exhibit the overall headlines.

Expected future changes affecting the coastal zone

There is little doubt that climate change will impact on the coastal zone in many different ways. A shift in mean conditions is to be expected, such as a rise in the mean sea level and a change in the direction and magnitude of mean wave fields and circulation patterns. Even more important might be a shift in extreme conditions. As a result, the coastal marine ecosystem will be greatly disturbed.

There is no doubt that the use of the coastal zone for human activities will continue to increase, maybe even more rapidly than in the past. New structures will affect the coastal dynamics, both physically and biologically. Changes in land use and river management will also affect the equilibrium of the coastal system, in particular through the retention of sediment and release of chemicals.

Marine resources are essential to mankind and their importance will increase. New technologies will be needed to meet human demands for food, energy and fresh water; these technologies should preserve the potential resources of the coastal marine environment for future generations.

A closer involvement of coastal marine science in coastal zone management should be encouraged. Coastal marine scientists and technologists, socio-economic experts and policymakers should work together on scenarios for future change. They should discuss which characteristics of the coastal system need to be predicted and monitored to ensure sustainable use. This would provide a means for the transfer of knowledge about scientific findings to all those concerned with the coastal marine environment.

Gaps in knowledge

Coastal marine science is expected to provide answers about the impact of future changes and clues as to how to respond. Consistent and verifiable answers require specific technologies and validated models encompassing all relevant physical, chemical and biological processes and their interactions. However, numerous gaps in knowledge still limit the predictive capability of current coastal marine models.

Several important categories of gaps in knowledge were enumerated by the different groups; particular emphasis was placed on:

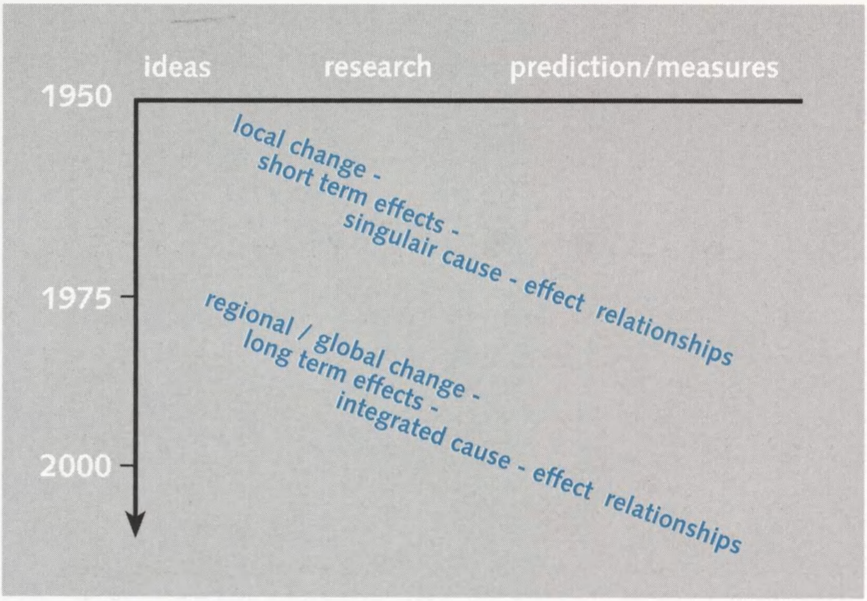
- the forcing of the coastal system by climate change. Present climate models do not yet resolve the regional scale. No information exists concerning shifts in extreme conditions.

- exchange processes in interface zones: the regions of transition between sediment and water, between water and atmosphere and between high and low density waters. These are concentration zones of substances and organisms; high dynamic activity results from strong interactions between physical, chemical and biological processes. Many of these interactions are not yet well understood.

- Microbiological and biochemical processes: (-) Bacteria are very abundant in the marine environment and rule many processes, but their behaviour is largely unknown. (-) Xenobiotic substances affect organisms by modifying cell functions; no consistent description is yet available. (-) Genetic adaptation alters the response of species to environmental change in a way no model is yet able to predict. (-) Genetically modified organisms may constitute a serious risk for the marine ecosystem.

A very crucial gap in knowledge concerns the role of extreme events. Little is known about the natural variability of coastal marine systems. To what degree do coastal characteristics reflect equilibrium conditions, or do they essentially reflect transient behaviour induced by the dominance of low-frequency events?

A key characteristic of coastal systems is their high variability on many scales in time and space. The long-term evolution is driven by residual forcing due to feedback mechanisms. Many of these feedback mechanisms result from non-linear interactions between fluctuating components of the system. A full description of relevant feedback mechanisms is crucial for long-term predictive modelling. This implies that in principle fluctuating components on all space and time scales should be taken into account. This is beyond the possibilities of present measurement technologies and modelling techniques. Simplification is



Progress in the scientific comprehension of coastal marine dynamics may evolve the public perception of coastal issues. Inversely, socio-economic developments and environmental change may generate new research themes. Coastal issues and major research themes have strongly evoluated in mutual interaction during the past decades. At present most emphasis is on comprehensive approaches of large scale and long term change and on the underlying basic processes and interactions.

possible only if reliable field information is available on the residual forcing relating to small-scale and high- frequency components. Present models are not yet capable of describing strongly non-linear phenomena and monitoring systems necessary to collect the relevant data are not yet available. Examples are: the formation of sand ridges, the patchiness of plankton blooms, and the recruitment of marine populations.

Barriers to progress in predictive modelling

A major inherent barrier is the vastness and great complexity of the coastal marine environment. This barrier cannot be removed.

Many of the gaps in knowledge previously described are due to a deficiency of experimental data. Improvement of predictive capabilities in coastal marine science is hampered more by lack of suitable technologies and methodologies for collection of data then by lack of adequate statistical or mathematical modelling techniques.

The high variability of coastal marine systems on many scales in space and time occasions the need for consistent field observation programmes concerning:

- long time series with sufficient time resolution of relevant variables at representative sites,
- large-scale synoptic experiments of limited duration with sufficient space resolution.

The choice of sites and variables should enable the computation of fluxes and budgets. Concentration of data sampling at selected sites should be encouraged.

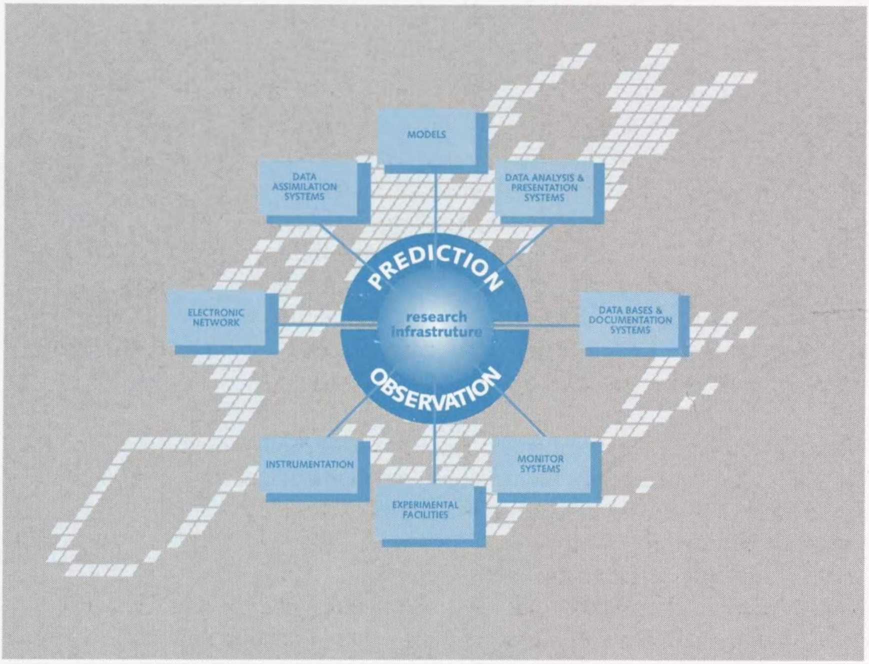
The implementation of large observation programmes requires sharing of facilities and equipment at the international level. Present coordination efforts often lack sufficient incentives to encourage wide participation in sharing programmes, for instance, through insurance against damage or loss of equipment. Data sets from large observation programmes should be available to a wide range of scientific users. Mechanisms stimulating free access to and exchange of data need to be improved.

In the past, the available instrumentation imposed heavy restrictions on the range of variables which could be measured in situ with sufficient accuracy and sufficient resolution in time and space. In fact many variables could not be measured at all on a routine basis. Important technological progress has been made in recent years. The improvement of remote sensing and acoustic techniques provides the opportunity for field observations covering a much wider range of scales. To exploit this opportunity fully, the launching of new satellite systems designed for coastal observation should be seriously considered. Through the application of new techniques, like gene probes, biosensors, optical analyzers or benthic laboratories, it would be possible to extend significantly the range of observable variables.

Contacts between coastal marine research groups are becoming closer, and the coordination of research programmes is improving. European programmes like MAST and ENVIRONMENT play an important stimulating role. Interdisciplinary projects are becoming more frequent, but no platform has yet been developed for systematic cooperation between physicists, chemists, biologists and technologists. In addition, there are still important barriers between research programmes dealing with technology development, and those dealing with process studies and with predictive modelling. There is no general guiding concept linking these different types of research. Such a concept would be of great help in strengthening cooperation between different branches within the coastal marine science and technology community and in focusing research efforts to achieve optimal progress in predictive modelling. It would also be an important instrument for establishing a closer communication between coastal marine scientists and other groups concerned with the coastal marine system: socio-economic experts, policymakers and users.

Grand Challenges

The further development of new powerful detection methods and their application in large-scale and long-term observation programmes will greatly improve understanding of the dynamics of the coastal marine environment and will allow for a more effective management of the coastal sea resources. These programmes should be designed to enable the computation of budgets and fluxes, the detection of trends and the study of physical, chemical and biological key-processes. Emphasis should be given to the feedbacks and non-linear interactions between these processes, which determine the long-term evolution of the coastal marine system. The development and deployment of high-tech instrumentation in comprehensive observation programmes should be promoted in a coordinated European effort, taking into account the diverse characteristics of European regional and coastal seas.



CIPS, Coastal Information and Prediction System is a framework for coherent research programming and for communication between scientists and for communication with managers and users of the coastal marine system. The objective to create a generic system allowing monitoring and forecasting of the coastal marine environment. It should be designed as a flexible, modular framework, based on conventions, standards and networking facilities, providing European researchers with instruments, data and models and integrating technological, experimental and theoretical research.

Full advantage can be obtained from the observational effort only if it is programmed in direct relationship with the development of integrated coastal models. These models should be designed to optimize predictive capabilities and to be used in managing the coastal zone resources. Model concepts should be tested using historical data for different types of coastal systems occurring in Europe.

A grand challenge for coastal marine science is to create a coherent European framework for bringing together technological innovation, process research, observational programmes and model development. This framework should be designed following a flexible, modular concept, with local developers and users. It should be able to link together data sets, process descriptions and parameters, process interactions, mathematical solution methods, data assimilation techniques and information systems. This Coastal Information and Prediction System (CIPS) should become a standard instrument for operational and predictive modelling within the coastal marine science community. It can then serve as a tool for communication between scientists and for the coordination of research projects and constitute a common reference for programming and funding future research.

European research initiatives within the CIPS framework should take maximum advantage of national research programmes. Such initiatives constitute an important European contribution to LOICZ (Land Ocean Interaction in the Coastal Zone), a new international project on coastal fluxes and budgets initiated by the International Geosphere-Biosphere Programme.
With the development of CIPS, Europe will also play a leading role in the realisation of a coastal component of a Global Ocean Observation System (GOOS).

The coastal marine environment will experience great changes over the coming decades. This will be the case in Europe, but even more so in some other parts of the world. Coastal marine science should contribute to the identification of adequate responses. Besides predictive modelling, communication is the other grand challenge for the coastal marine community: communication with climate experts on regional predictions for climate change; communication with socio-economic experts on future scenarios for change due to increasing human exploitation of the coastal zone; communication with policymakers on planning of the coastal marine environment, on assessment methods and on the consequences of response strategies; communication with users on new exploitation technologies preserving the natural resources of the coastal marine environment; and, last but not least, communication with the public to promote awareness of the essential functions of the coastal marine environment for present and future generations.

In summary the following two Grand Challenges are defined:

- *to create a predictive generic framework in which advanced observation techniques, infrastructure for large-scale experiments, dynamic description of key processes, integrated modelling, data-assimilation and data management techniques are brought together, further developed and funded.*

- *to create mechanisms to improve the communication with socio-economic experts, with management authorities and with users of coastal marine systems.*

Future Euroconferences should be devoted to the advancement of these Grand Challanges and to the elaboration of further pertinent initiatives.

Annex 1

European Research Conference on

Prediction of Change in Coastal Seas

Port d'Albret

19-24 June 1993

Chairman: dr. J. Dronkers
Vice-Chairman: dr. J-M. Martin

Programme

Saturday, 19 June

17.00 - 19.00	**Registration:** hotel reception and conference secretariat
19.30 - 21.30	**Dinner**
21.30 - 22.00	Welcome speeches by *dr. J. Dronkers (conference chairman)* *dr. J. Boissonnas (CEC-MAST)* *dr. J. Hendekovic (ESF)* *dr. W.P.M. De Ruijter (ECOPS)*

Sunday, 20 June

09.00 - 09.10	**Opening Remarks chairman** Session 1: **The future coastal zone - threats and challenges** chairman: *J. Dronkers (NL)*
09.10 - 09.55	**The coastal ecosystem in 2030,** *S. Jelgersma (NL)*
09.55 - 10.40	**The physical coastal system in 2030,** *A. Vallega (IT)*
10.40 - 11.00	**Coffee break**
11.00 - 12.00	Plenary discussion: creation of groups and definition of tasks
12.00 - 14.00	**Lunch**

Session 2:
Sensitivity of coastal zones to change
chairman: *A. Sànchez-Arcilla (ES)*

14.00 - 14.45	Response of the coastal system to land-use change, *G. Billen (BE)*
14.45 - 15.30	Regional impacts of ocean/climate change, *H. von Storch (DE)*
15.30 - 16.15	Response of the coastal system to sea level change, *M. Stive (NL)*
16.15 - 16.45	Tea break
16.45 - 17.30	Integrated response of (semi-)enclosed seas to change, *C. Heip (NL)*
17.30 - 18.15	Integrated response of shelf seas to change, *D. Prandle (GB)*
19.00 - 21.00	Dinner
21.00 - 22.30	Group discussions

Monday, 21 June

Session 3:
Coastal zone process studies
chairman: *W.P.M. De Ruijter (NL)*

09.00 - 09.45	Transport and accumulation of sediment in the coastal zone, *I. McCave (GB)*
09.45 - 10.30	Water quality processes in the coastal zone, *B. Bayne (GB)*
10.30 - 11.00	Coffee break
11.00 - 11.45	Primary production of biomass in the coastal zone, *V. Smetacek (DE)*
11.45 - 12.30	Secondary production of biomass in the coastal zone, *P. Herman (NL)*
12.30 - 14.00	Lunch
14.00 - 15.30	Group discussions
15.30 - 16.00	Tea break
16.00 - 17.30	Group discussions
19.00 - 21.00	Dinner
21.00 - 22.30	Plenary session Presentation and evaluation of group discussions Reconsideration of group composition and tasks

Tuesday, 22 June

	Session 4:
	Instrumentation for coastal research
	chairman: *B.S. McCartney (GB)*
09.00 - 09.45	**New remote sensing applications,** *L. Alberotanza (IT)*
09.45 - 10.30	**Synergism between remote sensing and in situ methods for monitoring water quality in the coastal zone,** *J. Aiken (GB)*
10.30 - 11.15	**Applications of under-water acoustics in the coastal zone,** *P. Thorne (GB)*
11.30 - 19.00	Excursion to Dune de Pyla and Oysterfarm (La teste, Baye d'Arcachon)
19.00 - 21.00	**Dinner**

Wednesday, 23 June

	Session 5:
	Modelling coastal zone change
	chairman: *D. Prandle (GB)*
	First part session 5
09.00 - 09.45	**Diagnostic modelling of the coastal ecosystem,** *J. Baretta (NL)*
09.45 - 10.30	**Modelling small scale processes in large scale coastal models,** *S. Djenidi (BE)*
10.30 - 11.15	**The use of field data to enhance the predictive capability of coastal models,** *J. Backhaus (DE)*
11.15 - 11.45	**Coffee break**
11.45 - 13.00	Group discussions
13.00 - 14.30	**Lunch**
	Second part session 5
14.30 - 15.15	**Intrinsic limitations to predictability in morphodynamic modelling,** *H. de Swart (NL)*
15.15 - 16.00	**Modelling long term water quality change in coastal systems,** *C. Lancelot (BE)*
16.00 - 16.30	**Tea break**
16.30 - 18.00	Group discussions
19.00 - 21.00	**Dinner**
21.00 - 22.30	Group discussions

Thursday, 24 June

09.00 - 12.00	Plenary session - presentation of group discussions - synthesis - discussion - conclusions
12.00 - 12.30	Closure
12.30 - 14.00	Lunch

Conference participants at the terrace of the swimming pool of the Eurovillage Domaine de Pinsolle, Port d'Albret.

Annex 2

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