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Socioeconomic aspects of fluxes of chemicals into the marine environment

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International Geosphere-Biosphere Programme (IGBP)
Land-Ocean Interactions in the Coastal Zone (LOICZ)

Socioeconomic aspects of fluxes of chemicals into the marine environment

Scientific report of the workshop on socioeconomic aspects of fluxes of chemicals into the marine environment
Norwegian Institute for Air Research (NILU), Kjeller, Norway
8–10 March, 1999

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PREFACE

Expectations towards science and its societal value have undergone considerable change during the last years. Increasing awareness of environmental change and its impact on human welfare has brought about a shift from curiosity driven science to issue driven science. People are asking questions on the consequences of administrative and political actions and their expectation towards science is quite simple - to get answers, guidance and tools allowing them to deal with their specific issues. Research programmes such as the Environment and Sustainable Development Programme of the European Union are therefore designed to allow predicting the response of environmental and social systems to changing pressures and in particular to communicate the information to those who are concerned – the people.

To treat Integrated Coastal Zone Management as a serious policy objective means to change the utilisation of the coastal zone into a sustainable and environment-friendly process. This requires the integration of socio-economic science with natural science and, consequently, the integration of the two respective scientific communities. Only this will allow science to consider the different user needs and the limiting conditions on the side of the environment. Only this will allow a proper scaling of the problem and an approach at cross-border and international level. Coastal domains do not follow communal, regional or national borders. Furthermore, they are not limited to the immediate coastal zone, but sustainable management options for a coastal area need to include the river basin as a vital part of the water continuum. Many pollution problems of the coastal zone can only be solved effectively through interventions in the river system.

Here, the Fifth EU Framework Programme on RTD Activities provides the appropriate basis, as it allows integrating all related issues. In practice, this means that both the Key Action on "Sustainable Management and Quality of Water" and the Key Action on "Sustainable Marine Ecosystems" contribute to the research issues in coastal zone management. Research results from ELOISE projects will be used to underpin the implementation of and to update the forthcoming European Water Framework Directive. Obviously our task is to foster modern scientific agendas, and to concentrate and support the type of science that delivers the prerequisites for human welfare. To this end, we have to move much closer to holistic thinking than in the past. Following the requirements of FP5 therefore means to review past and current scientific work, to identify the clients and issues and take this as the foundation for the new design of European research and support policy, closely along the needs of the most important stakeholder – the people.

In response to the outcomes of the joint ELOISE-LOICZ working-group discussions on Coastal Management and user needs at the 1998 Annual ELOISE Conference in Huelva the Commission jointly with LOICZ/ELOISE has called for this science user workshop **"Socio-Economic Aspects of Fluxes of Chemicals into the Marine Environment"**, which was kindly hosted by the Norwegian Institute for Air Research in Kjeller. The objective was to provide a first overview of current client profiles and their major issues and to identify available deliverables from past and current LOICZ and ELOISE research against these needs. As a start of a hopefully continuous process the workshop in the medium- and long-term aimed to identify the best options to pursue a user and issue driven science and science funding policy and how the two projects can contribute and benefit in the context of the Fifth EU Framework Programme. As a first summary this monograph clearly shows that while there is already a lot to be delivered against the various needs quite an impetus is still necessary to improve the responsiveness of the projects and to generate a common language and corporate thinking of the coastal stakeholders to finally achieve a coherent strategy for Coastal Zone Management.

Christian Patermann	*Hartwig Kremer*
European Commission	International LOICZ Office

Contents

Joint ELOISE/LOICZ Workshop on Socio-economic Aspects of Fluxes of Chemicals into the Marine Environment

1 Introduction

A Workshop on "Socio-economic Aspects of Fluxes of Chemicals into the Marine Environment" was held at the Norwegian Institute for Air Research (NILU) in Kjeller, Norway from 8 through 10 March 1999 and was attended by 31 participants from 12 countries[1]. The workshop was sponsored and co-organized by the EU European-Land-Ocean Interaction Studies (ELOISE), the IGBP Land-Ocean Interactions in the Coastal Zone (LOICZ) program, and NILU.

1.1 Objectives of the Workshop

The main objectives of the Workshop were to:

- review and assess the information on methodologies for transferring the results from research projects, particularly the EU ELOISE and the IGBP LOICZ projects on socio-economic drives and pressures and their environmental and economic consequences in the coastal zone into the policy making mechanisms, and
- outline research needs on the basis of the above information.

Thus, the Workshop has created a platform for research scientists, representing both natural and socio-economic sciences to summarize the progress of their research on environmental and economic aspects of fluxes of nutrients, eutrophication compounds and toxic compounds in the coastal zone of Europe and to discuss with potential users of these results the mechanisms for translating the environmental data into the policy language.

1.2 Workshop organization and presentations

The Workshop organizers have distributed two templates to the participants prior to the meeting. The templates were organized in a form of two tables requesting the participants to provide information on:

- identification of user-resource system interactions and related demand for advisory scientific consultation, and
- identification of scientific deliverables, gaps and needs from the ELOISE and LOICZ projects and their translation into the policy language.

During the Workshop a number of invited papers were presented with focus on:

- current information from the ELOISE and LOICZ projects on the fluxes of nutrients, eutrophication compounds and toxic compounds and their concentration levels in the coastal zone of Europe,

[1] Belgium, Denmark, France, Germany, Greece, Italy, the Netherlands, Norway, Portugal, Spain, Sweden, UK.

- methodologies for integrated modeling and analysis of environmental contamination in the coastal zone, and
- user needs with respect to the application of integrated assessment of environmental and socio-economic consequences of fluxes of nutrients incl. eutrophication compounds, sediments, and toxic compounds in the coastal zone in Europe.

The above papers were based on information from the ELOISE and LOICZ projects, as well as from various national and international research programs/ initiatives.

The above papers were followed by contributions from other participants of the Workshop.

Papers presented at the Workshop are included in Appendix A. For some presentations only abstracts are available and they are included in Appendix B. The Appendices C and D present the Workshop Agenda and a List of Participants, respectively.

2 Results from the Working Group Discussions

The templates prepared prior to the Workshop and presentations during the meeting have contributed significantly to discussions carried out in working groups at the end of the Workshop. Three working groups were formed and they were asked to discuss the same topics related to:

- identification of user groups and their needs against which ELOISE and LOICZ research can provide scientific deliveries,
- identification of existing and future methodologies for translation of the results from ELOISE/LOICZ projects on pressures and environmental responses as well as economic forcing and consequences in coastal zone management into the decision-making process, and
- the role of LOICZ and ELOISE as brokers for the transfer of issues of concern from scientific community to clients and from clients to the scientific community.

Summary of the working group discussions and conclusions and recommendations reached in the groups are presented below.

2.1 Working Group 1 – Working Group Report; Chairman: Hartwig Kremer; Rapporteur: Jörg Köhn

> Participants: Rafael Sarda, Françoise Elbaz-Poulichet, Dag Eriksen, Jacques Guernot , Ole Hertel, Bente Lomstein, John Munthe, Oddmund Otterstad, Alena Bartonova

The group discussion started with some introductory remarks summarized here:

> Science gains by **cross discipline concentration** and may go through a **learning process** on how to translate its results to bring them into decision-making.
>
> In this context and referring to the finding that not all individual projects will have a full coverage of disciplines potential was seen in **inter-project clustering** among existing and forthcoming ELOISE/LOICZ work.

In many cases evaluation and science translation needs a **broker**. **Social scientists** like in the Norwegian case (Fisheries) can function as a **glue** between the players. Other brokers have been identified among the group of **consultants** as well as more general in overarching programs like **ELOISE** and **LOICZ**. Their **early involvement** is recommended in the process of matching multi-client needs in terms of **scientific diversification**.

An appropriate **communication strategy** including e.g. summer or other regular schools on holistic thinking, science diversification and interaction as well as science communication is highly recommended. The latter must set the scene for a cross sector communication process aimed at translating scientific knowledge into products tailored for the different user groups and enabling application. Outcomes of this involvement and thus new parts of whole project designs are seen in

- introduction and testing of results in practical reality
- testing of models to get to an impact hypothesis;
- enhanced consultation through e.g. stakeholder networking and debates

The following section just lists the major input generated during the discussion and provides some first steps of refinement:

What is science asked to deliver? (Research team views on users and needs)

- a simple answer to the question of what has to be monitored? **Indicator: fluxes, keystone functions**, etc. in order to deliver against EIA and SIA (social impact assessment);
- predictions, i.e. function scenarios including state and development indicators
- better understanding of system's complexity and functioning
- user conflict analysis
- options for conflict resolution and related strategies

User perspective on science – expectations:

In principle:

- To be responsive to current and forthcoming questions around management of complex systems and thus to provide for user-oriented diversification of science disciplines
- To deliver peer reviewed scientific background information for political and administrative decisions (e.g. to answer the question whether the 50% N-reduction - is really necessary and allows for environmentally economic development)
- To get into dialogue with users
- To provide information (e.g. through MCA – multy criteria analysis) which helps mediating between contradicting interests of users among eachother, of users and scientists and users and policy makers
- To provide basic data
- To gain clarity on systems functioning for different client groups including the public by means of supplying the logic of thought (i.e. to explain the key figures of system - state and impact and related management response)
- To pinpoint alternatives and management perspectives
- To deliver special problem solutions like e.g. in the application of TBT etc.

Expected features around science communication and consultation:

- having a stage for mutual acceptance and finding common languages considering the users' competence for their issues of concern
- contribute to a common acceptance and ownership of coastal issues,their impact on human welfare and respective science addressimg it
- employing a participatory approach from the beginning

- allowing for scientifically prooven value judgements but keeping scientists on neutral ground in the brokering process
- including all users involved in system usage and/or management and linking up with peak bodies of professional branches requesting scientific knowledge, know-how or technology transfer
- exploiting contradictory positions of scientists towrds better understanding of processes involved in the issues

Identified user groups

(the group came up with a quite comprehensive list of users all of which evolved from the personal professional background of the participants)

A next step following this draft listing will be to allocate the users mentioned to the different stages in the PSIR framework. This may help to put some clarification on their specific needs with reference to were they interact with the system. Future objective here would be to set up user classifications based on their issues and needs to enable **a typology approach of stakeholder (here: user) – science interaction**.

Policy-makers, "Public sector" Administration and Funders:

- EC (different DGs)
- National Authorities (e.g. Fishery Authorities)
- Governments
- Ministries
- Communities
- CZ managers (also in the other categories)
- Water Management Authorities
- Regional Planners
- Quality Standard Setting Organisations
- Political parties and their research institutions / foundations
- National Science Foundations

Professional Private Sector Groupings (examples)

- Fishermens union (example for system dependent peak bodies)
- (New) Alliances of Fishermen to address their interests
- Agriculture/Aquaculture Industry (eg. Salmon or Oystergrowers)
- Tourism Industry
- Other Industry Sectors
- Quality Standard Setting Organisations
- Training and capacity building institutions

Intergovernmental Bodies and NGOs:

- NGO
- Environmental movements
- EPAs
- International Environmental Bodies
- FAO
- International Conventions like OSPAR/HELCOM

Science Community

- Research Institutions
- IGBP/LOICZ as overarching synthesising experiment like also ELOISE
- Quality Standard Setting Organisations
- Training and capacity building institutions

Science Communicators, and Disseminators:

- Translating institutions
- Consultants
- Training and capacity building institutions
- Political parties and their research institutions / foundations
- Scientists/Scientific journalists (scientific projects as brokers)

Some user needs

During the discussion it was tried to identify how science can make a contribution in terms of being problem oriented and beneficial for the quality of life of the European citizen.

The table shows a refined listing of the groups' contribution considering that the user i.e. the policy maker is interested in e.g. water as a resource rather than in details of hydrological cycles.

User needs (examples)	Scientific input	Delivering programmes
• guaranty continuous quality water supply for different purposes	Regulators of horizontal material/water fluxes and indicators of system states; Estimate the influence of socio-economic drivers on flux systems and derive policy response options	Multidisciplinary ELOISE/ LOICZ Projects
• determine impacts of environmental change on human health	Defining the loop from pressures on systems via system states towards human health impacts	ELOISE/LOICZ projects following the DPSIR framework in co-operation with social and medical science to allow following up on management issues
• source–receptor relationships (pollution)	Models of input – state and impact effect models in the receiving bodies	e.g. LOICZ/ELOISE projects working on critical load issues for horizontal or vertical fluxes
• indicators for human exposure to pollutants in urban areas	Models of input – state and impact effect models in the receiving bodies (urban areas) with easy understand indicators for human uptake	s.a.
• improved measurement techniques	Cross programme collaboration and standardisation aiming to satisfy both, the different needs of: a) scientific accuracy and b) client requested accuracy	
• better process descriptions	Scenario models explaining observed change – external forcing interaction in catchment and coastal area regimes	s.a.
• assessment tools	Instruments assisting in e.g. the translation of biogeochemical figures into socio-economic ones – finally aiming at assessment of human welfare effects of change in coastal regimes or in other words: understanding the driver system (see also below)	Programmes following a holistic approach to grasp reality in a community setting, scenarios, guiding processes
• key indicators of change in regulatory processes and environmental state and impact	element cycles, pools and system budgets (N, P, C, sediments, pollutants) with reference to the critical load for receiving bodies; hydrological models; oxygen depletion prediction etc.	Classical ELOISE/ LOICZ projects and new approaches addressing the whole watercontinuum and its catchment areas
• socio economic indicators featuring human welfare effects	Investigating land-use and cover changes (increase and decrease of population/urbanization/ tourism) and their relation to flux changes along the water continuum; as well as Development and application of monetary and non monetary	ELOISE/LOICZ projects building upon the DPSIR framework concept and including environmental economics; (Special emphasis again on projects crossing different boundary condidtions, s.a.)

User needs (examples)	Scientific input	Delivering programmes
	figures appropriate to put values to change scenarios and their driving forces	
• new monitoring methods and parameters	Indicators and assessment tools featuring e.g. water quality and influencing forces, i.e. the state of environment (s.a.)	s.a.
• to have a dynamic component in scientific statements which allow for decision making and risk management (in other words: answers to the "what ... if" questions)	time series studies and models; hind-, now and forecasting tools and hypothesis testing	Integrated dynamic modeling projects
• response to events	Decision support tools translated into client language and communicated continuously	ELOISE/LOICZ projects including a client oriented communication strategy from the beginning – employing if possible target group mentors

The learning process of how to make science "useful" i.e. userfriendly and applicable

A few steps to be taken during the learning process of making science deliverables applicable to societal problems (which does not mean that science in general is not applicable but underlines that there is still a visible need to bring it closer to the user groups):

- scientists have to learn how to communicate with users
  - how to approach and involve the public sector
  - how to approach and involve the private sector
- reports; scientific publications need to be fed into the process of finding the appropriate client language (translation of science knowledge into scientific know how e.g. through delivery to consultants like National Environmental Research Institutes)

Other tools to foster the learning process:

- involve science translator/science communicators in the projects regularly;
- involve users from the beginning, - meet them e.g. in management schools etc.
- identify those kinds of results, which will only be useful for other scientists – work out the more general ones and provide them into the process of participatory science communication;
- arrange for regular conferences, workshops with users, to properly address audience resistance/willingness to take data and respective information
- offer training (young scientists e.g. in summer schools) building capacity in particular on identifyinmg and formulation joint issues, improved holistic thinking and scientific approaches/networking
- in this context provide training for translating science into media language and for preparing clear statements because scientists frequently run the risk of being misinterpreted by media or policy;

- Minimize the time lag between production and use of data; (keep uptodate basic research information available, which will prove advisory for example if an industry develops a project at certain resources or sites, like for instance scientific knowledge on atmospheric pollution processes etc – key words again are EIS and SIS (social impact assessment)
- provide comprehensive information for off site implementation measures, i.e. national aquatic action plans – i.e. dealing with the issue of up-scaling;

Working Group 1 – Conclusions and Recommendations

The following conclusions have been reached:

- Identification of users and user-needs must become part of the project functional and also in a financial sense
- Formation of project teams should be oriented along the scientific requirements (diversification, including social science and economists) as well as the communication demands
- Stakeholder-analysis and participation (e.g. continuously by means of mentors of client target groups involved in respective project teams) must become part of the project;
- The latter means to have an early and lasting user involvement based on appropriate communication strategies and clear outlines of the bargain character of the process (highlighting the mutual benefits – based on joined ownership of issues)
- Referring to the private sector it might be appropriate to approach the peak bodies of user groups and again develop the issues jointly

2.2 Working group 2 – Working group report;

Chairman: Chris Crossland; Rapporteur: Maarten Scheffers

Participants: Christos Anagnostou, Horst Behrendt, Arve Berntzen, Knut Breivik, Gary Geernaert, Gabriel Kielland, Kerry Turner

The discussion in the group started with the identification of particular problem issues that are relevant to land-ocean interactions and coastal zone management. The next step was to identify specific relevant scientific knowledge gaps, in the context of the needs of a range of users.

Coastal Management was portrayed as a multi-layered process, often encompassing different levels of users and user needs, from the truly global to the local. These user levels can be identified in terms of different spatial and organisational scales. At the global and international level users are the parties to international conventions and agreements or enabling agencies (e.g. UN Conventions on Climate and Biodiversity). The next level is the international transboundary level, e.g. OSPAR or HELCOM agreements covering regional seas and the related drainage basin effects. At the national/regional and local levels many users can be identified, with their site specific and often conflicting needs.

The group identified **problem issues**, which highlighted long term generic requirements such as:

- the need for methods and techniques adapted to integrated coastal management (toolbox)
- a management system with the ability to cope with the consequences of extreme events, i.e. early warning systems, improved forecasting systems and better information on public risk perception and risk communication and management

- the inclusion of monitoring, and continual re-evaluation of management options within the coastal management cycle
- the need for public education and awareness capacity building

Pollution Problems

Two different types of pollution were discussed. Bioaccumulating stock pollution caused by artificially produced contaminants i.e. pesticides, POPs and PCBs, and by heavy metals like Mercury (Hg) and copper, etc.; and flow pollutants such as nitrogen, phosphorus and carbon. Under the sustainable development strategy the policy for contaminants should be to phase out their use and to remove them from the environment. For nutrients, cost-effective reduction options will involve combinations of land use changes, buffer zones creation and improved efficient treatment standards.

The working group identified several gaps in current knowledge:

- sources and loading data on a drainage basin scale
- transport mechanisms (e.g. role of groundwater)
- bioaccumulation and "acceptable" levels of risk
- data aggregation possibilities and limits
- dose-response relationships
- remediation options and costs
- decision making rules under uncertainty

The group discussed the issue of the requirements of users at different levels. Local case studies (in particular "hot spots") were found to be very relevant as a first order approach for problem identification and to examine in detail ways to mitigate specific local impacts. Detailed science from local work is required for risk assessments, health related problems and remediation questions. On the other hand, aggregation is necessary for the development of policies at a regional scale, or across a transboundary catchment area.

For natural scientists the application of the precautionary principle is often sufficient at the national and international scales. Economists are usually interested in cost data at the local scales, but with an increasing scale they require cost and benefit analyses and risk-benefit assessments. Other social scientists emphasize the importance of local value and belief systems as well as the functioning of international scale resource and political regimes.

Nature Protection

The group considered two aspects of nature, nature conservation and nature preservation.

The main goal of nature conservation is to manage a rate of change in environment and to maintain ecosystem integrity and functional diversity in a sustainable manner, given a number of stress and shock events. Better knowledge on the co-evolution of the natural system as a result of natural changes and the human impact is important for integrated management. The challenge is to both understand better the process and feedback effects involved and to mitigate welfare decreasing impacts as cost-effectively as possible. This requires knowledge on functional processes and uses i.e. coastal protection, sediment filter or buffer zones and knowledge on natural variability and cycles of ecosystem changes. An identified gap in management knowledge was the need for a set of sustainability indicators to track environmental change at all management levels.

Nature preservation is based the protection of existence values and culture heritage values for current and future generations. Users can be identified at several levels i.e. at the global level international conventions are requiring knowledge on response options; while at the local/regional scale a better understanding of beliefs, values and cultural heritage values is required. A specific group of users are scientists who use protected systems as a "natural laboratory", to further basic scientific understanding ("environmental knowledge") which itself underpins improved applied science ("environmental know-how").

Infrastructure Development Protection

Within drainage basins there are economic activities like agriculture (irrigation), manufacturing and transport (channelisation, shipping) which require of ten extensive and long term infrastructure investments. The resulting structured pose complex environmental impact problems over their entire life cycle. Problems range from acid sulphate soil exploitation causing adverse effects on fisheries and habitats (mangroves) in the coastal zone (e.g. in Vietnam, Queensland, Australia, Netherlands and East Anglia, UK).

At the shoreline other structures such as moorings, ports, etc. require protection from the sea and impose multiple impacts on coastal systems. Offshore and onshore subsidence as a result of gas and oil extraction is also causing problems for sea defences in for example the Wadden Islands and in Lagos, Ghana. The exploitation of marine aggregates is another problem area. Marinas often become "hot spots" problems because of the pollution caused by anti-fouling (TBT) and waste treatment together with the land conversion and congestion cost caused by mass tourism.

Resource Exploitation

A major gap exists in our knowledge on the ecosystem resilience and integrity. The complex question is what kind and degrees of stress and shock can be allowed before the system flips into a new and unknown configuration which may or may not be a useful to humans.

The group discussed the following resources overexploitation problems:

Waste Disposal/Dumping

Sources of waste are shipborne waste, dumping, fishing nets and ballast water. On the international level there are conventions which ban pollution of the marine environment by waste but enforceability is low. Practically the only way to prevent this is to invest in education on a local or regional level.

Tourism and Recreation

Distinction was made between land based and sea based tourism. Tourism has a large influence on the environment, but its economic value is important too. A new areas of interest is ecotourism, together with its principles and practises, which have yet to be properly formulated. Mass tourism creates a range of problems including, environmental (local) pollution and resource degradation, loss of local community values and lifestyles, health effects for the tourists themselves.

Fisheries

Two levels of activities are distinguished, commercial fisheries and recreational fisheries. There is a conflict between them which is expressed in the form of local income versus cultural income. The question is how to balance the interests of both? Commercial marineculture and aquaculture are a cause for particular concern.

Estuaries were recognised as "hot spots" with multiple problems often requiring mini integrated management plans.

Conflicts and conflict resolution

There is an endemic problem in coastal areas because of multiple stakeholders with conflicting interests. The appropriate level for solving these conflicts is at the local and regional user level. The group identified the following issues that have to be further elaborated:

- performance of management tools: scenarios, models, decision-support systems, risk-benefit analysis, etc.
- compensation agreements, including upstream/downstream issues
- new participatory processes to legitimise the management process and foster consensus
- coordination agency for integrated management in coastal areas

Environmental Technology

The group identified the need for the development of environmental remediation and alternative protection technologies. In the case of "softer" engineering solutions the consequences for risk perception amongst the public has to be investigated.

ELOISE projects and problem areas

The working group briefly evaluated the 29 ELOISE projects in terms of their contribution to the mitigation of the problem areas (see Table 1) identified by the group. It was concluded that many of the scientific knowledge gaps and management needs were not addressed by any of the funded projects. A majority of the projects were narrowly focused on a set of pollution and resource degradation processes and effects, stopping short of human welfare consequences. The human dimension was not at all well represented in the projects.

Table 1.. ELOISE projects and problem areas.

No.	Short name	Title	Problem area
1.	CHABADA	Changes in bacterial diversity and activity in Mediterranean coastal waters as affected by eutrophication	pollution (sustainability indicators) nature
2.	NICE	Nitrogen cycling in estuaries	pollution (sustainability indicators) resources (estuaries)
3.	METRO-MED	Dynamics of matter transfer and biogeochemical cycles: their modelling in coastal systems of the Mediterranean Sea	pollution (nutrients) nature resource conflict

No.	Short name	Title	Problem area
4.	ESCAPE	Entangled sulphur and carbon cycles in Phaeocystis dominated ecosystems	pollution (nutrients) resources
5.	COMWEB	Comparative analysis of food webs based on flow networks: effects on structure and function of coastal plankton communities	resources (fisheries)
6.	PHASE	Physical forcing and biogeochemical fluxes in shallow coastal waters	pollution (nutrients)
7.	MMS 2000	Marine monitoring system 2000+ for the North Sea Region	tools for ICZM nature
8.	FECTS	Feed-backs of estuarine circulation and transport of sediments on phytobenthos	pollution (nutrients)
9.	KEYCOP	Key coastal processes in the mesotrophic Skagerrak and the oligotrophic North Aegean: a comparative study	pollution (nutrients)
10.	DOMTOX	Importance of dissolved organic matter from terrestrial sources for the production, community structure and toxicity of phytoplankton of the European Atlantic and Baltic coastal waters	pollution (sust. Indicators)
11.	EULIT	Effects of eutrophicated seawater on rocky shore ecosystems studied in large littoral mesocosms	pollution (nutrients)
12.	BIOGEST	Biogas transfer in estuaries	pollution (atmospheric) resources (estuaries)
13.	POPCYCLING-BALTIC	Environmental cycling of selected persistent organic pollutants (POPs) in the Baltic region	pollution
14.	DUNES	Integrated management methods: monitoring environmental change in coastal dune ecosystems	nature resources environmental technology
15.	ECOFLAT	The eco-metabolism of an estuarine tidal flat	pollution resources (estuaries)
16.	TOROS	Biogeochemistry of an acidic and metal-rich river-estuary system, consequences for Atlantic shelf waters	pollution
17.	ROBUST	The role of buffering capacities in stabilising coastal lagoon ecosystems	resources (estuaries) nature environmental technology
18.	EROS-21	Biogeochemical interactions between the Danube river and the north-western Black Sea	pollution
19.	BBCS	The Baltic basin case study: towards a sustainable Baltic	conflicts tools resources nature (indicators)
20.	RANR	Regional analysis of subsurface retention of nitrogen and the impact on N export from land	pollution conflict resolving

No.	Short name	Title	Problem area
21.	EUROSSAM	European salt marshes modelling	nature environmental technology conflicts tools
22.	BASIC	Baltic Sea cyanobacteria	pollution nature (indicators)
23.	ISLED	Influence of rising sea level on ecosystem dynamics of salt marshes	nature resources
24.	MAMCS	The Mediterranean atmospheric mercury cycle system	pollution
25.	ANICE	Atmospheric N inputs into the coastal ecosystem	pollution
26.	MOE	Mercury species over Europe: relative importance of depositional MeHg fluxes to various ecosystems	conflicts pollution
27.	CLICOFT	Effects of climate induced temperature change on marine coastal fishes	resources (fisheries) nature (conservation)
28.	SUB-GATE	Submarine groundwater fluxes and transport processes from CH4 rich coastal sedimentary environments	pollution conflicts
29.	BASIS	Barents Sea impact study	resources tools

The science produced in ELOISE and LOICZ should make a practical contribution to coastal zone management. This can only be achieved when some of the research projects have a more multidisciplinary character. This means that natural and socio-economic science should be linked in one project, which produces both 'science' outputs and policy relevant findings.

Working Group 2 – Conclusions and recommendations

- The lack of an overall coherent set of goals for the science programme should be addressed. The core overall goal should be the achievement of integrated coastal management within a sustainable utilization of resources strategy; and the maximization of the contribution that science can make in practice to this objective.
- There is an urgent need to more effectively communicate the findings and methods of science to user groups in order to facilitate better and more comprehensive access to that information pool. This requires a proper communication strategy and action plan, making use of professional science communicators.
- The science programme lacks a sufficient focus on the human dimension and socio-economic/management analytical methods and techniques. A number of key problem issues have not been adequately addressed. A phase three of the ELOISE programme could be used to plug these gaps by funding a synthesis research exercise in order to determine precisely what is known and what is not known about the principles and practice of coastal zone science and management.
- The dearth of process mechanisms and outcomes for more participatory decision making in coastal zones needs to be corrected. This is both a scientific research need and also an opportunity to include users in the combined scientific and decision making exercise.

2.3 Working group 3 – Working group report;

Chairman: Jozef M. Pacyna; Rapporteur: Nicola Pirrone

Participants: Michel Frankignoulle, Ernesto Funaro , Bernhard Glaeser, Anders Grimvall, Graham Leeks, Elisabeth Pacyna, Wim Salomons, Sandra Martinho

Introduction

During the ELOISE / LOICZ workshop held at NILU, Kjeller, Norway on March 8-10, 1999 it was stressed the importance of socio-economic aspects in evaluating the impact of anthropogenic/economic activities in coastal zones on the marine environment. The meeting represented the first attempt within ELOISE to elaborate future strategies for fostering the exploitation of results for potential end-users. The workshop is a follow up of the discussion started during the meetings of the ELOISE Working Group No.1 on Fluxes and Cycling and the ELOISE Working Group No. 4 on "Coastal Zone Management and Integration of Natural and Socio-Economic Sciences" held during the 3rd Annual ELOISE Conference in Huelva, Spain in 1998. Indeed, the discussion was addressed to the following key issues:

- Exploitation of outcomes of EU-DGXII funded research projects (in the view of 5th FWP);
- Identification of communication barriers between science and decision makers and mechanisms of translation as well.
- Definition of the P-S-I-R (Pressure-State-Impact-Response) framework.
- Evaluation of major constraints in developing and using integrated models for coupling natural and socio-economic sciences.
- Review the current status of the research developed under the ELOISE umbrella in the view of this integrative data and management needs.

The ELOISE/LOICZ workshop was a first attempt to outline future initiatives to elaborate strategie(s)/methodologies for potential end-users of scientific results provided by ELOISE / LOICZ projects. The discussion on different aspects outlined in the workshop objectives was organised into three working groups in which scientists with different background and users with different needs were represented.

Objectives

The objectives of the WG No. 3 discussion was to outline future initiatives addressed to link major social and economic aspect(s)/issue(s) raised in the context of the coastal zone management and environmental protection measure(s)/policy on local vs. regional scales. The discussion focused on four different tasks as summarised below.

Task-1: To identify the user groups and their needs against which ELOISE and LOICZ research can provide scientific deliveries.

The identification of the user groups that may use the research results coming out from the ELOISE and LOICZ projects has been the major goal of this task. As a first step of the implementation process of research results related to different topics of concern for CZ management, the WG stressed the importance of developing a series of tables/templates in order to identify for each user groups the scale of action.

It should be taken into account that in the European Union every country has very often a different setting of political and administrative sub-regions to which control authorities (i.e., regional EPA agencies) as well as institutional offices (i.e., local government) belong to. Therefore, the WG would suggest in the context of future work/concerted initiatives/research projects to develop/define typical user groups that may act on similar geographic scales (i.e., urban, county or province, regions, national, European) on a given set of environmental issues. Depending upon the scale of the problem that a given user is facing to, the scale of action (of the user) must be related to the scale of the problem. In order to better reflect the importance of different needs related to different types of user groups, the WG concluded the discussion on Task-1 adopting the following statement:

Incorporation of users has to reflect the differences in history and culture existing in and among European Countries.

In general, the WG discussion on users and their needs have been limited by the fact that the Group was formed mostly of scientists from ELOISE and LOICZ projects. It was agreed that in this respect the whole Workshop should be considered as the first activity in a series of activities attended by the producers of science results and their users. The next meetings may be oriented towards certain well defined groups of users and their needs.

Task-2: To identify existing methodologies for translation of existing data from ELOISE/LOICZ projects on Pressure and Environmental Responses as well as Economic Forcing and Consequences in Coastal Zone Management into the decision-making process (incl. Science Communication).

The WG discussion focused primarily on the Drivers-Pressures-State-Impact-Response (D-P-S-I-R) framework. The major concern among all the WG members was to evaluate the state of knowledge of different links included in the D-P-S-I-R framework. Analysing the different links existing between major components of the D-P-S-I-R framework it was concluded that the knowledge of the link between Socio-Economic Drivers (SED) and Environmental State Changes (ESC) as well as that between Socio-Economic Drivers and Environmental Pressures (EP) **is moderate**, whereas the link of SED, EP as well as the ESC and Impacts **is weak**. The state of knowledge of the links between the Policy Response Options and all other parts of the D-P-S-I-R- framework **is not yet studied**.

Then, the WG analysed the structure and goals of current ELOISE projects that can potentially provide support or methodologies for improving our capability of implementing the components reported in the P-S-I-R framework. The following ELOISE projects were in focus:

ELOISE Project	Title	Objective	Scale	Coordinator
NICE	Nitrogen Cycling in Estuaries	Observe the fate of anthropogenic nitrogen into estuaries and coastal waters	International	T. Dalsgaard (DK)
METRO-MED	Dynamic of matter transfer and biogeochemical cycles: their modeling in coastal systems of the Mediterranean sea	Study and model the processes of mattr transfer (exchange and storage) biogeochemical cycles in the coastal zone system	International	C. Anagnostou (GR)

ELOISE Project	Title	Objective	Scale	Coordinator
MMS 2000	Marine monitoring system 2000+ for the North Sea Region	Render favorable conditions to create an integrated European marine monitoring and forecasting system for th eNorth Sea region based on fixed monitoring networks of national origin.	International / Regional	R.J. Akkerman (NL)
EROS-21	Biogeochemical interactions between the Danube river and the north-western Black Sea	Develop a framework of coupling of biogeochemical models of the river and marine system to counteract continuing eutrophication.	International / Regional	J.-M. Martin (IT) and C. Lancelot (BE)
BIOGEST	Biogas transfer in estuaries	Determine the distribution of biogases affecting climate and atmospheric chemistry in surface water of European estuaries	International / Global	M. Frankignoulle (BE)
POPCYCLIN G-Baltic	Environmental cycling of selected persistent organic pollutants (POPs) in the Baltic region	Develop a multicompartmental model to study the fate and behaviour of POPs in the Baltic Sea environment.	International / HELCOM major user	J.M. Pacyna (NO)
DUNES	Integrated management methods: monitoring environmental change in coastal dune ecosystems	Evaluate dune ecosystem vulnerability, both on spatial and temporal scales, due to natural and anthropogenic impacts.	International / Regional	A. Williams (UK)
TOROS	Biogeochemistry of an acidic and metal-rich river-estuary system, consequences for Atlantic shelf waters	Study and quantify the fluxes of trace metals discharged and how they are modified by estuarine processes.	International / Local	F. Elbaz-Poulichet (FR)
BBCS	The Baltic Basin case study: towards a sustainable Baltic	Develop a framework for sustainability in Baltic Europe, including maintenance of maximum flexibility for alternative future use	International	B.-O. Jansson (SE)
RANR	Regional analysis of sub-surface retention of nitrogen and the impact on N export from land.	Develop improved procedures for regional analysis of the N export from land to sea and to investigate the export control.	International / National	A. Grimvall (SE)
MAMCS	Mediterranean Atmospheric Mercury Cycle System	Develop state-of-the-art mesoscale/regional modeling framework to improve our knowledge on biogeochemical cycle of mercury in the Mediterranean Region.	International / Regional/ Local	N. Pirrone (IT)
MOE	Mercury Species Over Europe	Identify and quantify sources of atmospheric mercury species focusing on production and fluxes of MeHg.	International / Regional	A. Iverfeldt (SE)
BASIS	Barents Sea impact study	Assess the impact of global changes on cultural and socio-economic systems which are dependent on renewable natural resources in the Barents Sea region.	International / Regional	M. Lange (DE)

The following statement can summarise the conclusions of the WG No. 3 on the issues/topics reported in Task-2:

ELOISE is focused on the advancement of science and lesser the advancement of management

Task-3: Review Current and Planned Research.

The discussion focused on the need of developing different strategies for improving our ability in the exploitation and dissemination of research results. It was stressed the importance of developing an **exploitation plan** which can be regarded as a concerted / coordinated / multi-tasks (levels) action including the utilisation of different communication tools / media such as:

a) Marketing Mix strategies which include dissemination through TV / Press / etc. with specials on issues/topics related to different aspects of socio-economic activities in coastal zone and more in general on key questions involved in the P-S-I-R analysis at local/ regional and global scales.
b) Dissemination of results through special sessions held in the context of international conferences and workshops (i.e., 3rd ELOISE conference in Netherlands) in which to prepare / reframe / re-analyse the scientific results of ELOISE projects. The concerted actions with the activities of LOICZ and other existing programs should be encouraged.
c) The ultimate goal is to develop an Exploitation Plan / Action Plan which should include:
   a) A list of potential user groups.
   b) A list of data available for further analysis/exploitation.
   c) Preparation of video/tapes of relevance for local TV / Radio as well as update and maintain internet sites.
   d) Booklet for schools at all levels of education from elementary to university levels.
   e) Produce results/analysis in such a format for being used by professionals in the field of dissemination of scientific and socio-economic science results.

Make Our Language and Objectives More Users Oriented.

Task-4: Could overarching projects i.e., ELOISE, LOICZ broker the transfer of issues of concern from the scientific community to clients and vice versa.

General conclusion of the WG discussion on the above subject can be defined as follows:

The Involvement of Users is Hampered by the Lack of an Exploitation Plan of the ELOISE as a Whole.

Working Group 3 – Conclusions and Recommendations

The European coastal region has been and will be modified by humans. Yet, the human factor (i.e., morphodynamic changes, cultural changes, cultural conflicts, land use changes, property rights/user rights, competition for space and space management) is missing in the ELOISE projects. To solve this we need:

a) Involvement of the social sciences as equal partners in the future projects.
b) Encourage actions addressing the capacity building in holistic thinking. This may imply the development of Advanced Study Course as part of dissemination plan for young scientists and environmental planners.
c) Facilitate the interactions between leading scientists.

3 Conclusions and Recommendations

The European coastal region has been and will be modified by humans. Yet, the human factors, such as morphodynamic changes, cultural changes, cultural conflicts, land use changes, property rights/user rights, competition for space and space management are often missing in current studies on coastal zone management. One reason for slow progress in bringing human factors to CZM is an endemic problem in coastal areas related to the fact that there are multiple stakeholders in the coastal zone with conflicting interests. Major focus of the Workshop was to identify these stakeholders and their needs from science. Finally, it was discussed whether science today could address the stakeholders needs and what are the factors of science limitations in this respect.

The following conclusions have been elaborated during the Workshop discussions:

1. The research activities, such as ELOISE are focused on the advancement of science and less on the advancement of management in the coastal zone. The science program of many of these activities often lacks a coherent set of goals towards the achievement of integrated CZM within a sustainable utilization of resources strategy. The scientific community should also address the probability, in terms of space and time, of the identified hazards having impact on the coastal zone.

2. The science program of many research activities lacks a sufficient focus on the human dimension and socio-economic/management analytical methods and techniques. Involvement of social sciences as equal partners of natural science is indispensable in order to address a number of key problem issues in CZM which have not yet been adequately addressed. Activities, such as ELOISE could be used in the future to plug these gaps by focusing on a synthesis research exercise in order to determine precisely what is known and what is not known about the principles and practice of coastal zone science and management. In this way, the science of ELOISE will make a practical contribution to CZM.

3. The implications of the scientific and socio-economic findings should be discussed in partnership with the appropriate stakeholders, including policy makers. The language of science and its objectives should be more user oriented. Stakeholder analysis and participation should become a part of a research program in order to facilitate better and more comprehensive access to the information pool. The aim is to achieve the best possible decisions regarding mitigation and adaptive measures that will cope with the impacts of natural and human-induced changes in the coastal zone.

4. The involvement of stakeholders in the coastal zone research is often hampered by a lack of exploitation plan of research findings. Actions addressing the capacity building in a holistic thinking should be encouraged. As an immediate action, it was proposed to develop an EU Advanced Study Course for young scientists and environmental planners.

5. The dearth of process mechanisms and outcomes for more participatory decision-making in coastal zones needs to be corrected. This is both, scientific research need and also an opportunity to include users in the combined scientific and decision-making exercise.

Acknowledgements

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Appendix A

Papers presented at the Workshop

Global Change – The LOICZ approach

by

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Abstract

The global International Geosphere-Biosphere Program (IGBP) aims to quantitatively understand the biophysical processes that regulate the Earth's surface and its capacity to support life. Land-Oceans Interaction in the Coastal Zone (LOICZ) is one of the eight core projects studying the Earth ecosystems. LOICZ is generating more accurate estimates of the fluxes of materials into, through and out of the world's coastal zone.

The LOICZ program has two major thrusts. First, the development of horizontal and, to a lesser extent, vertical material flux models (or budgets) from continental basins through regional seas to continental ocean margins, and the influence of human activities. The second thrust is addressing the scaling of the material flux models at spatial scales from local to global levels and across temporal scales. LOICZ aims to have within two years, a collection of coastal biogeochemical budgets that is an adequate basis for globalisation (more than 150), and a system of typologies that can be used for a first-cut globalisation synthesis.

LOICZ started its first phase in 1993, developing comprehensive science and implementation plans and establishing a global network of some 2000 researchers. A second 5-year phase began in 1998.

It is clear that a useful and practical knowledge of the globally heterogeneous coastal zone depends on harnessing an array of research from natural and social sciences, and recognition of both anthrocentric and geocentric driving forces of change. The LOICZ program is designed to encompass these elements in providing science information to the global community and which should prove vital for use by global decision-makers and coastal zone management.

Introduction

For more than a decade, the International Geosphere-Biosphere Program (IGBP) has been harnessing scientific skills throughout the world to address Global Change. The global program aims to quantitatively understand the biophysical processes that regulate the Earth's surface and its capacity to support life. Land-Oceans Interaction in the Coastal Zone (LOICZ) is one of the eight core projects of IGBP, and is providing science information to answer the generic question: "How will changes in land use, sea level and climate alter coastal ecosystems, and what are the wider consequences?" (see IGBP website, http://www.igbp.kva.se/)

Fundamental to answering this question is the need to recognise that the area of the Earth's surface where land, sea and atmosphere meet and interact - the coastal zone - is not a line boundary of interaction but a global compartment (Figure 1). It is of special significance, not only for biogeochemical cycling and processes but increasingly for human habitation.

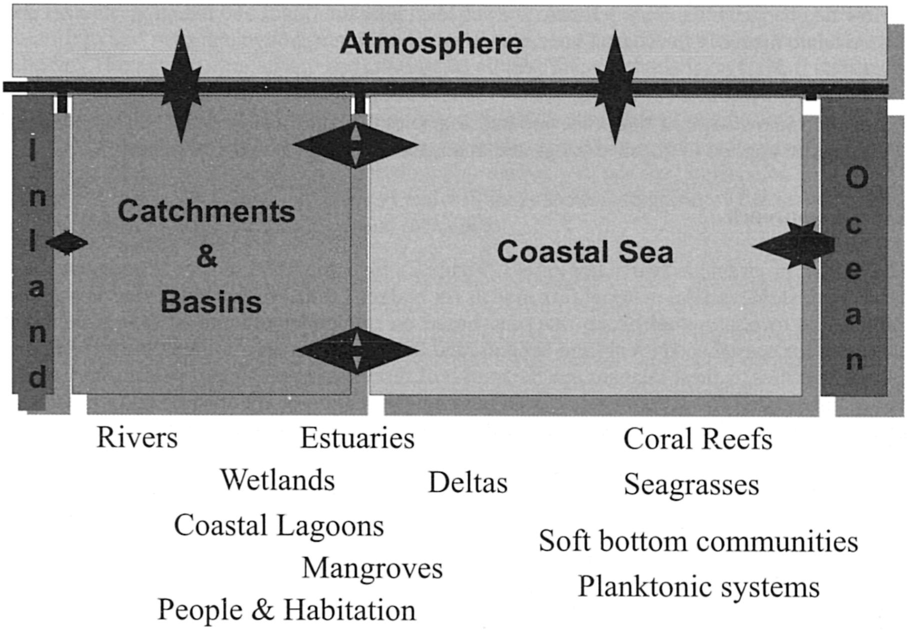

Figure 1. The coastal zone is not a line boundary but a vital global compartment with many boundaries and fluxes involving interacting biophysical, geochemical, and socio-economic processes.

The vital nature of the coastal zone and it importance to global change considerations and the Earth's peoples is now generally acknowledged by scientific and political forums. In comparison with the relatively uniform environment of the sunlight zone of the open ocean, or the rapidly mixing environment of the atmosphere, the spatial and temporal heterogeneity of the world's coastal zone is considerable. Consequently, considerable methodological problems are associated with developing global perspectives of the role of this compartment in the functioning of the total Earth's system.

Practical knowledge of the heterogeneous coastal zone depends on harnessing an array of research from natural and social sciences and recognising both anthrocentric and geocentric driving forces of change. The LOICZ program is designed to encompass these elements in providing science information to the global community and which should prove vital for use by global decision-makers and coastal zone management.

LOICZ Purpose

LOICZ is trying to generate more accurate estimates of the fluxes of materials into, through, and from the world's coastal zone (Pernetta and Milliman, 1995). Major questions that LOICZ addresses on a global scale are:

- Is the coastal zone a sink or source of CO_2?
- What are the mass balances of carbon, nitrogen and phosphorus in the coastal zone?
- How are humans altering these mass balances, and what are the consequences?

- How do changes in land use, climate and sea level alter the fluxes and retention of water and particulate matter in the coastal zone, and affect coastal morphodynamics?
- What is the role of the coastal zone in trace gas (e.g., DMS, NO_x) emissions?
- How can knowledge of the processes and impacts of biogeochemical and socio-economic changes be applied to improve integrated management of the coastal environment?

LOICZ Approach

The LOICZ program has two major thrusts (Figure 2). First, the development of horizontal and, to a lesser extent, vertical material flux models (or budgets) from continental basins through regional seas to continental ocean margins, based on our understanding of biogeochemical processes for coastal ecosystems and habitats, and the human dimension. Here, the influence of human activities on these changes and the impact of flux changes on human welfare are vital areas of enterprise. The second thrust is addressing the scaling of the material flux models at spatial scales from local to global levels and to a lesser extent across temporal scales.

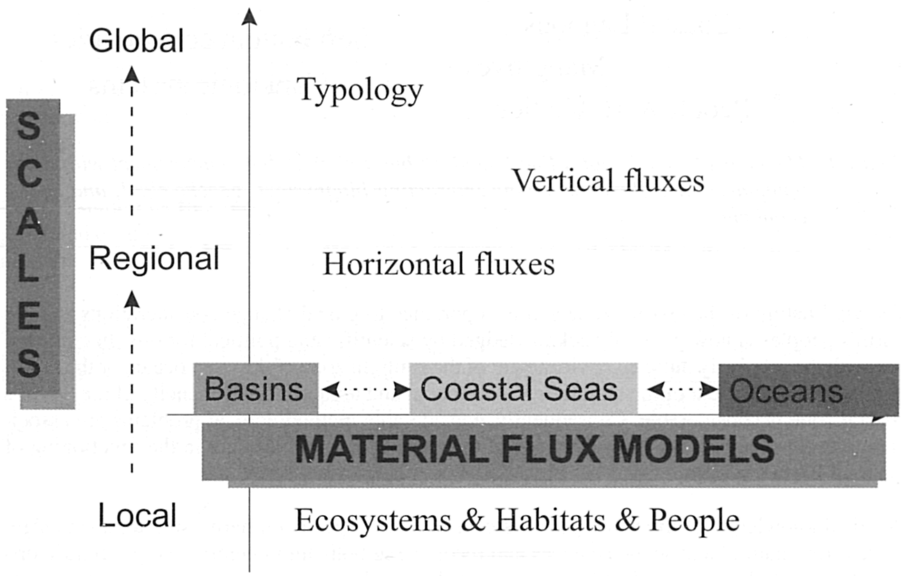

Figure 2. Representation of the two major dimensions of the LOICZ approach.

LOICZ Activities

The LOICZ activities are organised through four working areas, or Foci:

- Focus 1: The effects of changes in external forcing or boundary conditions on coastal fluxes
- Focus 2: Coastal biogeomorphology and global change
- Focus 3: Carbon fluxes and trace gas emissions
- Focus 4: Economic and social impacts of global change in coastal systems

The Foci bring together an integrated program of research and assessment addressing material fluxes into and between coastal basins and coastal seas, and describing forcing functions and boundary fluxes with atmosphere and continental slopes. The emphasis is on C, N, P (especially CO_2, with consideration of trace gases) and dissolved and particulate states and forms of matter. The socio-economic dimension is important to LOICZ: the effect of people activities on the material fluxes and how the subsequent changes in the coastal zone may influence the human dimension of the coastal zone. Our modeling approaches will use the "currencies" of biogeochemistry (especially carbon and energy) and will include considerations of the monetary and societal values in expressing changes and influences.

The development of carbon, nitrogen and phosphorus budgets at local and regional scales for coastal seas, including flux boundary conditions at landward estuarine environments and at continental margins environments, is a core element of LOICZ (Figure 3). Allied river basin work is to elucidate the material input conditions and processes, including the socio-economic effects and conditions, influencing and modifying riverine and ground water discharges.

LOICZ aims to develop a suite of horizontal material fluxes models (continental basin to continental shelf margin) from case studies in different regions of the world, which take account of the range of linking and forcing variables.

To meet this challenge of better describing and understanding the dynamics of the land sea interface, a number of topical core projects are to being implemented. These will include capture and integration of research outcomes from the array of existing and contributed studies and other relevant research (particularly at local scales) which address the fundamental questions of ecosystem function, diversity and ecology, and the developing information base on the socioeconomic dimensions.

In addition to the biogeochemical and socio-economic dimensions and assessments of horizontal material fluxes (including groundwater), the scaling issues and necessary methodological developments are crucial to LOICZ. We have a strong involvement by researchers to develop typological approaches, tools and methods. This work is trying to find a coherent approach and tool kit to resolve the up-scaling issue. The development of further databases, identification of key indicator variables for monitoring (particularly at local and regional scales) and abilities to pursue scenario building ("what if.....") are planned activities.

Collaboration and partnerships are vital for LOICZ. While new projects are established to meet goals and fill gaps, LOICZ depends on existing data and information. The LOICZ program is organised around a structure of major projects (including commissioned tasks and contributed relevant research projects) and activities which synthesis the global science knowledge, involving both original research activities and integration of our global science knowledge about the coastal zone. Major projects include:

- Foci-related, addressing key LOICZ elements and developing new tools, and
- Regional, addressing specific issues and enhancing skills, case studies and intuitively different – climatic, biophysical/socioeconomic impacts – global areas, integration of local-regional scales, models and needs of science for application to globally representative coastal zone management issues.

A network of global researchers continues to make available data and science findings from topical and local scale projects. Synthesis of scientific information and uncertainties is approached by a coordinated framework and integration processes to bring together the expertise and scientific information about the coastal zone through commissioned reviews, expert working groups and task teams, workshops and open science meetings for peer-review and tools assessments.

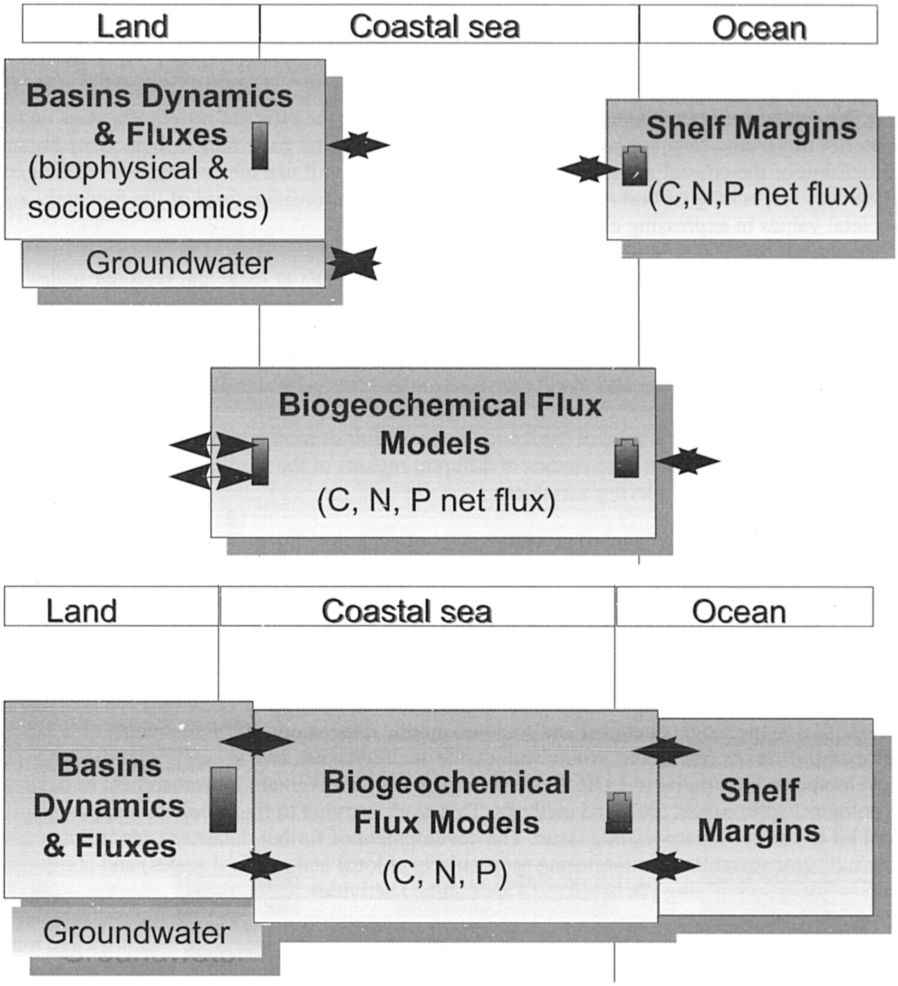

Figure 3. LOICZ approach to horizontal flow: Key elements (top) and their alignment (bottom) which describes material flow and the human dimension in the coastal zone for a site or region.

LOICZ aims to facilitate the necessary research activities by encouraging national support for key projects. Where possible, LOICZ looks to provide appropriate seed funding and particularly seeks avenues of funding from international and regional agencies and organisations to support targeted research, data assessment and capacity building and training. LOICZ funds are mainly directed to the processes of integration and synthesis of science information, facilitating networking and researcher collaboration, and communication and transfer of information, tools and skilled inputs to the global agencies (IGO's and NGO's) and the wider community.

LOICZ started its first phase in 1993, and has developed comprehensive science and implementation plans and establishing a global network of some 2000 researchers. Engaging and involving IGO and NGO "client" organisations in the LOICZ work of research, integration and product delivery is important to ensure the transfer of our science knowledge for application by decision makers and other global interests in coastal zone management (Figure 4).

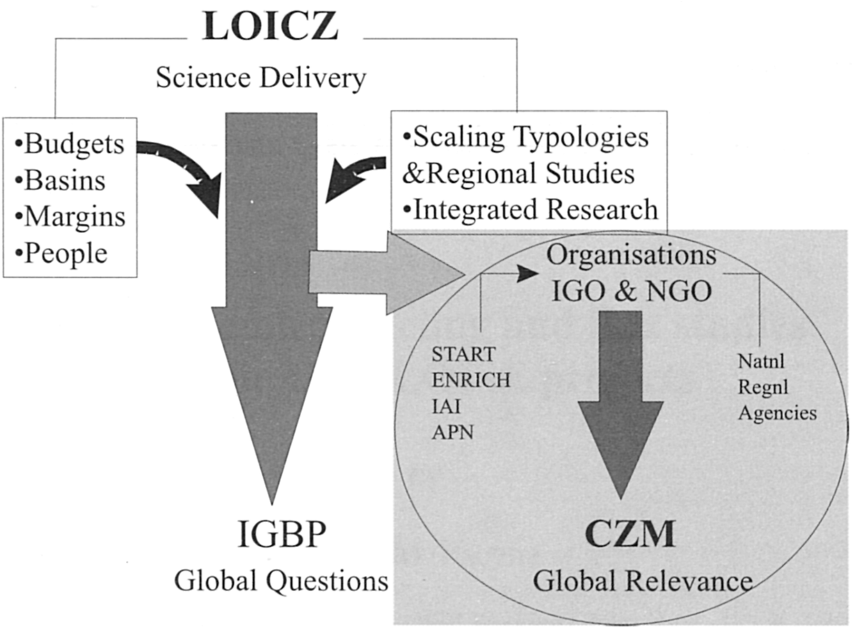

Figure 4. Representation of the major directions for use of LOICZ science: a) by IGBP program and b) by global organisations (IGO's and NGO's), regional programs and national agencies

LOICZ began its second 5-year phase in 1998 and we are putting increased effort both into consolidating our partnerships and into developing new regional projects in Africa, Australia, Latin America and Europe. However, commitment of people and their regionally and nationally supported research is fundamental to our success.

Timeframes and Projected outcomes

The intended outcomes to be achieved within the 10-year lifetime of the original LOICZ proposal (i.e., by 2002) include not only an initial globalised estimate of coastal zone biogeochemical functions and material fluxes, but also an assessment of specific data and techniques needed to refine the estimates at all scales. This improved understanding of sensitivity and interactions at various scales will ultimately be the major legacy of LOICZ to coastal zone science and management, as the estimates of biogeochemical fluxes and functions will be the contribution to overall goals of IGBP in understanding the total Earth system.

LOICZ aims to have within three years, a collection of coastal biogeochemical budgets that is an adequate basis for globalisation (more than 150), a compendium of information on coastal basin dynamics, and a system of typologies that can be used for a first-cut global synthesis. It is expected that the system will involve multiple typologies - groundwater and surface water fluxes, for example, may be considered separately and compared. Similarly, we envisage several stages of superimposing the human dimension on the natural environment, mainly through case study evaluations for different regions and at different spatial scales. The overall synthesis of the LOICZ information to achieve a global statement against our goals will occupy a large number of scientists globally in the first years of the new millenium.

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Biogeochemical cycling and flux studies within the ELOISE projects

by

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Introduction

The European Land-Ocean Interaction and Shelf Exchange Studies (ELOISE) is an action (called "Thematic Network") where 29 coastal zone research projects of the European Commission are combined to focus on studies of how the land-ocean interaction operates and how this interaction is influenced by human activities (ELOISE, 1998). The EU Marine Science and Technology (MAST) program contributes to ELOISE with 11 projects and the EU Environmental and Climate program adds 18 projects.

Objectives and Structure of ELOISE

The overall goal of ELOISE is to determine the role of coastal seas in land-ocean interactions (including shelf-deep sea interactions along the shelf edge) in the perspective of global change. In general, there are four areas of research within the ELOISE projects focusing on:

- significance of coastal seas in the global change of the environment,
- human impact on coastal seas,
- socio-economic development and coastal seas, and
- methodology and implementation of the ELOISE project results.

The significance of coastal seas in global change is studied with the aim to further explain the biogeochemical cycles of carbon, nutrients, and selected trace elements and persistent organic pollutants (POPs) in the coastal zone, as well as fluxes of biogases from the coastal ocean which contribute to the climate change.

Studies of human impact on coastal seas concentrate on the assessment of the regional and global consequences of this impact through pollution, eutrophication and physical disturbance in the coastal zone. These studies focus on the following subjects:

- historical records of past changes in land-ocean interactions,
- interactions between pollution, eutrophication and physical disturbance,
- the biology of global change in the coastal zone,
- human impact through changing land-use and economic development, and
- direct effects of human activities in the coastal seas.

The main objective of studies on socio-economic development and its impact on the coastal seas is to formulate a strategic approach to the management of sustainable coastal zone resource use and development and to investigate the information on policy and market failures that hamper sustainable coastal resources management. This objective is being met through the interdisciplinary research (with natural and socio-economic sciences in place) on various strategies and techniques for cost-efficient and environment friendly management of zone resources.

The information on the ELOISE projects, including the main objectives of the projects is presented in Annex 1.

There are four Working Groups within ELOISE attempting some synthesis and even integration of results from the ELOISE projects:

- WG1 on Biogeochemical Fluxes and Cycles,
- WG2 on Ecosystem Structures,
- WG3 on Modeling and Data Management, and
- WG4 on Integration of Natural and Socio-economic Sciences.

This paper aims at presentation of research on biogeochemical cycling and fluxes of chemicals, carried out within the ELOISE projects and thus related to the WG1.

Biogeochemical cycle and flux studies within ELOISE

Main tasks of the ELOISE Working Group on Biogeochemical Fluxes and Cycles include:

- an attempt to integrate data from various ELOISE projects on sources, releases, pathways, and transfer of chemical measured/monitored in the coastal zone of Europe,
- identification of users and promotion of the ELOISE results in order to contribute to efficient coastal zone management, and
- advisory on new research avenues, with focus on aquatic continuum studies, e.g. coupled watershed-river-estuary-sea studies.

A summary of information on the chemicals studied within individual ELOISE projects and geographical region of these studies is presented in Annex 2.

Is the integration of data on fluxes and cycles from various ELOISE projects possible and how to obtain this integration?

The integration of data on fluxes and cycles from various ELOISE projects is a difficult task. The difficulties stem from the fact that the projects vary substantially with respect to the geographical coverage and time scale. Some of the projects employ measurements in small estuary systems and other projects study the open sea systems. Even within the open sea systems, the hydrology of one sea may differ significantly from the hydrology of the other sea.

The problem of scaling up or down of data from the ELOISE projects relates also to modeling and other techniques to study cycling of chemicals in various scale coastal systems.

At present the issue of data integration and scaling has been seen in the ELOISE as very important in order to attempt synthesizing the results of the ELOISE projects. Such synthesis is needed for the analysis of the contribution of ELOISE to a European-wide coastal zone management and research priorities. At the same time ELOISE alone is not going to cope with problem, at least not now. This problem can be tackled in cooperation with international programs/organizations, which have some experience in developing and applying various typology techniques. The IGBP Land-Ocean Interactions in the Coastal Zone (LOICZ) program is one of the programs with such experience.

Are the ELOISE projects developing methodologies for translation of the data on environmental pressures and responses into the decision-making process?

In answering the above question one should first define the role of scientists and managers in the coastal zone. The role of scientists is to rigorously examine various factors, both environmental and socio-economic, affecting the coastal zone system. The role of managers is to manage human activities in the coastal zone taking into account the results of the scientific achievements. The ELOISE scientists examine mostly the environmental factors affecting the coastal zone system. Obviously this examination is limited to the regions of individual projects. The problem of scaling up the project results to achieve the European picture of the coastal zone is extremely difficult, as mentioned already in this paper. However, the examination of ELOISE project objectives and preliminary results indicates that ELOISE is focused on the advancement of science and to lesser degree on the advancement of coastal zone management. As a consequence, there is only very limited attempt within the ELOISE projects at present to develop methodologies which will translate the ELOISE project results, particularly on fluxes and cycling of chemicals in the coastal zone in Europe, into the policy-making process.

The following factors seem to hamper the development of the above mentioned methodologies, and consequently the communication between scientists and science-users:

- a lack of issue driven science,
- limitations of coastal zone science, and
- a lack of matching of science priorities with the management priorities.

More user oriented objectives of research projects, also those within ELOISE, will make their scientific content more issue driven. To achieve this, larger representation of users in the future ELOISE projects is needed with clear definition of the user needs in Europe with respect to sustainable development of the coastal zone.

The degree of limitations of coastal zone science depends very much on the coastal zone issue to be addressed, and accuracy required when addressing the issue. In the current state of the ELOISE projects the user contribution is very limited, mostly to the fellow scientists using the outcome of current ELOISE projects in their future studies/measurements/models. In such case, the limitations of coastal zone science are easy to identify and probably a solution in a form of additional research can be outlined.

More difficult questions to address by scientists seem to be those defined by coastal zone managers. Sometime these questions can be too difficult to tackle, e.g. models are not able to provide the requested answers. There may also be a limit of scientific interest in defining the question by policy makers.

The limitations of coastal zone science from the user perspective within ELOISE projects can be discussed analyzing various links of the Drivers-Pressures-State-Impact-Response (D-P-S-I-R) framework. The most studied are the links between socio-economic Drivers (D) and environmental Pressures (P), and between Pressures (P) and environmental State (S) changes. Less studied and understood is the link between environmental State (S) changes and Impacts (I), while the links between the policy Response (R) options and other parts of the D-P-S-I-R framework are not studied at all within ELOISE at present.

Current research within the ELOISE projects on fluxes and cycling of chemicals in the coastal zone is based on science priorities and as such may not match the management priorities. This matching of priorities can be balanced when coastal zone managers are more directly involved in the ELOISE research, most likely already during the 5th phase of the EU Framework Programme for the period 1998-2002.

Final remarks

The following remarks can be defined:

- Future studies on land-ocean interactions in the coastal zone, carried out within ELOISE, shall focus not only on the assessment of fluxes, processes, fate, and environmental effects of chemicals, but also on socio-economic aspects of environmental strategies aiming at sustainable development of the coastal zone. This would require broader multidisciplinary character of such studies and consequently cooperation of natural and socio-economic scientists with coastal zone managers.
- Development of methodologies for translation of information on socio-economic drivers, causing certain pressures on the coastal zone and environmental responses to these pressures, as well as socio-economic aspects of the coastal zone change into the decision-making process shall be highly prioritized in future research. This activity creates a practical base for joint studies and interactions between representatives of various scientific disciplines involved in studying environmental and socio-economic changes in the coastal zone and coastal zone managers.
- Further steps towards developing procedures for integration of information on fluxes and cycles of chemicals in the coastal zone, studied within ELOISE and other international programs shall be encouraged following the attempts within LOICZ and the IOC Global Ocean Observing System (GOOS) activities. Indeed, with rather broad international research on fluxes and cycles of chemicals in the coastal zone, it is of utmost importance that we have means to scale up (or scale down in some circumstances) the outcome of regional or even local projects in order to obtain a balanced, global picture of environmental and socio-economic changes in the coastal zone. Such global understanding is needed for international agreements and strategies to counteract the change in the coastal zone.

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ELOISE projects

No.	Short name	Title	Objetive	Coordinator
1.	CHABADA (MAS3-CT96-0047)	Changes in bacterial diversity and activity in Mediterranean coastal waters as affected by eutrophication	Examine changes of microbial populations due to anthropogenic activity and how the previous balance can be redressed	E. Stackebrandt (DE)
2.	NICE (MAS3-CT96-0048)	Nitrogen cycling in estuaries	Observe the fate of anthropogenic nitrogen into estuaries and coastal waters	T. Dalsgaard (DK)
3.	METRO-MED (MAS3-CT96-0049)	Dynamics of matter transfer and biogeochemical cycles: their modeling in coastal systems of the Mediterranean Sea	Study and model the processes of matter transfer (exchange and storage) and biogeochemical cycles in the coastal zone system	C. Anagnostou (GR)
4.	ESCAPE (MAS3-CT96-0050)	Entangled sulfur and carbon cycles in Phaeocystis dominated ecosystems	Establish a link between the marine carbon and sulfur cycles	W. Gieskes and J. Stefels (NL)
5.	COMWEB (MAS3-CT96-0052)	Comparative analysis of food webs based on flow networks: effects on structure and function of coastal plankton communities	Develop methods for assessing and predicting the effects of nutrient supply on the stability and persistence of pelagic food web structure and function in coastal areas	Y. Olsen (NO)
6.	PHASE (MAS3-CT-96-0053)	Physical forcing and biogeochemical fluxes in shallow coastal waters	Investigate the physical forcing and high frequency variability of biogeochemical processes in shallow coastal waters	F. Møhlenberg (DK)
7.	MMS 2000 (MAS3-CT96-0057)	Marine monitoring system 2000 + for the North Sea Region	Render favorable conditions to create an integrated European marine monitoring and forecasting system for the North Sea Region based on fixed monitoring networks of national origin	R.J. Akkerman (NL)
8.	FECTS (MAS3-CT97-0145)	Feed-backs of estuarine circulation and transport of sediments on phytobenthos	Investigate the ecosystem loops in estuarine environments involving phytobenthos communities, hydrodynamics, nutrient cycling and sediment transport	A. Bergamasco (IT)
9	KEYCOP (MAS3-CT97-0148)	Key coastal processes in the mesotrophic Skagerrak and the oligotrophic North Aegean: a comparative study	Understand and model the processes that determine flux of C, nutrients and trace substances in the water column and sediment in different hydrographic and nutrient regimes and the vertical and horizontal fluxes between the pelagic and benthic systems	J. Gray (NO)
10.	DOMTOX (MAS3-CT97-0149)	Importance of dissolved organic matter from terrestrial sources for the production, community structure and toxicity of phytoplankton of the European Atlantic and Baltic coastal waters ...	Obtain enough information on the importance of DOM from terrestrial sources for the production community structure and toxicity of phytoplankton and protists of the European Atlantic and Baltic coastal waters	S. Maestrini (FR)

No.	Short name	Title	Objetive	Coordinator
11.	EULIT (MAS3-CT97-0153)	Effects of eutrophicated seawater on rocky shore ecosystems studied in large littoral mesocosms	In general: to improve the health of the coastal ecosystem and environmental management	T. Bokn (NO)
12.	BIOGEST (ENV4-CT96-0213)	Biogas transfer in estuaries	Determine the distribution of biogases affecting climate and atmospheric chemistry in surface water of European estuaries	M. Frankignoulle (BE)
13.	POPCYCLING-BALTIC (ENV4-CT96-0214)	Environmental cycling of selected persistent organic pollutants (POPs) in the Baltic region	Develop a multicompartmental model to study the fate and behavior of POPs in the Baltic Sea environment	J.M. Pacyna (NO)
14.	DUNES (ENV4-CT96-0215)	Integrated management methods: monitoring environmental change in coastal dune ecosystems	Evaluate dune ecosystem vulnerability, both on spatial and temporal scales, due to natural and anthropogenic impacts	A. Williams (UK)
15.	ECOFLAT (ENV4-CT96-0216)	The eco-metabolism of an estuarine tidal flat	Examine the carbon nutrient cycle of the tidal mud flat ecosystem	P. Herman and C. Heip (BE)
16.	TOROS (ENV4-CT96-0217)	Biogeochemistry of an acidic and metal-rich river-estuary system, consequences for Atlantic shelf waters	Study and quantify the fluxes of trace metals discharged and how they are modified by estuarine processes	F. Elbaz-Poulichet (FR)
17.	ROBUST (ENV4-CT96-0218)	The role of buffering capacities in stabilizing coastal lagoon ecosystems	Identify and define the biotic and abiotic components of internal processes and their interrelationships, which enable lagoons to act as buffers to external forces	R. de Wit (FR)
18.	EROS-21 (ENV4-CT96-0219)	Biogeochemical interactions between the Danube river and the north-western Black Sea	Develop an integrated frame-work of coupling of biogeochemical models of the river and marine system to counteract continuing eutrophication	J.-M. Martin (IT) and C. Lancelot (BE)
19.	BBCS (ENV4-CT96-0269)	The Baltic basin case study: towards a sustainable Baltic	Develop a framework for sustainability in Baltic Europe, including maintenance of maximum flexibility for alternative future use	B.-O. Jansson (SE)
20.	RANR (ENV4-CT97-0435)	Regional analysis of subsurface retention of nitrogen and the impact on N export from land	Develop improved procedures for regional analysis of the N export from land to sea and to investigate the export control	A. Grimvall (SE)
21.	EUROSSAM (ENV4-CT97-0436)	European salt marshes modeling	Develop a policy and management tool for the conservation and restoration of salt marshes	J.-C. Lefeuvre (FR)
22.	BASIC (ENV4-CT97-0571)	Baltic Sea cyanobacteria	Assess the input of new N and C into Baltic and identify factors controlling this process	L. Stal (NL)

No.	Short name	Title	Objetive	Coordinator
23.	ISLED (ENV4-CT97-0582)	Influence of rising sea level on ecosystem dynamics of salt marshes	Determine the influence of increased flooding frequency on ecophysiology of tidal marshes and to examine its influence on the sediment microorganisms	T. Cappenberg (NL)
24.	MAMCS (ENV4-CT97-0593)	The Mediterranean atmospheric mercury cycle system	Improve our knowledge on biogeochemical cycle of Hg in the Mediterranean Sea	N. Pirrone (IT)
25.	ANICE (ENV4-CT97-0594)	Atmospheric N inputs into the coastal ecosystem	Assess atmospheric inputs of N into the sea and the governing processes that are specific for coastal areas	G. de Leeuw (NL)
26.	MOE (ENV4-CT97-0595)	Mercury species over Europe: relative importance of depositional MeHg fluxes to various ecosystems	Identify and quantify sources of atmospheric mercury (Hg) species focusing on production and fluxes of MeHg	A. Iverfeldt (SE)
27.	CLICOFT (ENV4-CT97-0593)	Effects of climate induced temperature change on marine coastal fishes	Investigate and identify the mechanisms of the possible impact of climate induced temperature changes on the distribution and population dynamics of 2 fish species	H.-O. Poertner (DE)
28.	SUB-GATE (ENV4-CT97-0631)	Submarine groundwater fluxes and transport processes from CH4 rich coastal sedimentary environments	Quantify and model land-sea interaction of groundwater and coastal waters with special emphasis to submarine groundwater fluxes, transport processes, and CH4 fluxes	M. Schlüter (DE)
29.	BASIS (ENV4-CT97-0637)	Barents Sea impact study	Assess the impacts of global changes on cultural and socio-economic systems which are dependent on renewable and non-renewable natural resources in the Barents Sea region	M. Lange (DE)

ELOISE projects

Project	Region	Fluxes	Cycles
1) CHABADA	Mediterranean	N/P	-
2) NICE	Estuaries	N	N
3) METRO-MED	Mediterranean (2 regions)	C/N/metals	C/N/metals
4) ESCAPE	Norwegian coast/ North Sea	C/S	C/S
5) COMWEB	Baltic/ Mediterranean/ N-E Atlantic	C/N/P	C/N/P
6) PHASE	3 shallow sites	-	-
7) MMS 2000	North Sea	-	-
8) FECTS	Estuaries	Nutrients	Nutrients
9) KEYCOP	Skagerrak/N-Aegean	C/N/P/metals	C/N/P/metals
10) DOMTOX	Baltic/Eur-Atlantic	Nutrients as source of toxins	Nutrients
11) EULIT	Small sites	-	-
12) BIOGEST	Estuaries	Biogases, C/N	-
13) POPCYLING	Baltic	Persistent organic pollutants	Persistent organic pollutants
14) DUNES	-	-	-
15) ECOFLAT	Estuaries	C/nutrients	C/nutrient
16) TOROS	Estuaries	Metals	Metals
17) ROBUST	Lagoons	-	-
18) EROS-21	Black Sea	C/N/P/metals	C/N/P/metals
19) BBCS	Baltic	-	-
20) RANR	Various sites	N	-
21) EUROSSAM	Salt marshes	-	-
22) BASIC	Baltic	N/C	N/C
23) ISLED	Salt marshes	-	-
24) MAMCS	Mediterranean	Mercury	Mercury
25) ANICE	North Sea	N	N
26) MOE	Not specified Europe	Mercury	Mercury
27) CLICOFI	North Atlantic	-	-
28) SUB-GATE	Baltic	CH4	CH4
29) BASIS	Barents Sea	-	-

Pressure factors having impact on the level of fluxes and the state of the environment

by

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Despite the declining global birth rates in the last 35 years and recent policy initiatives towards more efficient and cleaner resource use in some regions, the large increase in world population, expanding economies in industrialising countries and wasteful consumption patterns, particularly in developed countries of the world, will continue to increase global resource and energy consumption, generate burgeoning wastes and spawn environmental contamination and degradation (WRI/UNEP/UNDP, 1992; Bergesen and Parmann, 1994; World Bank, 1995; Raskin *et al.*, 1996; UNEP, 1996-a; UNEP, 1997).

Recent survey carried out by major international organisations show that about 60% of the world population lives within 100 kilometres of the coastline and more than 3 billion people rely in some manner on coastal and marine habitats for food, building sites, transportation, recreation and waste disposal (i.e., WRI/UNEP/ UNDP, 1992; Leach, 1995; EEA, 1995; UNEP, 1997). Nearly 30% of the world's coastal regions are at high risk of degradation, particularly from land-based sources of pollution (i.e., industries, agricultural practices) and infrastructure development (i.e., dams, highways, ports) (UNEP, 1997; Bryant *et al.*, 1995; Richards, 1990; World Bank, 1995-a). The pressure of socio-economic factors on the European coasts are among the highest in the world, with some 80% at risk, followed by Asia and Pacific, with 70% of the coast at risk (EEA, 1995; UNEP, 1997; Kremer and Pirrone, 1999). In Latin America, about 50% of the mangroves are affected by forestry and aquaculture activities. Oil spills are particular threats in West Asia and the Caribbean, while infrastructure development for the tourism industry puts stress on natural coastal areas in most regions of the world. The overexploitation of marine fisheries and consequent decline in stocks of commercial fish species (over 60% of marine fisheries are heavily exploited in the world) is the cause of a widespread alarm in Asia, Pacific, North America and Europe (WRI/UNEP/UNDP, 1992; WRI/UNEP/UNDP, 1996; WWI, 1996 and references therein).

Global environmental change raises important issues for social and natural sciences and suggests the importance of interdisciplinary research. In order to understand the level of pressure of human activities on the environment there is a strong need to develop an integrated analysis of the temporal evolution of major driving factors causing the change on regional and global scales. The Driver-Pressure-State-Impact-Response (DPSIR) framework is an integrated strategy for merging the knowledge in socio-economic and natural sciences as outlined in Figure 1 and extensively discussed in Turner *et al.* (1998).

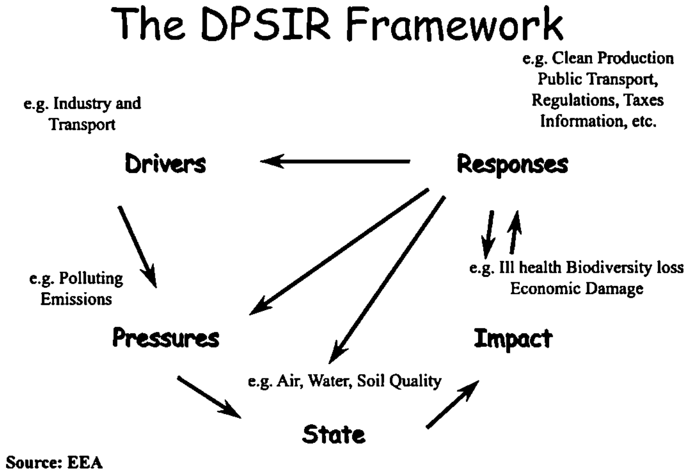

Figure 1. The Driver-Pressure-State-Impact-Response (DPSIR) framework (Source: EEA, 1995; Turner et al. 1998).

Spatial and temporal changes in pressure factors on the environment is primarily related to changes in economy which in turn reflects the change in major socio-economic drivers that include:

- Population growth.
- Increasing migration of population from rural to urban areas causing an increase in urbanisation rates which lead to an increase of:
  - solid waste generation,
  - water demand and wastewater generation, and
  - energy consumption and production.
- Increasing rate of economic growth (GNP).
- Increasing rate of national and international transportation of goods and services (i.e., tourism) much of which is concentrated in urban areas and coastal zones as well.

Rapid and profound changes are occurring in many social, institutional and economic systems of many countries in the world. Substantial progress has been made towards decentralisation of environment responsibilities from national to sub-national authorities, an increasing of the transnational corporations in environmental stewardship and policy development, and improvement in integrated environmental policies and management practices (UNEP, 1996-c; UNEP, 1996-d; Bergesen and Parmann, 1994). Increased willingness by Governments to co-operate on a global basis is confirmed by the multitude of world summits in the last two decade (i.e., Oslo-Paris Convention, Barcelona Convention, Kyoto Summit, Rio Conference) (UNEP/STAP/GEF, 1996; UNEP, 1996-c). As result, several countries report marked progress in curbing environmental pollution and slowing the rate of resource degradation as well as reducing the intensity of resources use. Recent survey (i.e., UNEP, 1997) show that in developing countries the rate of environmental degradation has been slower than that observed in industrial countries when they were at a similar stage of economic development (Figure 2).

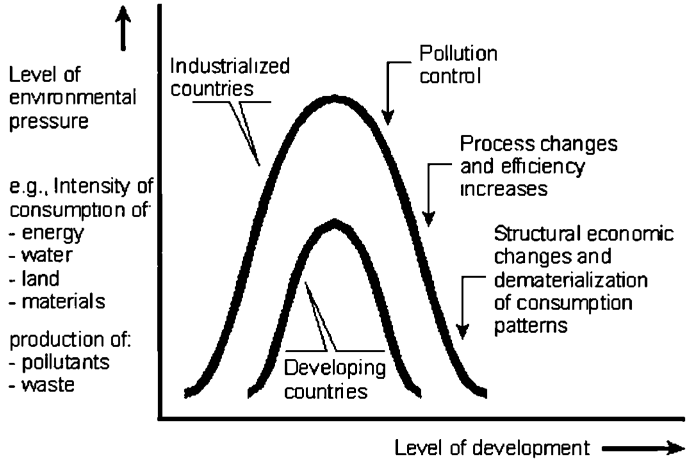

Figure 2. Level of Environmental Pressures at Different Levels of Development in Developed and Developing Countries (Source: UNEP, 1997).

Therefore, as consequence of these changes, fundamental global environmental trends are emerging in several regions (Berry, 1990; UNEP/WHO, 1992; WRI/UNEP/UNDP, 1992; UN, 1994; EEA, 1995; World Bank, 1995-a; World Bank, 1995-b; WRI/UNEP/UNDP, 1996; Brown, 1996; Pirrone and Allegrini, 1998; and references therein) which include the following priority environmental concerns:

- Use of renewable resources: land, forest, fresh water, coastal areas, fisheries and urban air are beyond their natural regeneration capacity and therefore are unsustainable.
- Greenhouse gases: are still being emitted at levels higher than the stabilisation target internationally agreed upon under the United Nations Framework Convention on Climate Change.
- Natural areas: the biodiversity they contain are diminishing due to the expansion of agricultural land and human settlements.
- Use of chemicals: the increasing use and spread of chemicals is causing major health risks, environmental contamination and disposal problems.
- Energy use: the increase in energy production and consumption in developed countries as well as in fast developing countries (i.e., nearly 10-15% yr^{-1} in China) is unsustainable.
- Urbanisation: the rapid and unplanned urbanisation, particularly in coastal areas, is causing major stress on adjacent ecosystems. The complex and often little understood interactions among global biogeochemical cycles are leading to widespread acidification, climate variability and changes in the hydrological cycles as well as loss of biodiversity, biomass and bioproductivity.

On regional and global scales, the energy production and consumption, the use of environmentally sound technologies, the use and demand of freshwater and benchmark data may be identified as the four key priority areas for immediate action for reversing the negative environmental trends. Current patterns of energy use require drastic changes because of destructive impacts on land and natural resources, climate, air quality, rural and urban settlements as well as human health and well being. The increase in energy demand to support and facilitate economic development in all regions of the world coupled with the absence of significant worldwide advances in the development and application of alternative energy sources and increased energy efficiency will inevitably exacerbate environmental degradation. The application of alternative energy sources needs to be enhanced and energy efficiency needs to be improved for both residential and industrial applications as well as the reduction in annual emissions of chemicals (i.e., Pb, Hg, Cd, PCBs, PAHs, pesticides) to the atmosphere must be actively pursued.

Appropriate technological improvements, which result in more effective use of natural resources, less wastes generation and less pollutant emissions per unit of product, are required in all economic sectors and particularly in industry, agriculture, transportation and infrastructure development. Global availability and worldwide application of the best available and appropriate technology (BAT) and production processes, including best traditional practices, has yet to be ensured through the exchange and dissemination of know-how, skills, and technology and through appropriate finance mechanisms (UNEP/WHO, 1992; UN-ECE, 1995).

Availability of water for industrial and residential applications is still a major impediment for further development in several regions. The discharge of contaminated wastewater to natural and artificial water reservoirs has a negative impact on human and health of natural ecosystems, whereas the scarcity of water together with insufficient arable land, will increasingly pose a threat to food availability in several regions, forcing a dependence on food trade (UNEP, 1995; UNEP, 1997; WWI, 1996; 1998). Greater efforts are needed to resolve issues related to land-based sources of pollution, non-point source runoff from agricultural and urban areas, protection of groundwater reservoirs, the impact of development projects on ecosystems, and competing demands for water supplies among different sectors of the society, among rural and urban communities and among riparian countries as well.

All regions experience problems related to either groundwater or surface water or both. Every day, 25000 people die as a result of poor water quality. Waterborne diseases still represent the single largest cause of human sickness and death worldwide. Some 1.7 billion people, more than one third of the world's population, are without safe water supply. In addition, an estimated one-quarter of the world will suffer from chronic water shortages in the beginning of the next century (UNEP, 1995; UNEP, 1997). The development and efficient management of water resources is a priority concern in West Asia, Africa, Asia and the Pacific. In Europe and North America, the protection of water resources from contamination, acidification, and eutrophication are highest on the agenda. Water supply to regions hosting megacities is a concern worldwide, particularly with regard to protection of groundwater resources, intrusion of salt into freshwater supplies and land subsidence. More than 1.5 billion people depend on groundwater for their drinking water. Other global priorities are the equitable distribution of water among riparian countries sharing international river basins, non-point sources of pollution, and the impacts of major dams and diversion projects. Water will be the major impediment to development in the future in several regions.

Assessments are required continually to guide rational and effective decision-making process for environmental policy formulation, implementation, and evaluation at local, national, regional, and global levels (EEA, 1995; UNEP, 1997; Turner *et al.*, 1998; Kramer and Pirrone, 1999). To improve the global capability for keeping the environment under continuous review, urgent action is required in the following fields:

- Investment in new and better data collection, in the harmonisation of national datasets, and in the acquisition of global datasets.
- Increased understanding of the linkages among different environmental issues as well as of the interactions between environment and development.
- Enhanced capabilities for integrated assessment and forecasting and the analysis of the environmental impact of alternative policy options.

- Better translation of scientific results into a format readily usable by policymakers and the general public.
- Development of cost-effective, meaningful and useful methods for monitoring environmental trends and policy impacts at local, national, regional and global levels.

Figure 3 illustrates the relationships among key actions, major environmental trends and social and environmental impacts. To achieve advances in one or all of these key areas for action, a change in the "hearts and minds" of everyone will be required, along with a worldwide transition towards equity and resource efficiency. The necessary financial resources will have to be made available at national and international levels. Estimates have indicated that if 2-3% of the Gross National Product (GNP) could be devoted to environmental education, protection and restoration, great strides could be made in halting the progress of major negative environmental trends. Implementing the pledges made at Rio Conference to increase development aid to the equivalent of 0.7% of the GNP of industrial countries and to provide new additional funding is the prerequisite for initiating action to reverse global environmental degradation (EEA, 1995; UNEP, 1997).

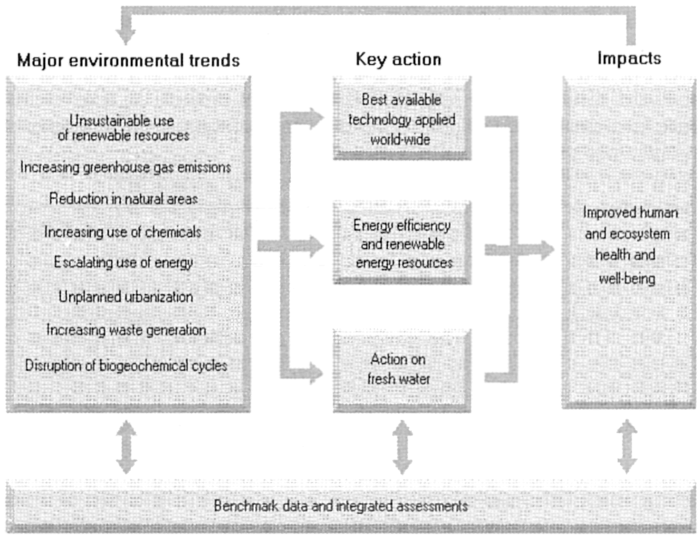

Figure 3. The Action Cycle between Major Environmental Trends, Key Actions and Environmental and Social Impacts (Source: UNEP, 1997).

All major cities in the world suffer urban air quality problems. In Eastern Europe, air quality is considered the most serious environmental problem. Acid rain and transboundary air pollution, once problems only in Europe and parts of North America are now becoming apparent in parts of the Asia-Pacific region as well as parts of Latin America (UNEP/WHO, 1992; EEA, 1995; UNEP, 1997; Pirrone *et al.*, 1996; Pirrone *et al.*, 1998; Mamane and Pirrone, 1998). Large regions are at risk from the effects of both climate change and acidification. Despite co-ordinated action worldwide, damage to the ozone layer continues faster than expected, with the next 10 years predicted to be the most vulnerable. Cases of non-compliance and growth in illegal trade in ozone-depleting substances are significant and growing problems. All regions express concern over global warming, but special emphasis is placed by developing countries on the need for adaptive mechanisms to cope with accompanying climate variability and sea-level change.

The rapidly rising demand for energy to support economic development will aggravate these problems, particularly in Asia and the Pacific, where a 100% increase in energy use is predicted for 1990-2010 and in Latin America, with a predicted energy growth of 50-77% (World Bank, 1995-b; EEA, 1995; UN-ECE, 1995; UNEP, 1997). It is expected that for the near future fossil fuels (coal, oil and natural gas) will continue to be the primary energy source. Based on these estimates emissions of chemicals i.e., mercury to the atmosphere will continue to rise in the global atmosphere as well as on regional scales (see Figures 4 and 5) if no significant improvement will occur in controlling or/and reducing the emissions in developed and fast developing countries. Although mercury emissions from natural sources show seasonal patterns, they are not expected to show substantial variations over time (i.e., decades), by contrast, emissions to the atmosphere from major anthropogenic sources depends upon economical development of the region as well as advances in and implementation of control technologies used to reduce and/or to control emissions (Pirrone *et al.*, 1996; Pirrone and Allegrini, 1998). Annual emissions of anthropogenic Hg to the atmosphere in different regions of the world during the last decade show an interesting dichotomy: the emissions in the developed countries increased (since 1983) at the rate of about 4.5 to 5.5 $\%yr^{-1}$ up to 1989 and have since remained nearly constant, while in developing countries the emissions continue to rise steadily at the rate of 2.7 to 4.5 $\%yr^{-1}$ (Pirrone *et al.*, 1996). The latter is in part due to the fast industrial and economical growth (5-10% per year of the GNP) of several developing countries of Asia (i.e., China, India) and South America (i.e., Brazil) during the last decade (Pirrone and Allegrini, 1998).

A review of past, present and future policy responses to environmental issues in different regions of the world indicates that typically these responses focus first on institutional and constitutional issues and then on the implementation and enforcement of often disjointed sectoral environmental legislation and regulations. Subsequent actions concentrate on developing comprehensive strategic and integrated plans for the protection of the environment, such as National Environmental Action Plans (NEAP) and an array of concerted command-and-control measures. Progression through the cascade of policy responses is often constrained in developing regions by weak institutions, insufficient human and financial resources, ineffective legislation, and a lack of compliance monitoring and enforcement capabilities. In other instances, environmental institutions and regulations have been introduced at the request of external forces such as international conventions and strategies, donor requirements and structural adjustment programmes.

In the more developed regions of the world, experience with environmental management and conservation is extensive and of longer duration. Adequate safeguards in the initial stages were largely achieved through control policies. Effective implementation of such policies relied on legislation and measures such as emission standards and limits as well as on maximum permitted rates of resource use (UN-ECE, 1995; Raskin *et al.*, 1996; UNEP, 1996-b; UNEP, 1996-c; UNEP, 1996-d). Today, countries are increasingly using a mix of command and control policies and market-based incentives to achieve cleaner and more resource-efficient production systems and to modify consumers' attitudes. More integrated approaches that rely on cleaner production processes rather than on end-of-pipe solutions and accounting on a cradle-to-grave basis are being tested in a number of countries, addressing the industrial, agricultural, forestry, transportation, and fishery sectors. Unfortunately these measures have not yet been used to their full potential anywhere.

Despite the contradicting tendencies described above, a heartening sign is the tendency to strengthen regional and sub-regional co-operation worldwide. This might well prove to be one of the most powerful mechanisms to move national and global institutions forward towards sustainable development.

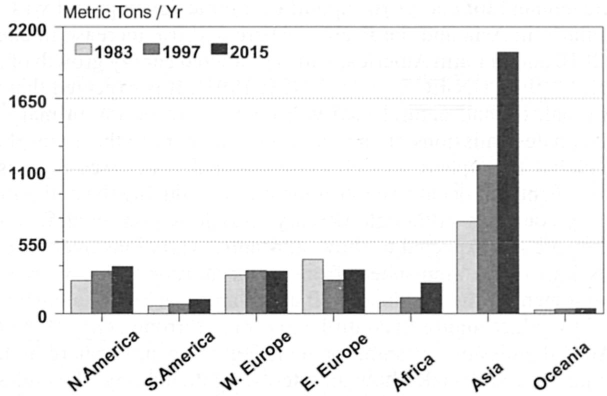

Figure 4. Worldwide Anthropogenic Mercury Emissions to the Atmosphere by Regions (Source: Pirrone et al., 1996; Pirrone et al., 1998; Pirrone and Allegrini, 1998).

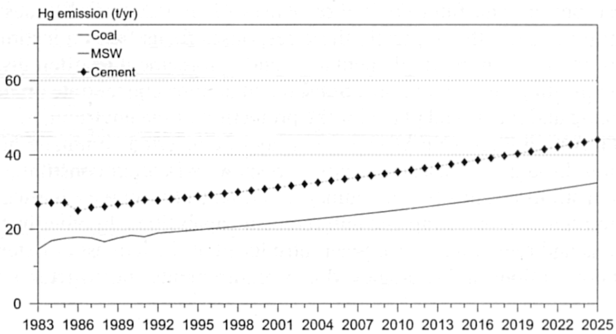

Figure 5. Past and Projected Trends of Mercury Emissions to the Atmosphere in the Mediterranean Region for Major Sources (Source: Pirrone et al., 1999). (MSW = Municipal Solid Wastes.)

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Nutrient fluxes from the atmosphere to coastal seas – socioeconomic dimension, system performance, and research needs

by

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Socioeconomic context

Coastal zone ecosystems are constantly under dynamic stress. Natural and anthropogenic nutrient inputs are episodic, there are strong seasonal and interannual variabilities, and there have been observed in many regions a steady increase in anthropogenic influence. Under the more extreme events, ecosystem resilience may be threatened, and the nonlinearities of ecodynamics can even shift the system past a saddle point into a new asymptotic state, in analogy to strange attractors. The preservation of our coastal ecosystems is increasingly threatened, and there are major socioeconomic as well as ethical consequences if action is not taken to protect them.

One of the visions of most industrialized nations is to guarantee the stability and protection of natural habitats, for use by both today's societies and future generations. As one of the natural habitats of grave concern, the coastal oceans are also exploited for their fisheries and they are used extensively to support recreation, tourism, and trade. Growing coastal populations, increased industrialization, and the lack of well performing ecosystem scenario models makes policymaking difficult. With the goal to promote sustainable development, the scientific community has taken on the responsibility to assure that ecosystem models are developed and implemented, where performance and accuracy are based on the best available information emerging from all disciplines. The big issues are eutrophication, and the impacts of the dangerous anthropogenic compounds (e.g., POP's, mercury). The focus of this paper is on the topic eutrophication.

Eutrophication events have substantial socio-economic implications. Oxygen depletion (which is often associated with eutrophication) has a dramatic effect on fisheries, which in turn affects the livelihood of a specific societal sector which tend not to be evenly distributed geographically. The coastal fisheries communities at risk often have few other employment options to tap in periods of economic hardship. Given the usual rural locations made up of small fishing communites, government derived economic recovery plans are not well suited to these types of socioeconomic sectors. Eutrophication additionally affects the recreation sector, which sustains tourism. For many nations, the loss of tourism adds another economic dimension, with recovery rates requiring many years if the environment is damaged. It is the government's responsibility to assure that policies are enacted which avert socioeconomc losses and protect the environment, and failure in this responsibility is a measure of committment and reputation.

The most important management tool needed by the coastal management community is a coupled dynamic-stochastic ecosystem model which is linked to a monitoring network, which together can be used to carry out simulations of a variety of ecosystem states. The model-based scenarios would be driven by a wide range of environmental conditions and anthropogenic activities. This is no easy task. Research must be dedicated in a systematic way to designing such a system, establishing the systems requirements, and define precisely the desired performance levels based on the resistance and resilience within the ecosystem under study. It is assumed herein that the ecosystem will be allowed to absorb a certain amount of anthropogenic input and human influence, as long as the ecosystem is able to remain resilient and dynamically stable. A priori controls on system scenarios for policymaking include the following points:

- how much financial risk for severe eutrophication (and subsequent socio-economic loss) is the government willing to accept, with regards to the amount of anthropogenic influence and human influence on the ecosystem, i.e., within the margins of system uncertainty?
- are anthropogenic emissions reduction (and human influence) policies able to be constructed so that they are not simply uniform over a large scale, but rather can the policies be derived by considering the sum of local policies which can be designed for local conditions, i.e., considering nonlinearities and spatial variabilities of economic valuations of environmental risk within a larger region (like a nation)?

For the scientific community, the challenge is to improve system performance and accuracy, by including a sufficient number of processes in the various parameterizations. Given the nonlinearities inherent in dynamic systems, feedbacks among processes will be necessary to treat. There are five components of the system to focus on:

- emissions inventories of both anthropogenic and natural nutrients;
- transport into the water column via atmospheric pathways;
- transport into the water column via rivers;
- ecosystem dynamics, response and relaxation processes; and
- economic valuation of the effects of unwanted ecosystem states.

Each of these components has varying levels of accuracy and performance, and there is some nonlinear feedback between components. The system in reality is complex and can be chaotic as a response to extreme events (or closely spaced extreme events).

Ultimately, the system needs to provide the following to the policymaker:

a matrix of policy options which can be used to regulate and/or safeguard the natural ecosystem against damages induced by anthropogenic activities.

This product of the model system relies on extensive understanding of ecodynamics and the range of natural and anthropogenic forcings which perturb the ecosystem. As a tool for practical use, the model based system would require sufficient spatial and temporal resolution to resolve episodes, the use of environmental indicators to allow for on-line assessment and forecasting, links to well designed monitoring data bases, and integration with a geographic information system (GIS).

Eutrophication - the systems view

Within the coastal water column, the marine ecosystem is governed in large part by the nutrient input from both natural and anthropogenic sources (transported both via rivers as well as the atmosphere), mixing within the water column, biogeochemical processes, and removal via advection or exchange with the sediment. Nutrients may enter the water column (cf., mixed layer for our purposes here) via an upward flux from the benthos and/or bottom waters, lateral influx from riverine sources, and downward from the atmosphere via the air-sea interface. The flux from bottom waters is more prevalent during upwelling events and/or during intense mixing (associated with storms), and needs to consider the role of benthic-pelagic coupling in shallow water coastal environments. While the riverine input is a relatively steady (or rather, less intermittent) input, the atmospheric source is driven primarily by seasonal anthropogenic activities and transport from upwind sources. Due to the highly variable windfields and precipitation patterns, the atmospheric input is dominated by a small number of intense episodic events distributed over the year. Depending on location, the atmospheric input constitutes between 20-50% of the total nutrient load to the coastal ocean (Pearl and Fogel, 1994), and the set of atmospherically deposited compounds is overwhelmingly dominated by the nitrogen species. Sulfur, carbon, silicon, sodium, and chloride are additional compounds to consider.

In large parts of Europe and based on simple models, the atmospheric input of nitrogen (N) to marine ecosystems has been hypothesized to exceed acceptable levels for at least the summer months, when the role of atmospheric inputs may have detrimental effects on marine systems (Markager, et al., 1998). During the more serious events of nutrient input, oxygen supply is reduced in both the mixed layer and bottom waters after periods of rapid biomass growth. Severe oxygen reduction may have long lasting effects. The oxygen reductions often favor the more resistant species which sometimes can include the more toxic algae, and the interannual connections between severe events are poorly understood. Resilience on the seasonal and interannual time scales are most likely affected by the timing of severe events, e.g., if in the spring or late summer. At present, there is no systems study which has documented the degree of risk.

Eutrophication events are characterized by increases in algal biomass, and often also with nuisance and harmful algal blooms. Oxygen problems are another common feature often associated with eutrophication. Due to varying resistances, the food web undergoes rapid change prior to and during eutrophication events. Driving these events are nutrient inputs from both rivers and the atmosphere. River inputs tend to dominate during the winter and spring runoffs, which occur over the period of several months. In many regions, estuaries remove a significant fraction of the input, thus diluting the offshore effects. Nutrients entering the water column via rivers are typically in the form of dissolved organic nitrogen (DON), which becomes available to phytoplankton after a short period within the water column.

Atmospheric inputs are highly episodic with large spatial variation. Over the last few decades, there has been observed a gradual increase of nutrient loads to the water column, in most part due to increased use of fertilizers in the farming and agriculture sectors. Unlike river-borne nutrients, atmospheric borne nutrients are typically in the form of elemental nitrogen, and are available for uptake by plankton almost immediately.

The nutrient sources are such that the winter and spring seasons are heavily dominated by the river inputs, which in turn act as the dominant controls on the spring bloom. On the other hand, it has only been recognised within the last decade that atmospheric nitrogen deposition is an important component of the nutrient load to aquatic systems (Hinga et al., 1991). Prior to this time the focus had been primarily on the loads of nutrients from rivers for all seasons of the year. This recognition has stimulated researchers to measure the rates of the atmospheric input and to predict deposition rates using modelling tools (Asman et al., 1995). These recent research activities have confirmed the notion that atmospheric contribution is an important component of the mass-balance of nutrients to aquatic systems.

The impact of atmospheric deposition on the receiving system is poorly understood. In order to explore the governing processes, research has demonstrated that addition of rainwater to both phytoplankton populations and to mesocosms will stimulate the growth of algae (Pierls and Paerl, 1997), thus answering the question of the availability of atmospherically derived nutrients to phytoplankton. Investigations have also suggested that episodic deposition events, e.g. large rainfall events, have the potential to add considerable quantities of available N to the surface layer, thus stimulating new production (Owens et al., 1992). Since much of atmospheric nutrient deposition originates from fixed nitrogen, it has a different isotope signature than most of the nitrate within the surface layer of the ocean. Stable isotope studies using 15N have demonstrated that phytoplankton communities have a 15N isotope signature that is partly determined by atmospheric nitrogen deposition, thus demonstrating the utility of stable isotopes to track the nutrients in the water column which contain a signature of atmospheric pathways (Paerl, 1995).

An emerging topic regarding atmospherically deposited nutrients is the role of organic nitrogen compounds (DON) as a significant additional source of "new" nitrogen loading to the oceans. In some areas the DON load can equal the inorganic N load (Cornell et al., 1995). Recent bioassay experiments have confirmed that 20-30% of the DON is directly available to phytoplankton on time scales of several days (Pierls and Paerl, 1997). An important consideration in determining the influence of DON deposition on aquatic communities, is the ability of DON to stimulate the growth of harmful and nuisance blooms of algae (Paerl, 1995).

Although previous studies have confirmed the availability of atmospherically derived nitrogen and mass-balance estimates have determined that the atmospheric deposition is an important component of the load, we have little understanding of the response of aquatic systems to this important input of nitrogen. Through the analysis of monitoring data from the Danish Monitoring Program it has been determined that the nutrient load in the Kattegat is twice as great as the river load during the important summer months when nitrate concentrations are at their annual minimum in the surface water (Markager et al., 1998). One hypothesis to test is that atmospheric nitrogen deposition will increase the photosynthetic performance of phytoplankton for nitrogen limited populations.

Focussing on the atmospheric inputs during the summer and early autumn, the occurrence of heavy rainfall events can therefore have dramatic effects on the upper water column's biomass. In addition, for typical rainfall events in mid summer, biomass increases of 50% can be expected, which at times has may be sufficient to shift the coastal ocean into a "bloom" state. The nutrients which are associated with wet deposition include signatures of both local and long range transported anthropogenic emissions, which need to be considered for policy formulation.

In order to resolve the effects of individual rainfall events and the role of summer season atmospheric deposition on coastal ecosystems, it is desired that a model system can become available to the policymaker with sufficient accuracy to sensibly select the best of a set of proposed policy options. According to the dynamics governing the water column biology, such a model would require a temporal resolution on the order of 6 hours, and N budgets in the water column which have uncertainties no greater than around 20%. These resolutions and the 20% uncertainty limit are desired, based on the rapid response times of marine ecosystems to sudden changes in water column nutrient content, and based on the strong variabilities in ecosystem nonlinearity when the ecosystem is out of equilibrium (Daniel Conley, personal communication). Spatial resolution of 5-10 km over the effects domain is necessary, for resolving the strength and extent of bloom events. Unfortunately, existing models perform with crude resolution and the uncertainties attached to many of the most important parameterizations (of emissions, transport, chemical transformation, deposition, and effects) generally exceed 50%. There is a large gap between the desired model performance and present capabilities.

On prioritizing research needs

We use as our approach the development of a model based system, which can both predict coastal ecosystem response and also carry out scenarios. The desired level of accuracy for nutrient budgets is 20%. Because the model calculates the nutrient input from the atmosphere, the desired level of accuracy for the system should contain an overall performance analysis of the system of linked processes: source emissions, transport, and deposition.

Our present level of uncertainty can be estimated roughly as follows:

- nitrogen emissions from agriculture: 40-50%. These values depend on the spatial and temporal resolution of emissions reported by authorities.

- transport, transformation, and dry deposition in short range conditions: 10-30% for non-reacting species, such as particulates; 30-50% for chemically reacting species, such as ammonia.
- transport and deposition in long range conditions with no rain: 10-50% depending on model type used for trajectory analysis and chemical reactions.
- receptor site scale: if greater than 40 km horizontally homogeneous grid scales, uncertainty is below 20%. Uncertainties increase with decreasing size of the desired receptor location and increasing subgrid variability.
- wet deposition: roughly 35% using uncertainties in data analysis from rain collectors and extrapolation of the results from one measurement location to another within a region containing large spatial variabilities.

In the next sections, we review the state of the art in deposition modelling.

A critical review of the state-of-the-art for atmospheric deposition

Air-sea nutrient exchange, or more colloquially "nutrient deposition" takes place by two independent mechanisms, dry and wet. Dry deposition is a continuous process which occurs when the gaeous concentration immediately above the surface is different from the concentration in the thin laminar layer of the upper ocean water column. Turbulent and/or laminar diffusion as well as direct exchange processes (e.g., bubble ejection and surface tearing) act on this difference to produce a spatio-temporal gaseous nutrient flux. The diffusion rate is also based on the properties of the chemical characteristics of the specie undergoing transport across the air-sea interface. The dry deposition may be treated as a local process, driven by upwind terrestrial and/or non-terrestrial regional atmospheric and surface sources, both which are ultimately responsible for range dependent air-sea fluxes.

Particulates also participate in the dry air-sea exchange. Particulates originate from three sources: upwind terrestrial anthropogenic and natural emissions, sea spray, and aerosol formation due to chemical reactions in the marine boundary layer. The local air-sea exchange of submicron particulates are governed by the same set of processes which determine gas exchange, but the larger particulates are governed by deposition velocities related to their density. In most part, the larger particulates of terrestrial origin are depleted from the atmosphere at a rate which depends on their size, concentration, and distance from the souce; but the sea spray aerosol introduce a more complicated range pattern of air-sea particulate exchange which contains a unique chemical content and range dependence. We will only briefly touch on the particulate exchange processes later in this paper.

In contrast to the gaseous and particulate fluxes by "dry processes", wet deposition is episodic and occurs during rainfall events. During such events, depositing raindrops contain gaseous or particulate nutrients originating from upwind regions and/or scavenged both within the cloud and during their descent through the air column. While the frequency of occurrence of rainfall in the midlatitudes is typically between 5-10% of the time, the efficiency of wet deposition depends also on the duration of time between rainfall events. The time span between rainfall events allows the atmosphere the chance to accumulate gaseous nitrogen emitted from ground-based sources, and it provides the atmosphere the chance to form aerosols from homogeneous and heterogeneous reactions. The role of photochemistry also may be important between rainfall events, given that nitric acid and nitrate are key ingredients in the air chemistry which leads to eventual nutrient input. Therefore, if one compares several sites which have the same total annual rainfall and emissions inventories over the greater region, yet different numbers of rainfall events, those sites which have more rainfall periods (e.g., rainy days) may be more likely to have a greater wet deposition. This hypothesis has yet to be tested. Furthermore, modelling wet deposition cannot rely on local information only, but it requires models containing information on meteorology, cloud physics, and chemistry, as well as regional emissions source inventories which span a large geographic domain.

The nutrient compounds of interest may be distributed into the following groups (in part, after Asman and Larsen, 1996):

- The NHx group, comprising of NH_3 and NH_4^+, i.e., gaseous ammonia and ammonium in the aerosol phase;

- The NO_y group, comprising nitric oxide (NO), nitrogen dioxide (NO_2), dinitrogen pentoxide (N_2O_5), HNO_4 and nitric acid (HNO_3), nitrous acid (HNO_2), peroxy acetyl nitrate (PAN), nitrate in (NO_3^-) particulate aerosol, and nitrate radicals (NO_3). Of these, the dominant components over the sea are NO_2, HNO_3, PAN, and NO_3^- aerosol.

- Organic nitrogen compounds, which contain a variety of airborne particles which are advected from terrestrial sources out over the sea. There are only crude parameterizations for these sources, and there is evidence that at times this contribution may be significant (Jaenicke [MPI-Mainz]; Kevin Noone [Univ. Stockholm], personal communication).

There is some geographic variability of the relative contributions of the atmospherically-deposited nutrient compounds. Using data provided by Asman et al. (1994), the calculations show that, for the Kattegat region alone, ammonia, ammonium and nitrate aerosols, and nitric acid, dominate the total load. Refer to Table 1. The computations in Table 1 are modelled using yearly mean values. Dry deposition estimates used deposition velocities, combined with estimated surface concentrations derived from the use of the Air Chemistry and Deposition (ACDEP) model, described in Hertel et al. (1995). While the ACDEP model uses

Table 1. Relative average percentage of various compounds deposited to the Kattegat averaged for the year 1990 (computed from data provided by Asman et al., 1994).

Compound	dry	wet	TOTAL
NH3	17.4	6.7	24.1
NH4+	1.8	35.5	37.3
NO	0.2	0.0	0.2
NO2	1.9	0.0	1.9
HNO2	0.1	0.0	0.1
HNO3	4.9	9.4	14.3
HNO4	0.1	0.1	0.2
NO3 radical	0.0	0.1	0.1
N2O5	0.8	1.6	2.4
PAN	0.4	0.0	0.4
Organic NO3-	0.2	0.0	0.2
NO3-	0.7	18.1	18.8
Total N	28.5%	71.5%	100%

a resolution which is smaller than most other models, it is typical of most mesoscale atmospheric models in that its governing physics is based upon simplifying surface layer assumptions, e.g., the constant flux layer and horizontal homogeneity for computing local surface fluxes. Wet deposition estimates are based upon trajectory analyses of parcels from source regions which are up to more than 1000 km upwind. The wet deposition estimates are compared to a time series of rainfall chemistry data collected at the island of Anholt and other Danish and Swedish stations (for the Danish calculations), and systematic deviations of local deposition compared to coarse grid estimates (by EMEP) are based upon rainfall measurements collected at nearby stations.

The relative magnitudes of the dry and wet contributions are by no means the same over the Scandinavian region or Europe as a whole. In the north Baltic, the relative contribution of the dry deposition to the total is 11% and this contribution increases in importance as one moves to the south Baltic, where it is 24% (see Lindfors et al., 1991). In the south part of the North Sea, the relative contribution has been reported to be 45% (Harrison, 1993). During the summer and early fall, the relative contribution of atmospheric deposition to the total nutrient input (atmos + rivers) climbs substantially. In the Danish inner waters and Kattegat, for example, the atmospheric deposition exceeds 70% of the total during late summer.

The values presented by Lindfors had an estimated uncertainty for the wet deposition component to be approximately 35%. Given that the variability of dry deposition velocities reported in the literature for the same compound are of the order 100% uncertainty (Asman et al., 1994), one can apply even greater uncertainties in the dry deposition estimates for most nitrogen compounds than are applied for wet deposition.

From a research perspective, it is important to prioritize efforts which can reduce the total uncertainty of N estimates to the ecosystem. Referring to the relative contributions in Table 1, one can easily argue that given that there is uncertainty with each estimate, it is important to assure that the uncertainty is smaller for those species which contribute more to the total. This would suggest that (for the Kattegat region), priority should be placed on ammonia and nitric acid by dry deposition; and ammonium, nitrate, ammonia, and nitric acid via wet deposition. As will be seen later in this paper, these compounds within the atmospheric system do not behave independently and they are involved in chemical reactions within the air column. For the dry deposition component, the physics and chemistry of ammonia and nitric acid are inseparable and involve, e.g., reactions with sea spray; for the wet deposition component, the regional sources inventories, cloud history, and raindrop scavenging mechanisms especially in-cloud are important.

At present, there have been only a few studies, which have combined the spatio-temporal resolution deposition inventories with details of the biological activity in the water column. The deposition to the ocean is highly variable in time and space, and because of interannual meteorological variability, the interannual signal of both dry and wet deposition can be significant. One hypothesis to test is that the inventories of deposition may need to place greater weight on particular months or seasons to satisfy the nutrient needs of the marine biological system during varying phases of its life cycle. Furthermore, the variability along the coastline and the decrease with distance offshore both play key roles in the defining the percentage of total deposition, which is due to the dry deposition and wet deposition components as a function of location. As we will see later, there is tremendous variability in the proportion of dry to wet deposition, and such variability is important in defining accuracy criteria to flux estimates of specific chemical compounds. Returning to the overall strategy to simultaneously estimate all fluxes into the biological system (from atmospheric wet and dry input, riverine input, and other sources), policy studies which focus on emissions reductions strategies from various anthropogenic sources will ultimately need to face this issue of combining biological response to the weighting of particular seasons or locations in the environmental impact assessments, and specifying accuracy criteria to the nutrient inputs as a function of time and scale. So far this has not happened.

As an illustration of the issue regarding the relative contribution of various wet and dry deposited compounds, and the issue of scale, we remind the reader that eutrophication is a problem which is primarily associated with the near-coastal zone and often in shallow water. In these regions (which are small compared to a typical basin), the interpretation of data in Table 1 may be misleading since coastal, inland water, and/or shallow regions exhibit much higher deposition than is represented in the average for the Baltic, Kattegat, North Sea, or any other large basins. For example, according to Skov et al. (1996) there is wide variability in the deposition of nutrients to various regions. As given, the dry deposition component in the eutrophication-risk areas tends to be of equal or greater importance than wet deposition, in many cases. Note that this conclusion is based on the fact that the dry deposition rate decreases exponentially as one moves farther from the sources, and the eutrophication-risk areas are near the coast. On the other hand, wet deposition tends to have less spatial variability than dry deposition.

As mentioned earlier, one key objective of research efforts in air-sea exchange is to understand the governing processes to such a degree that accurate parameterizations can be developed based on easily observed physical, chemical, and/or biological parameters. These parameterizations participate in high resolution models which can produce accurate flux estimates over a wide range of environmental conditions and as a function of location, and which relate the responsible source regions to the issues affecting the receptor sites. For the sake of this study, the primary receptor issue dealt with here is the risk for eutrophication. This implies that the responsible emissions are well understood, transport and surface exchange processes are described for a wide range of conditions, and any feedbacks from the ocean are accounted for. Most transport models use the budget approach, i.e., where the chemical content in any layer or parcel is the consequence of flux into or out of the layer (including the air-sea flux) and chemical transformations within the parcel. Because the emissions processes and parameterizations, transport dynamics and governing assumptions and model architectures all contribute to overall uncertainty, a key issue in research and monitoring is to have at hand field measurements. They can be used to improve parameterizations for transport and surface exchange and as boundary conditions in models. Model performance defined according to the distribution of uncertainties represents a key modelling research topic.

Table 2. Proportion of dry deposition to total deposition, where total=wet+dry using ACDEP (Hertel et al., 1993) (after Skov et al., 1996) in coastal areas.

REGION	Area (km^2)	Dry deposition (% of total)	Total deposition density (kg N/km^2)
Kattegat (Danish part)	14775	35	1.11
Great Belt	3654	53	1.04
Little Belt	2050	56	1.03
Limfjord	832	50	1.13
Ringköbing fjord	294	58	1.14
West Baltic	3232	49	0.92

Nutrient sources

Based on model computations derived from available information (and often without information from urban sources), the most recent estimates indicate that more than 50% of the atmospheric nutrient input to coastal marine waters is derived from ammonia (NH_3), and roughly 90% of this portion originates from agricultural activities (Asman and van Jaarsvet, 1992). The remaining part of the input is derived from nitrogen oxides (in particular the NO_y group), dominated by nitric acid, and nitrogen particulates. While the percentage of organic nitrate to the total atmospheric nutrient input is poorly understood and is often not included in the inventories, the nutrient input may be underestimated by as much as 30% depending on location and season.

Atmospheric ammonia is a consequence of emissions caused by mainly agricultural and farming practices, and meteorological transport processes are responsible for redistributing the ammonia from the various source regions. Emission processes from agricultural sources depend on many factors (Isermann, 1990, 1994; Frency et al., 1983; Horlacher and Marschner, 1990; van der Molen, et al., 1990), e.g., manure handling systems (farm stables, storage facilities) and meteorological conditions. The emission increases with temperature and windspeed. Precipitation can, depending on the conditions, decrease or increase the emission (Bussink et al., 1996; Bussink, 1996).

The first step in the process of estimating emission rates is to gather inventories, which can be placed on geographic grids, for use in meteorological transport and deposition models. It must be pointed out that there is tremendous seasonal variability, and most emission occurs during the spring and summer. Since the greatest risk for eutrophication occurs during these same seasons, the real emissions rates for the risk seasons for marine eutrophication studies can be as much as a factor of two higher than the figures reported based on an annual average (after Asman and Larsen, 1996). Little is known about short-term variability of the emissions, and the uncertainties in the short-term inventories. Model performance will ultimately require that either short term emission rate inventories are constructed and/or the emissions functions are parameterized in terms of key indicators of farming practices. While the latter approach is labor intensive and has been done to estimate patterns of variability (see, e.g., Skov et al., 1996), the process-defined inventories serve one key advantage in that it provides the possibility to carry out scenario studies on specific human practices and also to evaluate a variety of policy instruments. It furthermore allows the necessary temporal resolutions required to make local and regional estimates of the severity of anthropogenic practices on the environment and also to design and assess the impacts of policy instruments.

As an important anthropogenic component of the net N input, the emission rates of NO_x over Europe need to be considered. These emissions are based on both mobile and stationary sources from the industrial and traffic sectors, and these rates are roughly proportional to urban population density. In western Europe, the mobile sources slightly dominate over the stationary sources in terms of their relative contribution to the total emissions, while in eastern Europe the stationary sources slightly dominate (Pacyna et al., 1991). The annual averages for Europe indicate that the NO_x emissions are of the same order of magnitude as the NH_3 emissions.

Calculations of emissions, transport, and deposition are generally on scales, which are substantially greater than 15 km. Even in the best resolution models (e.g., ACDEP), emissions are assumed to be homogeneously distributed within each square grid of 15 km dimension. While this grid size is much smaller than that of most other models which use the available emissions inventories, it is not clear what the ideal grid size must be in order to assure that accurate inventories can be computed, where both local and regional source inventories are adequately accounted for. This issue requires that there must be a compilation of gridded emissions inventories over a variety of time and space scales, within a typical reference geographic region, so that a practical spatio-temporal constraint may be applied to the scales of emissions inventories and subsequently to model performance and accuracy. This issue has yet to be resolved.

Transport processes and dry deposition

Chemical compounds emitted from point and area sources are dispersed in the atmospheric boundary layer at a rate which depends on both the windspeed and atmospheric stratification. If the atmosphere is relatively cloud-free, the compounds are mixed according to the vertical distribution of stratification. The presence of clouds complicates the vertical distribution, as parcels which advect through the clouds will undergo wet chemical reactions, and produce heterogeneity in the chemical content. These clouds furthermore can act as strong exchange mechanisms between the boundary layer and the free troposphere via higher entrainment rates, and they provide a source for tropospheric gases and particles for wet deposition farther downstream. In this section, we will deal with transport issues which are associated with dry deposition only, and postpone the cloud related issues to a later section. To simplify the discussion, we will assume that the boundary layer is cloud-free.

Once the anthropogenic gases and particles are released into the atmosphere from surface sources, they are distributed in the vertical column by mixing processes. A key issue is in assessing the mixing height, and the amount of chemical compounds in various layers in the atmospheric boundary layer (ABL). For the air-sea flux problem, it is important to estimate the concentration in the lowest layer of the ABL, i.e., the surface layer, at varying distances offshore, given information on the chemical distribution in the ABL before it advects from the coastline out to sea.

The vertical distribution of concentration depends on the stratification, which in turn depends on the buoyancy (associated in part with the temperature difference between the air and surface) and windspeed. Neutral or unstably stratified conditions, normally encountered on warm sunny days over land, are associated with rapid mixing through a relatively deep boundary layer (order of one kilometer deep). Unstable conditions are also encountered if the surface is warmer than the air, as is the case when cold air is blown over warm water. On the other hand, stably stratified conditions are associated with suppressed mixing, and the vertical dispersion rate of surface based pollutants under such stratified conditions can be extremely slow. Stratified conditions are often encountered during the nocturnal clear sky boundary layer over land, and/or when warm air is advected over the cold sea. For comparison, the time scale for pollutants to be mixed through an unstable boundary layer is on the order of 10-20 minutes, while the time scale for mixing during stable conditions may be on the order of several to many hours. Over the coastal seas of Europe, stable conditions are typical during the spring season through summer, while unstable conditions are more typical for the rest of the year.

When the air mass leaves the coastline, it can be characterized as terrestrial in nature, where its turbulence levels, heat content, and chemistry are based on surface characteristics and emissions associated with upwind natural and anthropogenic processes. The turbulence levels are typically higher than over the sea, and the heat content of the atmospheric boundary layer will exhibit a diurnal cycle, depending on the large variability of surface temperature over the course of the day. Furthermore, without any major source of water vapor, the boundary layer over land is typically drier than it is over the sea.

After passing the coastline, the air mass will immediately encounter a very new surface type. The coastal marine surface responds to the velocity of the advecting air mass (via the windspeed), and waves will form. These waves grow with distance offshore, eventually break, and sea spray is produced, thus introducing sea spray and water vapor to the air column. With decreased drag over the ocean compared to land (due to the flatter ocean surface), the air mass will also accelerate in its lowest layers. The marine nature of the surface will also provide a continuous source of water vapor to the advecting air mass due to evaporation, producing higher humidity with fetch. Finally, due to the high heat capacity of water and the mixing potential of the coastal oceans, the sea surface temperature has a very small diurnal variability. The diurnal and weekly variability in atmospheric stability is driven mainly by the large fluctuations in atmospheric temperature caused by offshore flow, and the surface temperature can be considered to be (to some approximation) a constant over these time scales. Depending on stability, the wind will rapidly accelerate rapidly and will double in speed within 10 km offshore (in general), thus producing a vertical flux divergence which is quite sharp in the first 3 km.

To complicate this transition region where the air mass modification is taking place after leaving the coastline, the boundary layer and all its physical and chemical properties must be partitioned into two parts: an upper part which will slowly lose memory of the upwind coastline as the air mass advects further out to sea, and a lower part (the internal boundary layer) which immediately takes on the characteristics associated with the new marine surface. The internal boundary layer (IBL) will increase in depth with increasing distance offshore, and increasingly engulf the previous boundary layer. Depending on the characteristics of the IBL, the new boundary layer far downwind of the coastline may be deeper or shallower than the depth before the air mass left the coastline. Far downwind of the coastline, the marine atmospheric boundary layer will have a new heat and momentum budget, different stratification, more water vapor, and sea spray aerosol, than it did before leaving the coastline. It will also have a different set of chemical reactions than before, when it was over the land surface, and the new set of chemistry will be due to the presence of sea spray and more water vapor, and remaining signatures of anthropogenic chemical compounds. The budgets of specific compounds will rely on a detailed mathematical analysis of sources and sinks during the transport out to sea. The most important domain for analysis is from the coastline to around 20 km offshore.

At this point, we will shift from the qualitative description, and examine the quantitative approach in estimating the air-sea fluxes. We will first present the fundamental transport equations, and then find solutions to the equations based on a varying sets of simplifying assumptions. As we will see, the relatively nonreactive gases, such as water vapor, can justifiably be simplified by use assumptions such as a constant flux layer, horizontally homogeneous conditions, and no source or sink term within the surface layer. (We note that there is an exception to this statement for high windspeeds and in the tropics.) The nutrient gases, ammonia and nitric acid, cannot readily apply these simplifying assumptions, and there are severe constraints on which assumptions may be applied. These will be discussed herein, in most part since dramatic uncertainty and/or bias is introduced if such assumptions of homogeneity and the constant flux layer are blindly invoked.

The air mass modification is governed mathematically by the Navier Stokes equations, where nonstationary and inhomogeneity are not ignored. Winds within the idealized atmospheric boundary layer (ABL) govern the advection process and represent a balance of pressure gradients, Coriolis forces, gravitation, surface drag, and acceleration, and can be represented by:

$$\partial/\langle u\rangle\partial t + \langle u_j\rangle \partial\langle u\rangle/\partial x_j = -f(V_G - \langle v\rangle) - \partial\langle u'w'\rangle/\partial z \quad (1)$$

$$\partial\langle v\rangle\partial t + \langle u_j\rangle \partial\langle v\rangle/\partial x_j = f(U_G - \langle u\rangle) - \partial\langle v'w'\rangle/\partial z \quad (2)$$

The wind vector U_i=(u,v,w) in (1) and (2) has been partitioned into its mean and fluctuating parts, i.e., $U_i=\langle u_i\rangle + u_i'$. The Coriolis parameter is represented by f, which accounts for the motion associated with planetary rotation. Position vectors are denoted as x_i, or (x, y, z). G represents the geostrophic wind velocity, as the approximate windspeed above the boundary layer (in the absence of strong centripetal accelerations). As a general rule, the wind will rotate to the right during conditions of cold air advection (often associated with unstable conditions). Conversely the wind will rotate to the left with height during warm air advection (more often associated with stable conditions).

In similarity to (1) and (2), the conservation equation for other constituents (e.g., temperature, humidity, and gas) can be represented as:

$$\partial\langle c\rangle \partial t + \langle uj\rangle \partial\langle c\rangle/\partial xj = Sc - \partial\langle c'w'\rangle/\partial z \quad (3)$$

The scalar equation (3) includes a term S_c describing the net sources and sinks of c, where c can represent, e.g., concentrations of gaseous compounds. Equations (1, 2, 3) are based on the assumption that $\langle w\rangle=0$.

The last term on the right hand side of (3) represents the flux divergence of the chemical specie in question. The flux $\langle w'c'\rangle$ at height z will rely on a wide range of turbulent eddy scales, which act to transport concentrations down-gradient. Therefore, parameterizations of $\langle w'c'\rangle$ will require some knowledge of the turbulence levels as well as chemical concentrations, both as a function of height. As will be shown below, the turbulence levels are associated with the momentum flux; and the chemical concentrations will be distributed according to both turbulence and chemical reactions.

A typical depth of the marine atmospheric boundary layer (ABL) is on the order of 100 m for stable conditions and up to a kilometer for unstable flow. Because the momentum and heat fluxes decrease roughly linearly with height (for slightly unstable conditions), a shallow layer near the surface may be treated in a simplified way where the vertical gradient of the fluxes is much smaller than the gradients of the concentrations. This layer is termed the "surface layer". For momentum, heat, and moisture, the surface layer has been equivalently called a "constant flux layer" with the caveat that the layer exhibits a flux which changes no more than 10% from the surface value. It must furthermore be pointed out that the constant flux layer assumption is relevant only for the conservative species where the source term $S_c=0$, and if the domain is reasonably stationary and horizontally homogeneous. This constant flux layer assumption also requires that the left hand sides of (1), (2), and (3) can be ignored.

In the case of momentum, there is no source/sink term of any significance (except in the case of rain). However, in the case of many gases, the source term S cannot be neglected. For example, even for water vapor fluxes, the temperature and humidity budgets need to be coupled as a function of height across a slowly decreasing layer of sea spray aerosol, resulting in a divergence of both the temperature and humidity fluxes which increases with windspeed. Similarly, the reactive gases NH_3 and HNO_3, and other types of reacting gases, require additional budgets to be coupled to both water vapor and aerosol, resulting in a rather large flux divergence at heights especially above 5 m elevation over the ocean. Given that the NO-O_3-NO_2 system has been studied over land (Lenschow and Delaney, 1987; Vila-Guera et al., 1993) where strong flux divergences could be observed, we anticipate that the same flux divergence observed over land is also relevant over the ocean, though within a narrower range of conditions. Given that many of the gas fluxes are related to gradients and inhomogeneities in upper ocean biological processes (e.g., involving ammonia and carbon dioxide), the evaluation of regional fluxes may require averaging over areas of locally upward flux with adjacent areas of locally downward flux as described for the case of ammonia (see, e.g., Geernaert et al., 1997). For the strongly reacting and/or soluble gases, the traditional K-closure as was applied in M-O similarity theory may be inappropriate, and second order improvements may need to be considered (see, e.g., Fitzjarrald and Lenschow, 1983).

Because none of the assumptions concerning horizontal homogeneity applies to the coastal regions undergoing air mass modification, the constant flux layer assumption may be systematically and increasingly violated as one approaches the coastline from distances far offshore (during offshore flow). On the contrary, conditions of very long fetch are typically homogeneous to a sufficient degree such that the constant flux layer assumption is usually valid. One must note that many of the applications of air-sea flux estimates are in the coastal region which overlaps largely with the boundary layer transition region (where air mass modification is taking place), and careful evaluation of the constant flux layer assumption must be performed in such a region. Horizontal homogeneity of both the physical constituents (e.g., momentum) as well as horizontal gradients of sea salt and chemical species will complicate the mathematics of air-sea exchange in these coastal regions.

We will treat two classes of compounds in the next two subsections: the simpler, conserved species which do not react strongly with other chemicals, e.g., momentum, heat, and carbon dioxide; and a second class, which involves chemical species which undergo faster chemical reactions, e.g., ammonia and nitric acid. A special emphasis will be placed on the horizontal homogeneity criterion. In the subsection on conservative species, the basic framework for turbulence theory will be described. This is followed in the second subsection with corrections to the theory which incorporate chemistry as well as physics. In all the discussions, we will assume that to a sufficient degree the turbulence field is stationary.

Turbulent transport of conservative species

The turbulent transport issues will be tackled first by invoking the assumptions of stationarity and horizontal homogeneity. Such constraints are relevant for the open ocean under most conditions, or else during most onshore flow situations. For fetch limited conditions during air mass modification soon after the air mass leaves the coastline, systematic violations to the assumption of horizontal homogeneity will be introduced and tackled in this subsection.

For conditions when the terms on the left hand side of (1), (2), and (3) can be neglected and when there are no sources or sinks of the constituent above the surface yet within the surface layer, Monin and Obukhov (1954) devised a similarity theory (MOS theory) which relates the surface fluxes to the respective over-water profiles, where

$$\langle w'c'\rangle = \{(kz)^2 / \O_M \O_c\} (\partial U/\partial z)(\partial c/\partial z) \quad (4)$$

In (4), the stability functions $\O_M$ and $\O_c$ are unity for neutral stratifications and are greater/smaller than unity for stable/unstable stratifications (see, e.g., Geernaert, 1990). In MOS theory, it is asumed that the flux is related to the mean concentration gradient via an eddy viscosity, K, according to:

$$\langle w'c'\rangle = K\, \partial\langle c\rangle/\partial z \quad (5)$$

where $K=u^*kz/\O c$, k is the von Karman constant (=.4), and u^* is the friction velocity. The friction velocity is related to the momentum flux vector, τ, according to:

$$u^* = |\tau / r|^{1/2} \quad (6)$$

where ρ is air density, and

$$\tau = - \rho\langle u'w'\rangle i - \rho\langle v'w'\rangle j \quad (7)$$

The MOS theory furthermore assumes that one can write $\langle w'c'\rangle$ as the product of two scaling parameters, i.e., $\langle w'c'\rangle=u^*c^*$, where $c^*=(kz/\O c)\, \partial c/\partial z$, and $u^*=(kz/\O M)\, \partial U/\partial z$. One may now rewrite (5) as:

$$\langle w'c'\rangle = u^*kz\ \partial\langle c\rangle/\partial z \quad (8)$$

The flux of temperature and gaseous components will therefore require that one has stability functions for the specific components. Currently, the only measured stability functions are for momentum and heat. Functions for gases are assumed to be similar to those for heat, though this assumption has not yet been checked experimentally. The reader is referred to Panofsky and Dutton (1984) for a review of the current flux profile equations used in practice.

Integrating (9) for the horizontally homogeneous case, one obtains the classical bulk aerodynamic relations (Geernaert, 1990). Because u* is a key ingredient in all flux computations, including gaseous species, we will tackle the momentum flux first. For momentum, one arrives at:

$$\partial U/\partial z = (u^*/kz)\ \emptyset_M \quad (9)$$

where $\emptyset_M$ is the stratification function for momentum. Integrating (9) from the lower boundary, defined as the roughness length z_0, to z, and rearranging, one obains the bulk aerodynamic drag law, i.e.,

$$\langle -w'u' \rangle = u^{*2} = \rho\, C_D\, |U_z|\ U_z \quad (10)$$

where the momentum flux is here defined to be downwards, U_z is the wind vector at height z; and C_D is the drag coefficient, which in turn exhibits more than 60% uncertainty in the presence of swell, but much less uncertainty otherwise. A similar derivation can be obtained for the conservative scalars (positive upwards), i.e.,

$$\langle w'c' \rangle = A\, U\{c(z) - c(0)\} \quad (11)$$

where one notes that the quantity A represents the flux coefficient for constituent c and is expressed as:

$$A = \{k/[\ln(z/z_{0c})] - \Psi_c\}\{k/[\ln(z/z_0)] - \Psi_m\} \quad (12)$$

where Y_m and Y_c are, respectively, stability functions for momentum and the particular chemical compound.

The reader is reminded that the use of MOS theory is relevant only for homogeneous and stationary conditions, i.e., relevant for much of the open ocean. For any regional or inland sea or oceanic coastal zone, the terms on the left hand side of (1), (2), and (3) become increasingly important as one approaches the coastline. Therefore, one would expect that also for the conservative constituents (e.g., momentum) the concept of a "constant flux" layer will quickly become invalid for inhomogeneous conditions such as for short fetch flow. The equations may be generalized to (after Geernaert and Geernaert, 1997; Geernaert and Astrup, 1999):

$$\partial U/\partial z = u^*/kz\ (\emptyset_m - R - S + W) \quad (13)$$

$$\partial c/\partial z = (\langle w'c' \rangle/u^*kz)(\emptyset_c - R) + K_c - (AU)^{-1}\partial\langle Uc \rangle/\partial x + S/AU \quad (14)$$

where $\mu z/z_o \partial z_o/\partial x$; $S = \beta\mu\ (z/L)^2\ \partial L/\partial z$; $W = kzU^2/2u^{*3}\ \partial U/\partial x$; $K_c = (C_D^{1/2}[c-c_0]/k\ z_0)$; and $A = k/\ln(z/z_{oc})$. The quantity μ has a value of around 60 for neutral conditions; and ß is 5 for unstable and 2 for stable stratifications. The function $S(x_i,c_i,t)$ is a chemical source or sink term applicable to specific nitrogen species. One should notice that (13) and (14) will reduce to the standard MOS equations if the domain is horizontally homogeneous. The additional terms for nonhomogeneous conditions within (13) and (14) will add both bias and uncertainty in all coastal deposition models, if they are ignored (as in presently used models).

Theory for nonconservative species

In this subsection we evaluate the condition of horizontal homogeneity and introduce the source/sink term to the mathematical analysis. Thereafter, we will expand the set of issues, to tackle inhomogeneity. As will be seen, the source-sink term complicates both the set of air mass modification processes and the methods for estimating surface exchange.

If we maintain the assumptions of stationarity and horizontal homogeneity in equation (4), but retain the source term, we arrive at a flux divergence, which is represented according to:

$$\partial \langle c'w' \rangle / \partial z = S_c \quad (15)$$

Due to the existence of S_c, equation (15) implies that a vertical flux of a reacting gaseous compound will be controlled by relatively fast chemical reactions. Because the reaction rates are independent of height, while the turbulence mixing rates are nearly linearly increasing with height (in the surface layer), the term S_c increases in importance as one goes higher above the surface. This suggests that the constant flux layer assumption is valid immediately above the surface, and that the flux divergence will increases with z at a rate depending on the magnitude of S_c.

Over the sea there have been efforts to investigate the flux divergence of gases and explore techniques to parameterize the surface exchange based on a limited set of bulk input parameters. In connection with efforts to parameterize the air-sea exchange of ammonia and nitric acid gases which ultimately can influence water column nutrient budgets, equation (15) has been studied in a set of recent experiments conducted at Anholt Island in the Kattegate during 1991-1992; at Vindeby, Denmark in 1994 and 1995; and near Gotland, Sweden in September 1996, May 1997, and August 1998. The objectives of these studies were to determine the degree of flux divergence, examine the processes, which can lead to a functional form for S_c, and thereby explore techniques to improve estimates of the surface exchange. These experiments involved measurements of the key gas components (in this case, ammonia and nitric acid) at several levels, supported by particle measurements. In addition, momentum flux and bulk meteorology at several levels were provided. As reported in Geernaert et al. (1997), the source terms in these studies were parameterized in terms of a set of governing chemical reactions involving gaseous and particulate nitrogen species. A strong flux divergence was reported for HNO_3, and it is expected that NH_3 will also exhibit a strong flux divergence.

Horizontal variability also adds bias and uncertainty in measured deposition velocites, in addition to the role of local chemistry within the surface layer. Vignati (1999) reported that strong horizontal variability of the chemical concentrations would be large within at least 20 km from the coastline. Combined with information on windspeed variability over the coastal sea, future analyses may show that the presently used deposition velocities will likely need to be reported as a function of fetch, windspeed, and with a well parameterized source function. The general equation behind such formulations will be:

$$U\, \partial c / \partial x = \partial \langle w'c' \rangle / \partial z + S_{ci} \quad (16)$$

where the summation over Sc indicates all sources and sinks, including the roles of variable marine uptake (assuming that the biomass is also inhomogeneously distributed).

Surface resistance and microlayer processes

Simple models for air-sea nutrient exchange have been around for decades. The most popular due to its simplicity is the resistance method, which captures both the set of transport issues described above and the surface issues which we will introduce here. Applying the MOS theory with its fundamental assumptions, the total deposition, described by <w'c'> at the surface, or more equivalently, $v_d(c-c_o)$, is related to the set of resistances according to:

$$v_d = <w'c'>/(c-c_o) = (r_a + r_b)^{-1} \quad (17)$$

where r_a is the aerodynamic resistance governing turbulent transport of species c; and r_b is the surface resistance, governing the diffusion transport over the laminar sublayer. In essence, equation (17) implies that the turbulent transport associated with r_a represents the maximum possible deposition velocity for any specie undergoing air-sea exchange, and r_b is a correction factor which depends on the properties of the particular compound undergoing air-sea exchange.

The atmospheric resistance is related to the wind profile and drag coefficient according to:

$$r_a = (ku^*)^{-1} (\ln(z/z_0) - \Psi_m) = (u^* C_D^{1/2})^{-1} \quad (18)$$

Recall that $u^* = C_D^{1/2}$ U, and (18) can therefore be written as:

$$1/r_a = C_D U \quad (19)$$

The surface resistance, r_b, is more difficult to describe. The quantity r_b is based on the assumptions that there exists a relatively homogeneous laminar sublayer at the surface, and that the physical characteristics of the surface and the chemical properties of the gas govern the rate of diffusion. Kramm and Dlugi (1994) have suggested that r_b can be parameterized according to the magnitude of the roughness length (assumed to be the top of the laminar sublayer), z_s is the local height of the surface (which can change with the phase of the surface waves), the diffusion coefficient for the gas, and the sublayer Stanton number. An alternate simpler representation for r_b has been applied by Asman (1994), i.e.,

$$r_b = (ku^*)^{-1} \ln (z_o/z_c) \quad (20)$$

where z_c is the roughness length for the particular gas in question. For example, for ammonia and nitric acid, Asman (1994) has suggested formulations which depend on the Roughness Reynolds and Schmidt numbers.

Regardless of the choice of the r_b parameterization, the coefficients and empirical formulations are based on an extrapolated set of measurements from controlled laboratory conditions. For use in the real world, there are some key oceanographic processes which must be accounted for in order to justify the governing assumptions. First, the existence of the laminar sublayer which can be assumed to be in steady state or in dynamic equilibrium is not always valid over the ocean, in particular for windspeeds above 4 m/sec. At these windspeeds, capillary waves are continually breaking, subsurface bubbles are breaking on the surface, and for the higher windspeeds tearing of the wave crests by wind is commonplace. Any laminar layer is both local and short-lived, and the dynamics of a laminar layer wherever it occurs is rarely in equilibrium. Furthermore, the roles of bubble mediated flux and the role of wave breaking as a mechanism for direct air entrainment into the water column may outweigh all other mechanisms associated with a laminar layer. These processes are not accounted for in the simple resistance approach, and therefore there would be uncertainty introduced during such conditions when using single process parameterizations associated with laminar layer diffusion, as in the resistance method.

Table 3. Exchange velocities and removal rates of nitrogen (for U=5 m/sec), and for neutral stability, stationary and horizontally homogeneous conditions (after Asman and Larsen, 1997).

Compound	vd (mm/sec)	Removal rate (%/hr^{-1})	Relative contribution (%)
NH_3	7.6	2.7	61
NH_4+ aerosol	0.2	0.07	6
NO	3.5 X 10-4	1 X 10-4	1
NO_2	2.2 X 10-2	8 X 10-4	7
HNO_2	6.9	2.5	—
HNO_3	6.4	2.3	17
NO_3 radical	6.6	2.4	—
N_2O_5	6.1	2.2	3
PAN	1.0	0.36	1
NO_3 aerosol	0.2	0.07	2
Other species			2
TOTAL N Dry deposition			100%

Returning to equation (17), flux estimates are often made based on the assumption that the surface concentration, c_0, is negligible. This is certainly the case for nitric acid. However, for other compounds, Asman and Larsen (1994) have suggested that c_0 can be computed based on surface pH, the Henry's gas law, activity coefficients, and ambient concentrations. In reality, for some compounds especially ammonia, surface concentrations may be horizontally inhomogeneous, due in most part to biological activity, which in turn is highly inhomogeneous.

In many models, the spatial variation of ambient concentrations is based on exchange of the gaeous compound with the ocean, thus leading to an exponentially decaying concentration with fetch for offshore flow. Removal rates are often calculated based on typical deposition velocities and windspeeds, as reported in Table 3. In this table, no consideration of the MOS theory's limitations to horizontal inhomogeneity in either windspeed or chemical reactions is considered, and it is presently not known how much uncertainty in the calculated deposition velocities as a function of fetch is introduced due to the simplifying set of assumptions.

Measuring fluxes in the field

We have presented both theory and practical modelling approaches for air-sea exchange of gases. Small particles may also be treated as gases in the theory, if they are less than 0.1 micron, though otherwise, their deposition velocity is equivalently a settling velocity. We now introduce the sampling issues, without going into the details of the technologies. There are three commonly used techniques applied to gaseous exchange: the profile method; eddy correlation and its variates; and dissipation. All three have been applied to gases, e.g., water vapor and ozone. The profile method has been applied to those species which have a relatively small surface resistance, and the eddy correlation method has been applied to those species which are able to be sampled quickly enough with existing technology. Ammonia and nitric acid have been sampled only with the profile and relaxed eddy correlation methods. Carbon dioxide fluxes, on the other hand, have been obtained via the eddy correlation and dissipation methods.

Profile method. Ammonia and nitric acid have until recently relied on the profile method. For these two gases in particular, the flux divergence will introduce a correction to the (c/(z associated with the constant flux layer criterion, such that the magnitude of the correction increases nonlinearly with height (as a function of the source/sink term). Nonetheless, the profile method suffices as the method of choice for those species which cannot be sampled faster than once per five seconds. This method is relatively inexpensive, and requires a mast with sensors logarithmically spaced from a level near the surface up to perhaps 10-20 m altitude. For the conservative species, one can easily invert equation (11) to estimate the flux. One must also have a measure of u*, which can be obtained from a measure by various techniques, the simplest of which is the use of a drag coefficien.

Eddy correlation method. This is the preferred method, since it provides an accurate local measure of the flux. It is based on the assumption that one can write the downward vertical flux of constituent c as:

$$F = <-\rho wc> \quad (21)$$

Assuming that one is near enough to the surface where the air density r exhibits very small fluctuations, one can partition the vertical velocity and concentration into their mean and fluctuating components and obtain:

$$F = -<\rho><w><c> - <\rho><w'c'> \quad (22)$$

where primes indicate deviations about the mean. The trick in the eddy correlation technique is to average over a sufficiently long time where the mean vertical velocity <w> is so small that the first term on the right hand side becomes insignificant compared to the second term on the right hand side. With sufficient averaging, i.e., typically on the order of one hour is sufficient, one would then have:

$$F = - <\rho><w'c'> \quad (23)$$

This trick is merely a practical solution to a technical problem of orienting sensors in such a way that they are exactly horizontal. A small error of 0.20 inclination can create unwanted errors if the experimentalist used (23), and such inclinations pose no problem using (22) to determine the flux, since the flux covariance matrix can be rotated with the condition that <w>=0.

Because the fluctuations of vertical velocity have substantial energy even in the smallest scales, there is a requirement that the sampling of the chemical of interest is also possible and accurate on small scales. Sampling at 2-4 Hz or better is ideal, and the required sampling rate increases if one deploys the sensors closer to the surface.

Eddy accumulation and relaxed eddy accumulation methods. While use of the eddy correlation method is the ultimate goal of air-sea interaction experimentalists (because it is the only direct flux measure), an alternate approach has been used in recent experiments at NCAR and Risø/NERI. These techniques are based on the use of an accurate measurement of the vertical velocity, where the wind sensor has been installed in such a way that real time and accurate vertical velocity estimates are possible, i.e., one does not need to rotate the momentum flux covariance matrix to force <w> to zero. With this sensor, one installs two samplers which lead to two reservoirs, one reservoir which samples or collects the ambient chemical compounds for upward velocity, and second one for air associated with downward velocities. The difference in chemical mass between the two reservoirs, normalized by the integration time, represents the chemical flux.

Simplifications to this technique have also been proposed, in order to relax the requirements that each reservoir has a different mass, and avoid the problems encountered if pressure and temperature are not the same in each reservoir. Based on the assumption that one can sample the flow only, one can derive an expression such that:

$$<w'c'> = b\,\sigma_w\,(\rho_c+ - \rho_c-) \quad (24)$$

where the coefficient b has a theoretically value of 0.63 (see Lenschow, 1995, for more details), and s_w is the square root of the vertical velocity variance.

The relaxed eddy accumulation method (equation 24) has been successfully applied over land on several occasions during the past 5 years. Its use over the ocean has only recently been performed for the first time, i.e., on a fixed marine mast in the ASEPS project near Gotland in May 1997. The results of the Gotland study are yet to be presented.

Variance and dissipation method. Because of the constraints on the vertical velocity measurements with the eddy accumulation method where a stable platform is required, routine accurate techniques for ship-borne or buoy-deployed flux collection require a different approach. Both methods require high sampling rates, up to 1 Hz for the variance method and beyond 4 Hz for the dissipation method. The variance method is based on the integration of the normalized standard deviation of fluctuations of species concentrations (De Bruin et al., 1993):

$$<w'c'> = \sigma_c u^* Ø \quad (25)$$

where Ø represents the stability function of concentration variance (equal to two for neutral conditions), and σ_c is the square root of the concentration variance. The u* can be estimated by bulk techniques via the drag coefficient.

The dissipation method utilizes universal relationships applicable to the inertial subrange, and because the measurement does not require frequencies below 1 Hz, it is suitable for use on moving platforms, such as ships.

It is not clear whether the variance and/or dissipation methods are applicable to reactive gases such as ammonia and nitric acid. Such an analysis would be a useful exercise once sampling techniques for these gases improve to a point where they can be sampled at rates beyond 5 Hz.

Wet deposition

Unlike dry deposition where models are the main tool, wet deposition estimates have traditionally been carried out via on-site sampling at key locations, which give representative estimates for a specific region. Rain samples are collected and analyzed in order to represent the specific site, and interpolation between sites is based on climatological statistics of rainfall distributions between sites. Patterns of rainfall amounts are accessible from data bases at national meteorological organizations, and together with the site measurements, maps can be constructed for any given region. For the Danish monitoring program, NERI samples rain at 17 stations , using samples representing accumulations over 14 days.

As simple as the procedure noted above seems, there are some complications concerning the statistics of rainfall intensity, duration, frequency of occurrence, and related wind direction, which complicate the estimates between measurement sites. Furthermore, there are sampling problems associated with the specific sites which need to be summarized. Both of these represent sources of uncertainty which have resulted in a rather negative impact on validation experiments.

Nutrients in rainfall are the consequence of in-cloud and below-cloud scavenging of particulates and gases. Referring back to Table 1 and using model-derived data presented in Harrison (1993), the overwhelming proportion of wet deposited nitrogen originate in the form of ammonium and nitrate in the aerosol phase with smaller contributions originating from nitric acid and ammonia. Refer to Table 4 below. Note that while these data are relevant to the Kattegat and

North Sea regions, a general extrapolation of the results would indicate that the ammonium and nitrate aerosols overwhelmingly dominate the wet deposited nutrient contribution.

Table 4. Relative contribution of nutrient species to wet deposition using the ACDEP model (after Asman and Larsen, 1997; and Harrison, 1993).

Compound	Wet deposition contribution (%) (Kattegat)	Wet deposition contribution (%) (so. North Sea)
NH_4+ aerosol	50	38
NO_3- aerosol	25	56
HNO_3	13	
NH_3	9	
N_2O_5	2	
Other species	1	06*
Total wet deposited N	100%	100%

* dissolved organic nitrogen

The sources for these compounds are the same as those for the dry deposition estimates, i.e., anthropogenic and photochemistry. A key difference from the discussion regarding dry deposition is the set of wet chemistry processes associated with clouds, and the role of raindrops in adsorbing gaseous and particulate species during their in-cloud transport and below cloud free-fall.

Rainfall sampling and analysis issues

The sampling of wet deposition is carried out via precipitation collectors, whose contents are analyzed for concentrations of selected chemical compounds. An issue introduced with sampling practices is that considerable loss of precipitation in the samples can constitute a 5-10% uncertainty caused by both wind and evaporation, and increasing duration of the sampling period will therefore increase uncertainty. Because collectors are containers or funnels, which are exposed to the wind, precipitation may be displaced away from the opening causing a loss of sample due to aerodynamic blockage of the inlet. The proportion of underestimation of rainfall collected increases with windspeed. This loss of sample can be increased due to vortex motion inside the collector at high windspeeds (Irwin et al., 1993). Efforts have been underway to design better collectors and install them nearer to the surface to reduce aerodynamic blockage effects. Collectors which are open only during rain events have also been designed for experimental purposes, in order to assess the amount of evaporation over the sampling period. However, these instruments require a sensor, which opens the collector at a critical rainfall rate, and deposition associated with drizzle may be missed due to their rainfall rates being below the required limit. Obviously the length of the sampling period will introduce a varying degree of evaporation, depending on the ambient relative humidity and windspeed. A final source of uncertainty applies to those collectors, which are continuously exposed to the air, since dry deposition between rain events contributes to the bulk chemical concentration of nutrient species.

Because of the need to accurately assess regional nutrient loads to the marine system, it is practical to have data analyzed at coarsely distributed field stations, and interpolate between them based on information, which contains rainfall patterns. In most regions, the sampling stations are distributed in such a way that one can assume that, for practical purposes, the rainfall patterns are either linearly varying between the stations or the rainfall patterns are statistically homogeneous between sites. In this way, data bases from one station are often used to determine the most likely nutrient load per rainfall statistic (such as per rainfall amount), and one can extrapolate this statistic to the rainfall amount maps for the region. This approach is simple, and allows one to catalog the nutrient input strictly in terms of rainfall amount. It furthermore is based on the assumption that on the average the rain-bearing clouds are from the same statistically distributed set of directions which are evenly distributed over the course of the year. In this way, the source regions contributing to the rain events are statistically constant through the year. This is not always the case, and it introduces uncertainty to the estimates.

There are some dramatic limitations to the approach identified above. While providing a first order estimate of the wet deposition to a particular region, it does not allow the possibility to develop policy measures to control the responsible source processes. To conduct such studies, scenario studies are required, and this implies that trajectory models from the source regions must be constructed, where cloud physics and cloud chemistry are included in tropospheric dynamics and dispersion models. There has been tremendous theoretical work on cloud physics and chemistry to approach the problem (see, e.g., Pruppaccher and Klett, 1997). These works summarize the known chemistry, droplet size spectra, and cloud flow fields. The weak parts of the problem are the evolution of boundary layer thermodynamics and thermal fields associated with cloud formation, the relationships between the cloud edge exchange rates and boundary layer flow fields, and the time scales of ingested pollutants, pollutant-droplet interaction, and droplet dynamics while in the cloud. These points are important for modelling the flux of gaseous and particulate species into the cloud for processing and eventual removal by rainout.

In order to tackle the problem, Asman and Klett (1993) assessed the cloud processes in order to determine which processes and which compounds played key roles in terms of eventual wet deposition. They found that under Danish conditions, ammonium aerosol deposition was the consequence mainly of in-cloud scavenging of ammonium (relative contribution of 77%), and secondarily due to the in-cloud scavenging of ammonia (relative contribution of 15%); below scavenging of ammonia by the raindrops accounted for approximately 6% of the wet deposition. For nitrate deposition, the in-cloud scavenging constitute 91% of the total while the remainder was dominated by in-cloud scavenging of nitric acid. To sum up, the in-cloud scavenging processes overwhelmingly controlled the wet deposition amounts, and the only below-cloud scavenging contribution included a very small contribution from ammonia.

Wet deposition modelling

The study by Asman and Klett (1993) highlighted the need to characterize the cloud dynamics and chemistry properly in order to accurately estimate wet deposition. The difficulty in modelling is in obtaining realistic data for a variety of cloud types. Due to this difficulty, a practical approach has been taken where one selects a typical cloud type and a typical set of cloud characteristics associated with rainfall in order to simplify the model formulations. In the ACDEP model, the approach has been to assume that the cloud base for rain clouds is 280 m above the surface, and the lifetime of any given cloud has a time scale of approximately 30 minutes. This lifetime corresponds to the depletion and replenishment cycle for pollutants, which enter the cloud chemistry cycle and are removed via wet deposition. With these conditions, the cloud is able to provide a continuous supply of nutrients via rainfall, as along as the upwind sources continue to release pollutants as a steady rate (as is justifiably assumed). In contrast to ACDEP model, the EMEP model uses only a 1.5 layer atmosphere, i.e., a PBL and a fixed troposphere character.

To complicate the model performance more, the issue of model scale and the scales associated with the initial databases must be mentioned. Rainfall is typically lower over seas, which have a sea width beyond a critical value, i.e., with a width larger than order 10 km have an overlying atmosphere which is more marine than those seas/fjords with smaller widths. With a width much larger than 10 km, the Kattegat exhibits lower rainfall than the adjacent land masses, yet the coarse grid European rainfall data bases are unable to resolve even the Kattegat. Therefore, for many models, which operate on coarse grids (e.g., order 100 km), inland seas and marine systems will take on the atmospheric characteristics as if they were associated with a terrestrial surface. This only illustrates the scale incompatibility issue, when estimating loads via wet deposition to small seas and coastal aeras. So far, such scale incompatability has been a technical constraint due to the required computer power to run models, though faster and cheaper computers and the use of GIS are opening more opportunities.

While such models as ACDEP and EMEP are able to produce deposition estimates which, on the average, can produce trends and estimates for the research and policy communities, the assumptions which include fixed cloud base and height, lack of information on cloud variability, and no variable droplet size spectrum, introduce uncertainty in the estimates. Each region will exhibit its own statistical distribution of cloud types, cloud droplet size spectrum, and associated meteorological conditions, for rainfall events. Therefore, each region where models are used will exhibit a unique set of spatio-temporal set of uncertainties and biases. Such uncertainties and regional biases are difficult to resolve without performing sensitivity studies on newer and more complex parameterizations of the processes, which govern the cloud evolution. Efforts are underway at various institutions to include more details in parameterizations, and test them on a variety of situations and scenarios (e.g., the efforts ongoing at GKSS). However, this will require testing against field data in order to verify that the improved parameterizations actually lead to better model performance and reduced uncertainties.

Finally, the model calculations of long range transport often use simplistic formulations for lateral and vertical dispersion of air parcels, which contain pollutants emitted from sources far upwind. Calculations often track parcels over 500-1000 km, without information on the lateral dispersion. Higher resolution models, and the blending of Lagrangian and Eulerian approaches in calculating high resolution variability may be a practical solution to treat the coastal zone.

To test the assumptions used in existing models and help prioritize the issues, which will have the greatest impact on model performance and reduced uncertainty, two approaches may be taken. The first is to carry out numerical experiments, which tackle the issues identified above. The second is to carry out a hierarchy of experimental activities. Experimental activities could include measurements of the wet deposition during the course of rain events, with a much faster sampling rate than is currently used in most studies. This simple experiment would reveal information on the cloud chemistry budgets associated during the course of specific rainfall events. This may help determine if the wet deposition rate is a function of time since onset of the rain event, and if the rate depends strongly on the rainfall size spectrum, rainfall rate, cloud type, etc. More complicated studies could be carried out with in-situ cloud data, i.e., obtained with use of aircraft, airships, kites, and/or tethersondes. Remote sensing techniques may also be of use.

Summary

Studies of nutrient deposition to the marine environment are driven by the need to improve our understanding of the marine system, and to identify which policies are necessary to protect the coastal ocean from adverse and/or unwanted ecosystem states. Most eutrophication events occur in coastal and inland sea areas, and these events are assumed to be driven in large part by anthropogenic emissions. Due to this assumption, the probability of ecosystem resilience and stability is achievable only with clearly defined emissions reductions policies.

Nutrients from anthropogenic sources are transported to the water column by both riverine and atmospheric pathways. While riverine sources may be clearly delineated by the river drainage basin, atmospheric sources may be widespread over a large region discernable only throughout source-receptor modelling. Of the atmospheric pathways, wet deposition exhibits variability on the mesoscale, and is related to the local and regional distributions of emissions as well as variations in both meteorology and climatology. Dry deposition occurs as an exponentially decreasing function as one goes downwind of the various sources.

Dry deposition is therefore much higher in the shallow coastal waters, and it will decrease with increasing fetch. In the coastal waters, i.e., within 10 km of the shoreline, dry deposition often is more important than wet deposition, though this ratio reverses as one goes farther offshore. As an illustration, if one rearranges Table 1 where one assumes that the domain exhibits 50% wet deposition and 50% dry deposition, the values suggest that dry deposited ammonia is the most important contributor, followed by wet deposited ammonium. See Table 5.

Because the theory and application of offshore flow models often assume a constant boundary layer depth, and mixing throughout the boundary layer, the estimates will have their greatest accuracy for conditions of neutral to slightly unstable stratifications. Over much of Europe, such conditions exist during the autumn and winter, i.e., when the risk for adverse ecosystem effects is at a minimum. On the other hand, the transport dynamics for the other two seasons, i.e., spring and summer, are often dominated by stably stratified flow associated with a positive air-sea temperature difference. Such stably stratified conditions involve the development of an internal boundary layer with a rapid developing windspeed in the region from the coastline extending to distances of 10-20 km offshore. The first ten kilometers may also have severe wind acceleration. These spring and summer seasons are the most difficult to model given the present assumptions in most operational models. These two seasons, coincidentally are also the most important periods of the year for ecodynamics modelling and risks for adverse ecosystem states.

Table 5. Relative average percentage of various compounds deposited to coastal waters by adjusting the values representative of the Kattegat (after Table 1) to an equal contribution of wet and dry deposition.

Compound	dry	wet	TOTAL
NH_3	31	5	36
NH_4^+ aerosol	3	25	28
NO_2	3	-	3
HNO_3	9	7	16
N_2O_5	1	1	2
NO_3 aerosol	1	12	13
Other compounds	2	-	2
Total N	50%	50%	100%

The chemistry of the ammonia-nitric acid-sea spray complex introduces a flux divergence even in the absence of horizontal gradients. This flux divergence increases in importance as one increases in height within the surface layer, and it is not clear how it can influence the local deposition for these gases. Because the reactions involve the production of new nitrogen containing aerosols, the aerosol input may be extended to distances farther offshore than previously thought. Offshore flow modelling which captures the physics of flux divergence combined with the heterogeneous chemistry of the N compounds will be a research task for the near future. Operational models presently do not exchibit such capability.

Particle flux to the surface has not received much discussion in this paper. While a review of the processes is presented in Asman and Larsen (1996), there are a few developments, which need to be assessed. For offshore flow, the water vapor flux from the ocean will introduce a range dependent relative humidity, such that the relative humidity will asymptotically increase with range to a value, which is in equilibrium with the vertical flux. Typical asymptotic values for a height of 10 meters at large distances offshore is between 70-80% for clear sky conditions. The asymptotic value for lower heights will be even higher than 80%. This suggests that the size spectrum of aerosol will change with range offshore, and the deposition rates for the aerosol field will change. Aerosols furthermore will be produced by the sea surface, and these marine and terrestrial aerosols will paricipate in the air chemistry involving ammonia and nitric acid. In a recent PhD study, Vignati (1999) has addressed many of these issues in fetch dependent heterogeneous chemistry. However, the study of range dependent heterogeneous chemistry, range dependent rates of air mass modification (Geernaert and Astrup, 1999), and the local flux divergence caused by chemical reaction rates (Geernaert et al, 1997) still need to be combined in a full interactive model system. Simplifications of such a model system by relaxing varying sets of assumptions will be a logical next step, before developing ultra-high resolution coastal models operating on scales below 5 km.

Because ammonia has been noted by many to be emitted from the surface, the patterns of ammonia emission ultimately will rely on improvements in modelling the upper water column biology. Until that happens, the indicators of upper water column ammonia concentration will rely on indicators, and validating such approaches is difficult and not necessarily cost-effective. It may be more cost-effective to build the biology models.

For wet deposition, the in-cloud rain chemistry has not been resolved with short enough temporal resolution to reveal sufficient information on the physical, dynamical, and chemical budgets involved in the responsible clouds. In order to explore such budgets, experiments need to be conducted which sample every ten minutes or so, and simultaneously document the cloud evolution via in-situ or remote probing. Parallel model improvements may be explored via the testing of better cloud parameterizations, diffusion parameterizations which capture both lateral and vertical directions, and performing scenarios of the model uncertainty with sensitivity studies and scenarios.

In order to study ecosystem dynamics and to identify risks and forecast future events, nutrient budgets are needed to be accurate within 20%. Present models are operating at uncertainties greater than 50%, on average. This difference in desired performance and present capability serves as the justification and need for targeted research in key areas.

Research priorities

There are some key assumptions outlined in this paper, which are to be considered:

- Most of the marine socio-economic concerns in coastal zone management are from the beach to the first 10-20 km offshore of the coastline.
- For atmospheric input, the dry deposition will be very important in the first 10 km offshore of the coastline, and beyond this distance the wet deposition will dominate.
- Atmospheric input is far more important than riverine input, during the period from midsummer to early autumn.
- Uncertainties in emissions inventories are around 40%. Uncertainties in wet deposition measurements are around 35%. Uncertainties in dry deposition can be as great as 100%, depending on the compound. There is a dramatic mismatch between the desired level of accuracy (around 20% for the N budgets), and our present capabilities.

Priorities:

Uncertainty is distributed according to processes associated with emissions inventories and transport into the water column via both riverine and atmospheric pathways. The ultimate nutrient budgets (desired to have 20% uncertainty) will be the consequence of our present ability to parameterize these two sets of processes. It is therefore suggested that reserach should be dedicated to:

- reduce uncertainty in the emisions inventories to 10%;
- build multi-process marine ecosystem models with a sufficient level of detail and performance;
- build 3D high resolution dry deposition models, combining heterogeneous chemistry, flow acceleration, and upwind emissions, with accuracy on the order of 10%;
- build multi-parameter algorithms which may be used to extend wet deposition estimates to better accuracy over inhmogeneous domains within 10% accuracy, and which contain systematic meteorological and/or hydrographic variations; and
- build a cost-benefit analyis submodel for online integration into the effects and emissions submodels, for exploring the economics of various scenarios of emissions reductions strategies.

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Point and diffuse emissions of nutrients into German river systems: Causes of regional differences and changes since 1985

by

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Abstract

The nutrient discharges from point and diffuse sources in more than 200 German river basins were estimated for the period 1983-1987 and 1993-1997 with the model system MONERIS. The model distinguishes between six diffuse pathways and point source emissions from waste water treatment plants and direct industrial discharges. It was estimated that the total nitrogen input into the German river systems amounts about 850,000 tN/a in the period 1993 to 1997. These emissions were decreased since the mid of eighties by about 250,000 tN/a, mainly caused by the reduction of point discharges. For phosphorus the emissions were reduced by 58,000 tP/a and amount 37,000 tP/a in the period 1993-1997. A retention module is used for the estimation of nutrient loads from the emissions. The comparison with the observed loads shows a deviation lower as 30% and 50% for nitrogen and phosphorus, respectively. The regional resolution of the model allows the indentification of hot spots for the different pathways for phosphorus and nitrogen.

Introduction

The nutrient input into river basins larger than 1,000 km^2 was estimated for the periods 1983 to 1987 and 1993 to 1997 by the GIS (Geographical Information System) oriented model system MONERIS (MOdelling of Nutrient Emissions into RIver Systems; see Behrendt et al., 1999). The model distinguishes between point emissions by municipal treatment plants and emissions directly discharged by industry and different diffuse paths according to the hydrological components of the total runoff. An overview on the considered pathways gives Figure 1. The paths mostly related to agricultural activities are:

- emissions into surface waters from groundwater,
- emissions into surface waters from tile drainage,
- emissions into surface waters by erosion,
- emissions into surface waters by surface runoff (only dissolved nutrients).

Further, direct emissions into surface waters from atmospheric deposition and from the urban area collected by separate rain sewers and caused by combined sewer overflows and non-connected paved urban areas are considered as diffuse paths.

MONERIS is based on the approaches of Werner et al. (1991) and Werner & Wodsak (1994) but focuses on river catchments to compare the results of the emissions estimations with the observed nutrient load and other methods of source apportionment.

The data base of the model are digital maps of the land use, soil types, elevation and the river net. Further statistical data as pop-

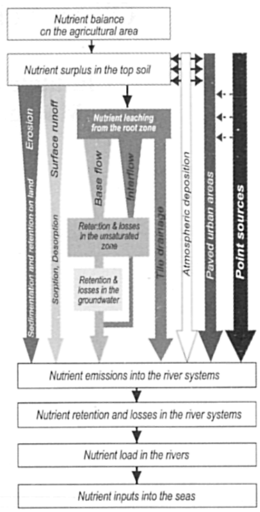

Figure 1. Pathways and processes within MONERIS

ulation, livestock numbers, yields and point source inventories are collected for the smallest administrative units and translated to the GIS. Input data are further maps on soil losses by erosion, precipitation, concentrations of nutrients in groundwater and tile drainage as well as the nutrient surplus on agricultural areas.

Results

The model results for the German parts of the four largest river basins are presented in table 1 to 4 for the period 1993 to 1995 and 1983 to 1987. The size of the catchments or the German part of these catchments are about 83,700 km^2 for the Elbe, 38,400 km^2 for the Weser, 102,500 km^2 for the Rhine and 56,400 km^2 for the Danube. Additionally the total of the different nutrient emissions for Germany is given in the table.

For phosphorus 49% to 76% of the total emissions into the river systems are caused by mainly agricultural paths as groundwater, tile drainage, erosion and surface runoff (see table 1). Within the more mountainous catchment of the Danube erosion and the emissions of dissolved phosphorus during periods of surface runoff are the dominant paths of phosphorus emissions. In the other basins erosion is also dominant, but the contribution of the emissions from the subsurface flows are increasing and represent at least in the Weser about 40% of the total agricultural input. Whereas the absolute amount of agricultural emissions has not changed since 1985 the total diffuse P-emissions were reduced by 7 to 24%. That is mainly caused by the decrease of the P-inputs from combined sewer overflows (CSO), separate sewer systems (SSS) and sewers without connection to waste water treatment plants (WWTP). These discharges were decreased by more than 50%, because phosphorus is completely substituted in detergents. In general the portion of diffuse emissions at the total phosphorus input has more than doubled from 1985 to 1995 (table 1 and 3). This is caused by the enormous reduction of point sources by about 80% in the most of German river basins (see Table 6). An overview on the regional distribution of the sum of diffuse Pemissions into the investigated river basins is given in figure 2 for the peirod 1993-1997. With regard to phosphorus the 50% reduction target given by HELCOM and OSPARCOM was reached in all German river basins.

The nitrogen input from agricultural paths amounts to 86% to 96% of the total emissions into the catchments. The emissions from the groundwater represent 71% to 77% of the total agricultural input for the river Danube, Rhine and Weser. This portion is only 57% for the Elbe. Tile drainage contributes to the total agricultural input between 20% and 29% for the Weser and the Elbe and is for the Rhine and Danube in a range of 15%. Also for nitrogen the portion of the agricultural emissions at the total input was increased between 5% and 15% in the last decade. Otherwise the total amount of agricultural nitrogen emissions is decreased, because the N-discharges by tile drainage are lower between 25 and 35%. This pathway reacts fast on the reduction of the nutrient surplus in the agricultural field by 27% in the West German countries and by more than 42% in the East German countries. Figure 3 gives an overview on the sum of diffuse nitrogen emissions into the German river basins in the period 1993-1997.

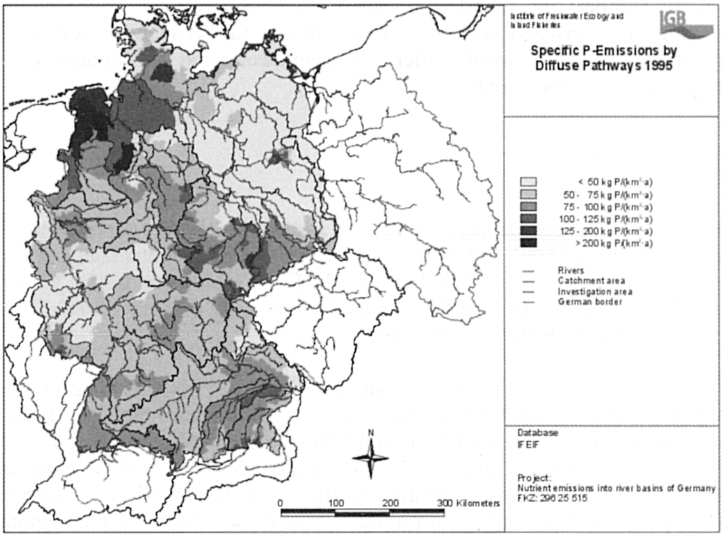

Figure 2. Map of the sum of specific diffuse phosphorus emissions into the river basings of Germany during the period 1993 to 1997.

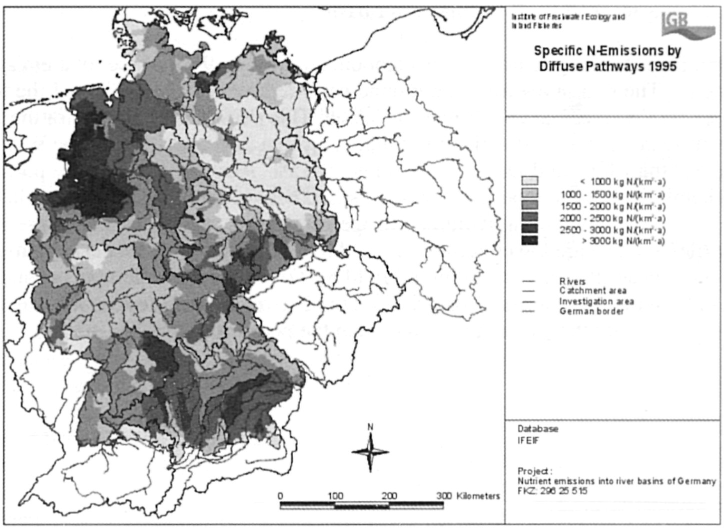

Figure 3. Map of the sum of specific diffuse nitrogen emissions into the river basins of Germany during the period 1993 to 1997.

Table 1. Nitrogen emissions from the pathways, its contribution to the total emissions and its changes for the German parts of the Elbe, Rhine and Danube basins and the Weser for the time periods 1983-1987 and 1993-1997

Pathway		Elbe			Weser			Rhine			Danube		
		1983-87	1993-97	Change	1983-87	1993-97	Change	1983-87	1993-97	Change	1983-87	1993-97	Change
Groundwater	[t N/a]	53,760	57,270	*+6.5%*	50,060	45,820	*-8.5%*	132,580	122,750	*-7.4%*	79,400	78,090	*-1.6%*
	[%]	24.5	38.8		46.8	53.9		33.5	44.2		52.9	59.5	
Tile drainage	[t N/a]	47,460	30,340	*-36.1%*	17,740	13,910	*-21.6%*	28,690	22,340	*-22.1%*	21,110	16,600	*-21.4%*
	[%]	21.6	20.6		16.6	16.4		7.3	8.0		14.1	12.6	
Erosion	[t N/a]	2,880	2,830	*-1.6%*	1,460	1,400	*-4.3%*	4,570	4,610	*+1.0%*	2,340	2,490	*+6.2%*
	[%]	1.3	1.9		1.4	1.6		1.2	1.7		1.6	1.9	
Surface runoff	[t N/a]	570	890	*+56.9%*	1,340	1,380	*+3.1%*	5,660	5,110	*-9.7%*	4,090	4,190	*+2.3%*
	[%]	0.3	0.6		1.3	1.6		1.4	1.8		2.7	3.2	
Atmospheric deposition	[t N/a]	4,060	2,700	*-33.3%*	960	740	*-22.5%*	2,760	2,300	*-16.8%*	1,790	1,440	*-19.8%*
	[%]	1.9	1.8		0.9	0.9		0.7	0.8		1.2	1.1	
Urban areas	[t N/a]	14,430	12,250	*-15.1%*	4,270	3,440	*-19.4%*	13,580	8,850	*-34.8%*	3,830	2,800	*-26.7%*
	[%]	6.6	8.3		4.0	4.0		3.4	3.2		2.5	2.1	
Sum diffuse sources	**[t N/a]**	**123,160**	**106,290**	***-13.7%***	**75,820**	**66,690**	***-12.0%***	**187,840**	**165,970**	***-11.6%***	**112,560**	**105,610**	***-6.2%***
	[%]	**56.2**	**72.0**		**70.8**	**78.4**		**47.5**	**59.8**		**75.0**	**80.4**	
Municipal WWTP's	[t N/a]	49,330	32,230	*-34.7%*	26,310	17,050	*-35.2%*	138,250	98,010	*-29.1%*	32.750	24,420	*-25.4%*
	[%]	22.5	21.8		24.6	20.0		35.0	35.3		21.8	18.6	
Direct industrial discharges	[t N/a]	46,760	9,000	*-80.7%*	4,890	1,320	*-73.1%*	69,450	13,740	*-80.2%*	4,780	1,270	*-73.4%*
	[%]	21.3	6.1		4.6	1.5		17.6	4.9		3.2	1.0	
Sum point sources	**[t N/a]**	**96,090**	**41,230**	***-57.1%***	**31,200**	**18,360**	***-41.1%***	**207,700**	**111,750**	***-46.2%***	**37,530**	**25,690**	***-31.5%***
	[%]	**43.8**	**28.0**		**29.2**	**21.6**		**52.5**	**40.2**		**25.0**	**19.6**	
Sum all sources	**[t N/a]**	**219,250**	**147,520**	***-32.7%***	**107,020**	**85,050**	***-20.5%***	**395,550**	**277,720**	***-29.8%***	**150,090**	**131,300**	***-12.5%***
	[%]	**100.0**	**100.0**		**100.0**	**100.0**		**100.0**	**100.0**		**100.0**	**100.0**	

Table 2. Nitrogen emissions from the pathways, its contribution to the total emissions and its changes for the German parts of he North Sea, Baltic Sea and Black Sea basins and entire Germany for the time periods 1983-1987 and 1993-1997.

Pathway		North Sea			Baltic Sea			Black Sea			Germany		
		1983-87	1993-97	Change	1983-87	1993-97	Change	1983-87	1993-97	Change	1983-87	1993-97	Change
Groundwater	[t N/a]	308,240	301,690	*-2.1%*	13,510	14,340	*+6.1%*	79,680	78,390	*-1 6%*	401,430	394,430	*-1.7%*
	[%]	35.3	47.0		22.1	32.0		53.0	59.5		37.0	48.2	
Tile drainage	[t N/a]	120,400	87,280	*-27.5%*	26,780	17,510	*-34 6%*	21,110	16,600	*-21.4%*	168,290	121,390	*-27.9%*
	[%]	13.8	13.6		43.8	39.0		14.0	12.6		15.5	14.8	
Erosion	[t N/a]	9,330	9,270	*-0.6%*	530	530	*+0.5%*	2,340	2,490	*+6.4%*	12,200	12,290	*+0.8%*
	[%]	1.1	1.4		0.9	1.2		1.6	1.9		1.1	1.5	
Surface runoff	[t N/a]	9,080	9,140	*+0.6%*	160	220	*+43.0%*	4,110	4,200	*+2.2%*	13,350	13,560	*+1 6%*
	[%]	1.0	1.4		0.3	0.5		2.7	3.2		1.2	1.7	
Atmospheric deposition	[t N/a]	10,040	7,510	*-25.2%*	2,210	1,560	*-29.4%*	1,790	1,440	*-19.9%*	14,050	10,510	*-25.2%*
	[%]	1.2	1.2		3.6	3.5		1.2	1.1		1.3	1.3	
Urban areas	[t N/a]	37,290	29,060	*-22.1%*	2,520	2,230	*-11.6%*	3,830	2,810	*-26.6%*	43,650	34,100	*-21.9%*
	[%]	4.3	4.5		4.1	5.0		2.5	2.1		4.0	4.2	
Sum diffuse sources	**[t N/a]**	**494,380**	**443,940**	***-10.2%***	**45,700**	**36,390**	***-20.4%***	**112,880**	**105,940**	***-6.1%***	**652,970**	**586,280**	***-10.2%***
	[%]	**56.6**	**69.1**		**74.8**	**81.1**		**75.0**	**80.5**		**60.2**	**71.6**	
Municipal WWTP`s	[t N/a]	256,460	173,110	*-32.5%*	14,070	7,320	*-48.0%*	32,770	24,440	*-25.4%*	303,300	204,860	*-32.5%*
	[%]	29.4	27.0		23.0	16.3		21.8	18.6		28.0	25.0	
Direct industrial discharges	[t N/a]	122,230	25,080	*-79.5%*	1,300	1,140	*-12.4%*	4,780	1,270	*-73.4%*	128,310	27,490	*-78.6%*
	[%]	14 0	3.9		2.1	2.5		3.2	1.0		11.8	3.4	
Sum point sources	**[t N/a]**	**378,690**	**198,180**	***-47.7%***	**15,370**	**8,460**	***-45.0%***	**37,550**	**25,710**	***-31.5%***	**431,610**	**232,350**	***-46.2%***
	[%]	**43.4**	**30.9**		**25.2**	**18.9**		**25.0**	**19.5**		**39.8**	**28.4**	
Sum all sources	**[t N/a]**	**873,070**	**642,120**	***-26.5%***	**61,070**	**44,850**	***-26.6%***	**150,430**	**131,650**	***-12.5%***	**1.084,580**	**818,630**	***-24.5%***
	[%]	**100.0**	**100.0**		**100.0**	**100.0**		**100.0**	**100.0**		**100.0**	**100.0**	

Table 3. Phosphorus emissions from the pathways, its contribution to the total emissions and its changes for the German parts of the Elbe, Rhine and Danube basins and the Weser for the time periods 1983-1987 and 1993-1997.

Pathway		Elbe			Weser			Rhine			Danube		
		1983-87	1993-97	Change	1983-87	1993-97	Change	1983-87	1993-97	Change	1983-87	1993-97	Change
Groundwater	[t P/a]	950	1,000	*+5.3%*	710	530	*-25.6%*	880	850	*-2.7%*	670	590	*-12.1%*
	[%]	5.1	14.0		8.3	13.8		2.3	7.1		6.3	11.1	
Tile drainage	[t P/a]	140	160	*+13.3%*	380	360	*-4.9%*	100	100	*+0.9%*	100	90	*-9.2%*
	[%]	0.8	2.3		4.5	9.5		0.3	0.8		0.9	1.7	
Erosion	[t P/a]	1,680	1,740	*+3.6%*	960	1,000	*+4.0%*	2,560	2,770	*+7.8%*	1,660	1,910	*+14.8%*
	[%]	9.0	24.4		11.2	26.1		6.8	23.0		15.6	36.0	
Surface runoff	[t P/a]	120	320	*+159.5%*	280	410	*+46.5%*	1,230	1,320	*+6.9%*	620	810	*+30.8%*
	[%]	0.7	4.4		3.3	10.8		3.3	11.0		5.8	15.2	
Atmospheric deposition	[t P/a]	130	70	-45.9%	16	14	*-9.7%*	48	46	*-5.4%*	30	29	*-5.7%*
	[%]	0.7	1.0		0.2	0.4		0.1	0.4		0.3	0.5	
Urban areas	[t P/a]	3,200	1,320	*-58.8%*	860	380	*-55.9%*	3,390	1,380	*-59.4%*	820	370	*-55.0%*
	[%]	17.0	18.4		10.2	10.0		9.0	11.4		7.8	7.0	
Sum diffuse sources	**[t P a]**	**6,230**	**4,620**	***-25.9%***	**3,210**	**2,690**	***-16.1%***	**8,210**	**6,460**	***-21.3%***	**3,900**	**3,790**	***-2.8%***
	[%]	**33.2**	**64.5**		**37.7**	**70.6**		**21.9**	**53.7**		**36.7**	**71.5**	
Municipal WWTP's	[t P/a]	10,210	2,380	*-76.7%*	5,010	1,070	*-78.7%*	25,970	4,990	*-80.8%*	6,140	1,410	*-77.1%*
	[%]	54.3	33.3		58.8	28.0		69.2	41.4		57.8	26.6	
Direct industrial discharges	[t P a]	2,350	160	*-93.1%*	300	50	*-81.6%*	3,370	590	*-82.4%*	580	100	*-82.7%*
	[%]	12.5	2.3		3.5	1.4		9.0	4.9		5.5	1.9	
Sum point sources	**[t P a]**	**12,560**	**2,540**	***-79.7%***	**5,300**	**1,120**	***-78.9%***	**29,340**	**5,580**	***-81.0%***	**6,720**	**1,510**	***-77.5%***
	[%]	**66.8**	**35.5**		**62.3**	**29.4**		**78.1**	**46.3**		**63.3**	**28.5**	
Sum all sources	**[t P a]**	**18,800**	**7,160**	***-61.9%***	**8,510**	**3,810**	***-55.2%***	**37,550**	**12,040**	***-67.9%***	**10,630**	**5,300**	***-50.1%***
	[%]	**100.0**	**100.0**		**100.0**	**100.0**		**100.0**	**100.0**		**100.0**	**100.0**	

Table 4. Phosphorus emissions from the pathways, its contribution to the total emissions and its changes for the German parts of the North Sea, Baltic Sea and Black Sea basins and entire Germany for the time periods 1983-1987 and 1993-1997.

Pathway		North Sea			Baltic Sea			Black Sea			Germany		
		1983-87	1993-97	Change	1983-87	1993-97	Change	1983-87	1993-97	Change	1983-87	1993-97	Change
Groundwater	[t P/a]	5,560	4,820	*-13.3%*	340	330	*-4.0%*	680	590	*-12.1%*	6,580	5,740	*-12.7%*
	[%]	7.1	15.9		8.3	20.2		6.3	11.2		7.0	15.4	
Tile drainage	[t P/a]	3,320	3,070	*-7.4%*	90	100	*+5.7%*	100	90	*-9.2%*	3,510	3,260	*-7.1%*
	[%]	4.2	10.1		2.2	6.0		0.9	1.7		3.8	8.8	
Erosion	[t P/a]	5,440	5,770	*+6.1%*	390	420	*+7.5%*	1,660	1,910	*+14.9%*	7,490	8,100	*+8.1%*
	[%]	6.9	19.0		9.5	25.9		15.6	35.9		8.0	21.7	
Surface runoff	[t P/a]	1,870	2,400	*+28.8%*	35	70	*+111.0%*	620	810	*+30.8%*	2,520	3,290	*+30.4%*
	[%]	2.4	7.9		0.9	4.6		5.8	15.2		2.7	8.8	
Atmospheric deposition	[t P/a]	230	160	*-29.4%*	70	41	*-39.3%*	30	29	*-5.7%*	330	230	*-29.2%*
	[%]	0.3	0.5		1.6	2.5		0.3	0.5		0.3	0.6	
Urban areas	[t P/a]	8,040	3,460	*-56.9%*	330	190	*-42.9%*	830	370	*-55.0%*	9,190	4,020	*-56.3%*
	[%]	10.2	11.4		7.9	11.5		7.8	7.0		9.8	10.8	
Sum diffuse sources	**[t P/a]**	**24,450**	**19,700**	***-19.5%***	**1,250**	**1,150**	***-8.5%***	**3,910**	**3,800**	***-2.8%***	**29,620**	**24,640**	***-16.8%***
	[%]	**31.0**	**65.0**		**30.4**	**70.7**		**36.7**	**71.5**		**31.7**	**66.2**	
Municipal WWTP's	[t P/a]	48,150	9,520	*-80.2%*	2,559	430	*-83.3%*	6,150	1,410	*-77.0%*	56,850	11,350	*-80.0%*
	[%]	61.1	31.4		61.9	26.3		57.8	26.6		60.8	30.5	
Direct industrial discharges	[t P/a]	6,160	1,100	*-82.1%*	320	48	*-85.0%*	580	100	*-82.7%*	7,070	1,250	*-82.3%*
	[%]	7.8	3.6		7.8	3.0		5.5	1.9		7.6	3.4	
Sum point sources	**[t P/a]**	**54,310**	**10,620**	***-80.4%***	**2,880**	**470**	***-83.5%***	**6,730**	**1,510**	***-77.5%***	**63,920**	**12,610**	***-80.3%***
	[%]	**69.0**	**35.0**		**69.6**	**29.3**		**63.3**	**28.5**		**68.3**	**33.8**	
Sum all sources	**[t P/a]**	**78,770**	**30,320**	***-61.5%***	**4,130**	**1,620**	***-60.7%***	**10,640**	**5,310**	***-50.1%***	**93,540**	**37,250**	***-60.2%***
	[%]	**100.0**	**100.0**		**100.0**	**100.0**		**100.0**	**100.0**		**100.0**	**100.0**	

The nitrogen inputs by groundwater show a different behaviour, depending on the residence time of water in the unsaturated zone and in the groundwater of the river basins. These residence times were raw estimated from the comparison of the long term changes of nitrate concentration and load as well as the nitrogen surplus in the agricultural sphere as shown in Figure 4. The regressions between the measured nitrate concentrations and the N-surplus of a mean of former years since 1995 shows that an optimum exists in the Rhine for the mean of 10 to 20 former years in the Danube for a mean of 20 years and in the Elbe for a mean of 30 years or more. If this long term behaviour is taken into account the comparison of the groundwater emissions in the period 1993-1997 and 1983-1987 should indicate a low decrease in the Rhine basin and a very low increase in the Danube. Long term observations of nitrate concentrations in groundwater were available for more than 200 monitoring stations in Bavaria and Baden-Württemberg.

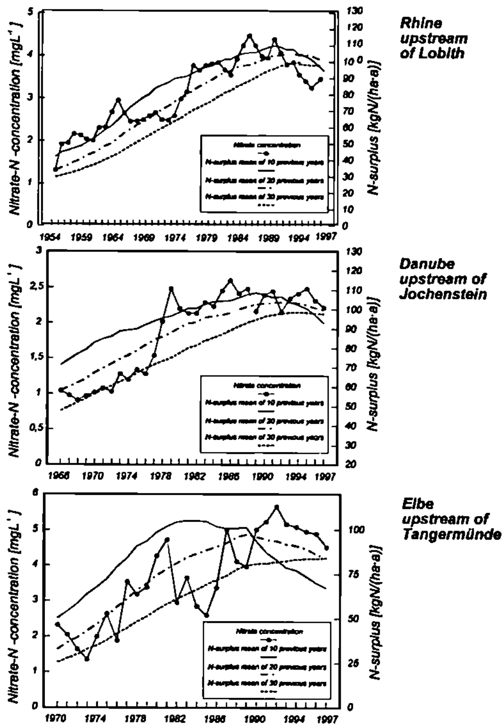

Figure 4. Comparison of the long term changes of the concentration and load of nitrate in the main German rivers and the long term average of nitrogen surplus in the agricultural sphere

The analysis of these measurements shows that the mean of data in Baden-Württemberg (mainly Rhine basins) indicates a decrease by 3% and an increase of 2% for the Bavarian stations (mainly Danube basin), which is in agreement with the results of the comparison of long term monitoring in the rivers and the long term changes of N-surplus.

As retention in the river systems has to be considered (Behrendt, 1996; Behrendt & Opitz, 1998; Billen et al., 1995), a direct comparison cannot be drawn between the model results and the measured load. But the changes of the nutrient emissions can be compared with the load, if we assume that the changes in the river parts of the Elbe, Rhine and Danube outside of Germany are nearly similar to those in the German parts.

As shown in table 5 and 6 the diffuse input into rivers was decreased by about 10% for nitrogen and 20% for phosphorus in the last decade, whereas the input of mineral fertilizer to the agricultural area has decreased in the total area of the Federal Republic and the livestock numbers have enormously reduced especially in Eastern Germany (Bach et al., 1998). Consequently, the surplus of nitrogen in the topsoils of agricultural areas has decreased by 27% (Western Germany) and 44% (Eastern Germany). For phosphorus the reduction of the surplus on agricultural top soils amounts to 68% for Western Germany and 115% for the eastern part (Bach et al., 1998).

Table 5. Changes of the nitrogen emission from different paths, nitrogen load and runoff for the four main river basins of Germany in 1995 compared to 1985 (1985 = 100%).

Basin		Elbe	Weser	Rhine	Danube	Total
Change of diffuse sources	[%]	84.7	87.9	86.2	93.8	88.8
Change of point sources	[%]	42.7	58.8	56.2	68.5	54.5
Change of total input	[%]	66.6	79.4	70.7	87.5	75.3
Change of measured load	[%]	77.0	77.3	82.3	95.6	
Change of runoff	[%]	99.7	93.0	93.0	100.1	

Table 6. Changes of the phosphorus emission from different paths, nitrogen load and runoff for the four main river basins of Germany in 1995 compared to 1985.

Basin		Elbe	Weser	Rhine	Danube	Total
Change of diffuse sources	[%]	70.7	82.8	73.9	95.5	80.6
Change of point sources	[%]	19.2	21.1	19.0	22.5	19.0
Change of total input	[%]	36.7	44.4	31.1	49.2	38.7
Change of measured load	[%]	38.8	32.9	41.1	59.2	
Change of runoff	[%]	99.7	93.0	93.0	100.1	

Reasons for the phenomenon of the low decrease of diffuse inputs into rivers at high decreasing surplus of the agricultural soils are the long residence times of water in the unsaturated zone and in the groundwater and the high level of phosphorus accumulation in agricultural soils.

A special problem of the modeling of nutrient input into river basins is the evaluation of the results. because the considerable amount of errors can influence the result. As shown by Behrendt (1998) the comparison of different methods of source apportionment can help to find out possible systematical errors as underestimation of the load or overestimation of input. Such an analysis was done for 31 river basins, for which the results of similar estimations were published.

From these investigations it can be concluded that indications of such systematical errors do not exist for nitrogen. The mean deviation between the different results is lower than 15% for the total emissions and the diffuse nitrogen inputs. For phosphorus this deviation is higher and amounts to 38%. Still, an overestimation of the input by erosion and

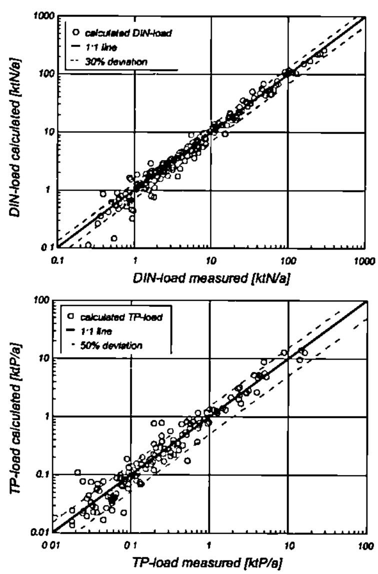

Figure 5. Comparison of measured and calculated nutrient load in German river systems for the period 1993 to 1997.

surface runoff as well as an underestimation of the measured load seems to be probable for phosphorus.

Because the model system MONERIS includes a module for nutrient retention within the surface waters of a river system, the transformation of the nutrient emissions in the nutrient load is possible. These loads can also be compared with the measured loads at the monitoring stations, which are located at the mouth of the different investigated river systems. These comparisons are presented in the Figure 5. The figure shows that the deviation between the measured and calculated load of dissolved inorganic nitrogen is in general lower as 30%, but the deviation is higher for 12% of the total number of the investigated river basins. For phosphorus the deviation is higher but in general lower as 50%. Larger differences occur for river basins where large lakes dominates the total surface water area of the basin and the lakes are directly upstream or very far from the monitoring station. That is an indication for a possible further development of the retention module, which has to take into account the distribution of the surface water within the basin. For both nitrogen and phosphorus the tendency to larger deviations between observed and calculated nutrient loads increases with decreasing size of the river basins.

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A synthesis of the results of TOROS and CANIGO projects on metal contamination in the Tinto-Odiel rivers (Southern Spain) and the Gulf of Cadiz

by

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Introduction

Metals are introduced in coastal waters by present or past mining activities, agriculture, industrial and domestic sewages. Unlike organic compounds or radionuclides, they do not degrade and thus are not expected to loose their toxic potential. In Europe the mining activity is one of the major source of metals in the coastal zone. Present and past mining activities leave metal rich wastes, which slowly release metals in rivers. Examples of small and large rivers affected by mine drainage are numerous over Europe: in France (the Dordogne river tributary of the Gironde; the Gardon and the Ardeche, tributaries of the Rhone), in England (the Tamar river; Lake district, ...), in Spain (rivers discharging on the North west coast; rivers discharging on the South-west coast).

In Western Europe Spain is the most affected country by metal discharges particularly in Andalucia where the main rivers flowing into the Atlantic Ocean drain metal mineralisation. In this region the oldest known mining activity (Leblanc et al., 1998) has left enormous metal-rich wastes. Some mines are still active in Andalucia and there is an important risk of accidental metal spill. This risk has been materialized recently by the collapse of the retaining dam of a tailing reservoir in Aznalcollar (April 25 1998). Between 5-7 10^6 m^3 of acid sludge and water (pH 2) were release into the Rio Agrio, a tributary of the river Guadiamar (Van Geen et al, 1998). The released sulphide sludge formed a layer of up to ca. 1 m thick over a distance of ca 40 km, covering more than 4000-5000 ha of the river bed and flood plains of the Guadiamar, in addition to surrounding agricultural fields (Medio Ambiente web site). In order to prevent from contamination the Donana Park (world's biosphere reserve of UNESCO) located at 45 km south of the mine, the waters have been diverted to the river Guadalquivir (40 km from its mouth).

The Gulf of Cadiz represents 5% of fish and shellfish catches for Spain (L. Suarez de Vivero, personal communication) and 10% for Portugal (Bebiano and Machado, 1992). In addition the waters from the Gulf of Cadiz contribute to 1520% of the Atlantic Inflow to the Mediterranean Sea (Van Geen et al., 1991, Morley et al, 1999).

One of the aims of TOROS project was to study the fate of metal in the Tinto and Odiel estuaries and in the Gulf of Cadiz (Figure 1). CANIGO project has been studying the metal fluxes in the Strait of Gibraltar. Both projects were initiated before the accident in Aznalcollar. This paper summarizes some of the results of the TOROS[1]and CANIGO[2] projects.

[1] TOROS (Tinto-Odiel-River-Ocean-Study), contract ENV4-CT96-0216, Environment and Climate, ELOISE, DGXII, European Commission

[2] CANIGO (Canary Azores Gibraltar Observations), contract MAS3-PL95-0443, MAST, DGXII, European Commission

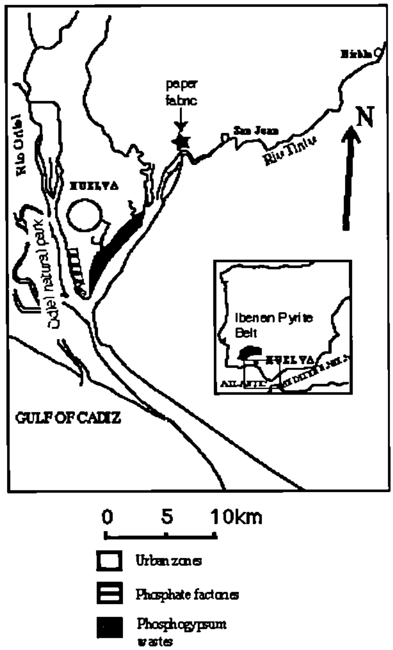

Figure 1. Map of the study area of TOROS and CANIGO projects. The Tinto and Odiel rivers meet in a common estuary (Ria) at Huelva.

Studied area

TOROS project has been studying metal biogeochemistry in the Tinto and Odiel rivers, mixing zones and the Gulf of Cadiz. The study area of CANIGO project was the Strait of Gibraltar.

The Tinto and Odiel (Figure 1) are relatively small rivers (83 and 128 km in length, respectively). They have similar drainage basin areas (around 1680 km^2). The mean water discharges of the Odiel and the Tinto rivers are $15m^3 s^{-1}$ and $3m^3 s^{-1}$ respectively. Important variations above and below this mean are observed (Borrego-Flores, 1992), with extremely low discharges during dry periods. Mining activity is less intense in the Odiel than in the Tinto catchment, where ore extraction is still taking place in the Rio Tinto mining complex. On the upper Odiel river a dam has been built which traps sediments and acid mine wastes from ore processing plants. The oxidation of pyrite in the mining zone produces sulfuric acid and as a consequence, the Tinto and Odiel waters are acidic (pH 2.5, Nelson and Lamothe 1993, Elbaz-Poulichet et al, 1996, Van Geen et al, 1997).

The estuarine zones of both rivers are sites of major industrial activity. On the east bank of the Odiel are phosphate-based fertiliser plants (processing imported apathite), a pyrite roasting plant and a Cu smelting plant. On the Rio Tinto there is a paper mill in Moguer, which processes eucalyptus wood from local sources. There are large waste deposits of phosphogypsum on the northern bank of the Tinto near the junction of the two rivers. Furthermore, the industrial area includes an oil refinery and other chemical industries, which are situated on the east bank of the outer estuary, downstream of the confluence.

Sampling and analysis

Within the TOROS project, four surveys were carried out: November 1996, June 1997, April 1998 and October 1998. 4 surveys of the Strait of Gibraltar were also performed in the framework of the CANIGO project from 1997 to 1999.

The methodology for water sampling and analyses has been described in Elbaz-Poulichet et al (1999a,b) and in Elbaz-Poulichet and Dupuy (1999).

Results and Discussion

Origins and metal (Fe, Ni, Cu, Zn, Cd, Pb, As and Hg) concentrations in the Tinto and Odiel mixing zones

Dissolved metal concentrations are variable. The concentration ranges observed in the Tinto and Odiel are reported in Table 1. These values are extremely high when compared to other European rivers (Table 1). In the Odiel mixing zone dissolved Hg concentrations reach 0.165 nM (Cossa et al, 1999). This represents more than 10 times the maximum value observed in the Seine river which is considered as the most heavily contaminated river in France (Cossa and Boutier, 1999).

Table 1. Dissolved metal concentrations (nM) in some contaminated European rivers near their mouth and in the Tinto and Odiel rivers.
** Fe and Zn concentrations in µM.*

River	Fe	Ni	Cu	Zn	Cd	Pb	As	Hg
Tinto (1)*	1229-12527	1617-2432	142-447559	265-890	682-2617	5555	203-29253	0.042
Odiel (1)*	39-734	1722-2491	67-136693	133-418	457-868	307	6-369	0.164
Garonne (2,3,4, 5)	139	6	13	18	0.52	0.26	20	0.0025
Seine (6,7,8)	40	70	31	200	2	2.5		0.014
Rhone (9,10)	232	27	35	20	0.27	0.42	26	0.0024
Scheldt (11)			35	352	0.27			
Tagus (12, 13)*	210	15	26	230	3.4	3	680	

Sources: (1) Elbaz-Poulichet et al, 1999; (2) Kraepiel et al, 1997; (3) Elbaz-Poulichet et al, 1987; (4) Seyler and Martin, 1990; (5) Cossa and Boutier, 1999; (6) Cossa et al, 1994; (7) Chiffoleau et al, 1994; (8) Huang and Mouchel, 1994; (9) Elbaz-Poulichet et al, 1996; (10) Guieu et al, 1993; (11) Zwolsman et al, 1997; (12) Cotte, 1997; (13) Seyler, 1985.

The primary source of metal is the drainage of mining wastes. However heavily contaminated sediments and phosphogypsum wastes constitute important secondary sources. The Hg concentration in the phosphogypsum waste is 1 to 4 ppm. The U concentration is 11 ppm. Assuming that the deposit contains 10^{10} kg of phosphogypsum (Travesi et al, 1997) the stocks on the bank of the Tinto are 10 to 70T for Hg and 110T for U. This stock has to be compared with the mean European Hg consumption estimated to 400-450 T/Year between 1985 and 1992 (OCDE, 1994).

Using Rare Earth Elements as tracers of phosphogypsum in waters we demonstrate that phosphogypsum wastes are leaking (Elbaz-Poulichet and Dupuy 1999) and supplies the waters with dissolved and particulate As, Hg and U (Elbaz-Poulichet et al, 1999a,b; Cossa et al, 1999).

Fate of metals in the Tinto-Odiel estuary

Metals in the estuarine zones of the Tinto and Odiel rivers have different behaviours and can be classified into two groups.

The first one, which includes Mn, Cu, Cd, Pb and Ni, has a Fe-like behaviour. They are supplied to the rivers by drainage of mining wastes in the mining area. In the Odiel mixing zone metal concentrations decrease continuously from the river endmember to the marine end-member (Figure 2).

Contrasting with normal estuaries (Boyle et al, 1997) where extensive Fe removal from the water occurs in the low chlorinity region of mixing zones, Fe is only slightly removed in the Odiel mixing zone (Figure 2). In the Tinto mixing zone Fe-like metals increase in the early stage of mixing (Figure 2) and then decreases with increasing salinity. The maximum of concentration in the low chlorinity region of the Tinto is attributed to a release of Fe from detrital pyrite and Fe-oxyhydroxides which are abundant in these sterile salt-marshes (Elbaz-Poulichet et al., 1999a,b; Elbaz-Poulichet and Dupuy, 1999). This means that even if attempts to clean the river in the mining region are made, the marshes near San Juan (Figure 1) will go on supplying metals and probably acidity to the estuary.

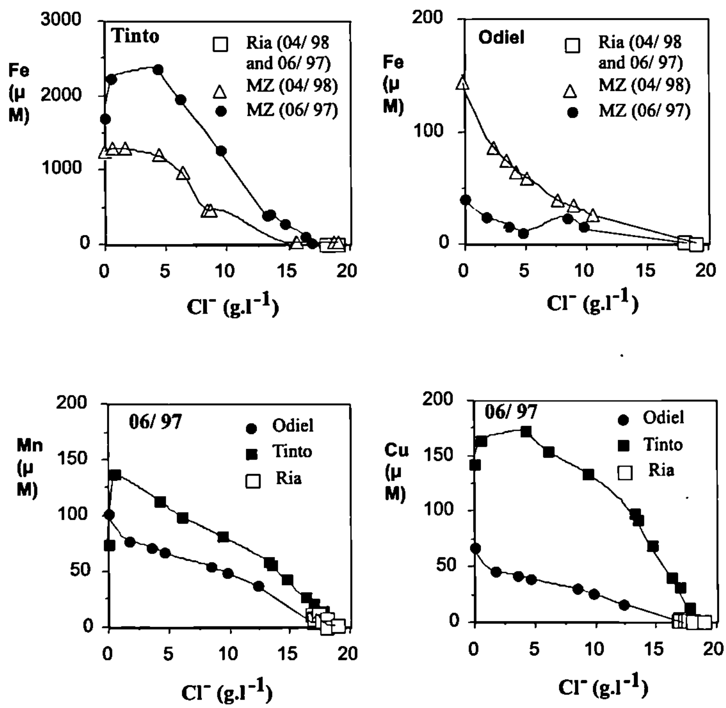

Figure 2. Characteristic distributions of Fe and some Fe-like metals in the waters of the Tinto-Odiel mixing zone (MZ) and in the Ria as a function of chlorinity.

The second group includes Hg, As and U. These elements are introduced in the estuary mainly by phosphogypsum waste deposits on the Tinto (Figure 3).

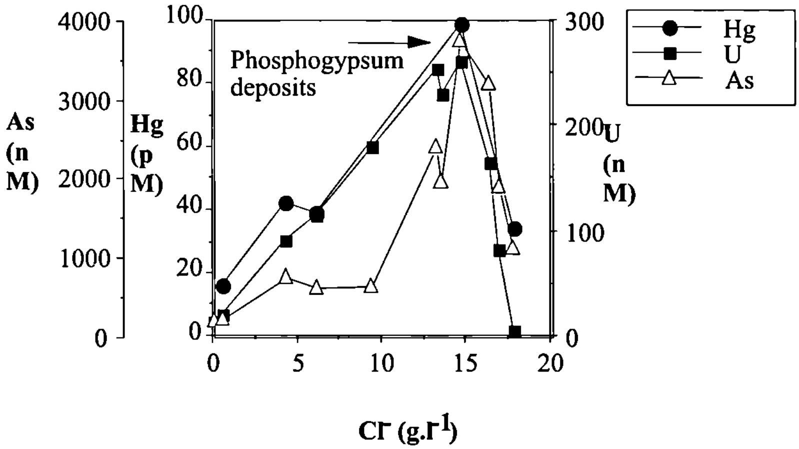

Figure 3. Distribution of As, Hg and U as a function of Chlorinity in the Tinto mixing zone in June 1997.

These elements are trapped by sediments in the estuarine zone (Elbaz-Poulichet et al., 1999a,b; Cossa et al., 1999). In addition algae play a role in removing As from the water column as suggested by the concomitant increase of As in suspended matter and chlorophyll-a (Figure 4). The observed cycling of Hg, As and U suggest that these elements represent a potential danger for a transfer along the food web (As), for an increased radioactivity in the marshes (U) and for a contamination of benthic organisms (Hg). Moreover the concentration of As in the sediments can reach 1800 ppm and the storage of these sediments after dredging operations of navigation channels can be problematic.

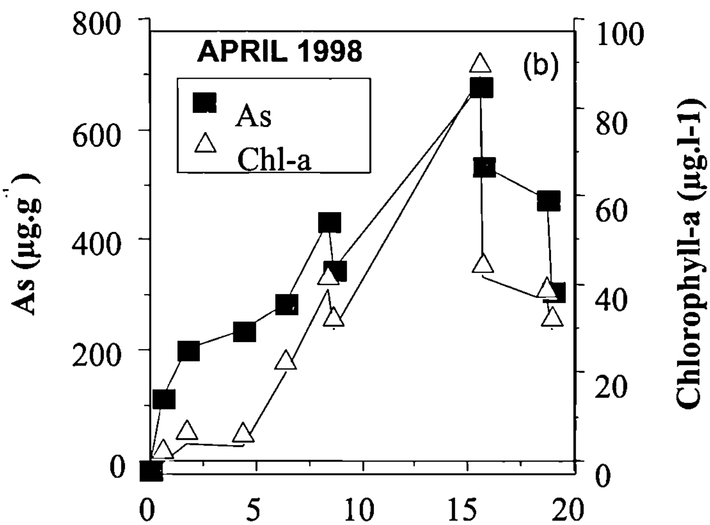

Figure 4. Distribution of As in suspended matter (µg.g-1 dry weight) and Chlorophyll-a in the Tinto mixing zone (April 1998).

Metal dispersion in the Gulf of Cadiz-consequences of the Aznalcollar spill

Both hydrodynamic modelling and field data show that an enriched metal plume of metals exists in surface waters along the northern coast of the Gulf of Cadiz. This plume is deviated towards the south-east (Morley et al., 1999).

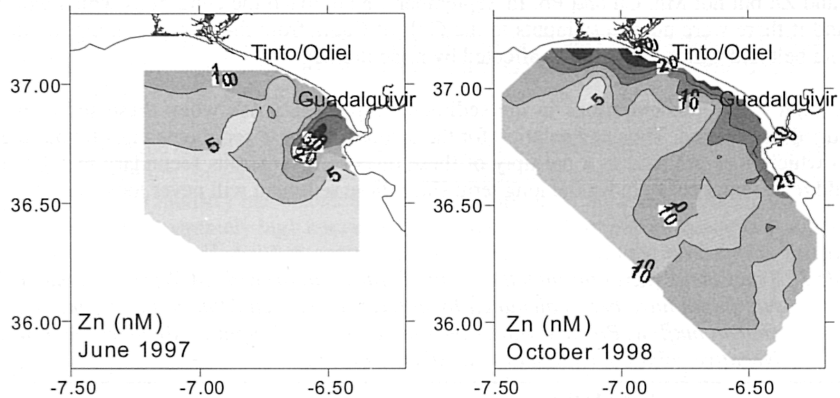

Figure 5. Dissolved Zn concentrations in the surface waters of the Gulf of Cadiz before and after the Aznalcollar accident (similar patterns are observed for Cu).

Continuous in situ monitoring of metal concentrations (Braungardt et al, 1998) revealed that the collapse of the tailing reservoir of the Aznalcollar mine has not impacted the chemistry of the coastal waters (Figure 5), up to 6 months after the accident (Achterberg et al, 1999).

Consequences of the contamination in the Gulf of Cadiz on the Mediterranean Sea

In a first approximation the long term water transports into and out of the Mediterranean through the Strait of Gibraltar can be represented by a simple two-layer model of exchanges (Bethoux, 1979; Bryden et al., 1994). The low density Atlantic waters entering the Mediterranean Sea in the upper layer, the high density Mediterranean outflow waters (MOW) leaving the Mediterranean Sea in the bottom layer. Our study (Morley et al., 1999) shows that the surface Atlantic waters an inhomogeneous. 3 waters masses having different metal concentration can be recognized:

- the North Atlantic Surface Waters (NASW),
- the North Atlantic Central Waters (NACW),
- the Gulf of Cadiz Waters (GCW).

This metal enriched water mass comes from the Gulf of Cadiz. It is NASW, which has been transiting through the Gulf of Cadiz where it has acquired elevated metal concentrations. In June 1997 the GCW were particularly well observed and were representing 20% of the inflowing Atlantic waters. This value is closed from the value given by Van Geen et al., 1991: 15±5%.

The corresponding metal fluxes are given in Table 2. The relative contribution of GCW to the Atlantic inflow (June conditions) range from 18% for As to 89% for Zn. Because enrichment of GCW is almost absent in September, the contribution of GCW is significantly lower and ranges from 5 to 67% respectively for Fe and Zn. Comparison of the fluxes with and without influence of GCW (Table 2) demonstrates clearly the significance of GCW influx to the Mediterranean in terms of trace metal loads particularly during June.

The Mediterranean Sea is a net source of As, Ni, Co and Cd for the Atlantic in June and September. When enriched GCW is present (in June) the Atlantic ocean is a net source of Mn, Fe, Cu, Zn and Pb to the Mediterranean. During the September conditions this flux is reversed for Fe and Zn but not Mn, Cu and Pb. In September we approach the conditions which would be found if there were no excess inputs to the Gulf of Cadiz from the rivers draining the Iberian pyrite belt and which are strongly affected by mine drainage.

The high metal concentrations in the sediments represent a risk when these sediments are dredged and wasted. Thus any solution for the disposal of these sediments must favour the option which does not lead to a multiply of these disposal. Numerous secundary metal sources could represent a problem for the long term since these sediment will never loose their toxicity.

Table 2: Trace metal fluxes through the Strait of Gibraltar. (a) with GCW; (b) without GCW. Net fluxes have been calculated by difference between Atlantic inflow and Mediterranean outflow. Positive values indicate a net metal input to Mediterranean waters. Negative values a net input to the Atlantic ocean.

(a)		Contribution to inflow waters (%)	Mn	Fe	Co	Ni	Cu	Zn	As	Cd	Pb
NASW		82	1010	514	54	1617	1166	955	23409	41	190
NACW		2.5	31	9	2	82	27	73	840	5	12
GCW	June	15	3140	564	59	986	1706	8732	5542	76	348
GCW	September	15	739	28	99	394	213	2183	5290	38	104
MOW			1162	887	623	3721	1342	6867	33278	190	219
NET Fluxes	June		3019	200	-508	-1036	1557	2893	-3488	-68	331
	September		617	-336	-468	-1628	64	-3656	-3740	-106	87
Contribution of GCW to the Atlantic inflow (%)	June		75	52	52	37	59	89	19	62	63
Contribution of GCW to the Atlantic inflow (%)	September		42	5	64	19	15	68	18	45	34

(b)	Contribution to inflow waters (%)	Mn	Fe	Co	Ni	Cu	Zn	As	Cd	Pb
NASW	97.5	1201	611	64	1922	1386	1135	27834	49	226
NACW	2.5	31	9	2	82	27	73	840	5	12
MOW		1162	887	623	3721	1342	6867	33278	190	219
NET fluxes		69	-267	-557	-1716	71	-5659	-4604	-136	19

The implementation of continuous monitoring systems for metal concentrations in the area similar to those, which have been used in TOROS, could be usefull. We also suggest continuous surveys of air quality (including metals) and epidemiological studies.

At a larger scale, calculations show that the metals discharged in the Gulf of Cadiz significantly increase metal to the Western Mediterranean Sea at the Strait of Gibraltar. Any changes in metal discharges (through sea level rise for example) in the Northern part of the Gulf of Cadiz may affect the contamination of the Mediterranean Sea.

Summary of potential risks and consequences for the management

The deliverables of TOROS and CANIGO's projects consist mainly in data sets, conceptual and numerical models for metal and nutrient cycling in the Ria de Huelva and metal dispersion in the Gulf of Cadiz.

Mining activity in the region is old (4500 years) but metal contamination has strongly increased during the last century. In addition the development of an important industrial activity, in particular the fertiliser industry has enhanced the contamination of the estuary during the last 50 years. Owing to the extremely high concentrations which are observed we consider that potential risks exist for fish and shellfish contamination in the Gulf of Cadiz, particularly for some crustaceans.

Acknowledgments

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Coastal Management and Sustainability in Baltic East Germany: Learning from Scandinavia?

by

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Abstract

The Baltic coastal region in East Germany is unique because of its rural character, because it is a predominantly agricultural and thinly settled landscape. Its natural environment should be preserved. At the same time, the coastal zone is regarded as the basis for the region's social and economic development, mainly tourism, agriculture and industrial manufacturing. Nearly a decade after Germany's reunification, the eastern half of the country is still in a state of transformation with unemployment rates around 20% and steady out-migration. Under what conditions can sustainable coastal development be achieved, in order that both the demand for satisfaction of socioeconomic needs and for environmental preservation be met? The focus of this research project is on the human ecological perspective of coastal zone management (CZM) and draws upon Scandinavian experiences.

To assess and evaluate the natural potential of the coastal zone in the German state of Mecklenburg-Western Pommerania for landscape planning is still a task to be completed in addition to the data collection already done. Research is needed in the following areas:

- economic and social components that may be able to transform the structural crisis of the Baltic coastal region into a self-sustaining development;
- conditions for an environmentally sustainable coastal development in combination with the transformation of the structural economic crisis;
- the environmental sensitivity of landscapes depending on differing uses, including recreation and tourism;
- CZM concepts that include soil revitalization and other protection programs.

Regional development in the Baltic coastal region will have to deal with the issue of harmonizing conflicting goals. Conflicts between economic and ecological goals materialize both when new institutional CM structures are built up and when old German Democratic Republic (GDR) related institutions are shut down. These conflicts appear in all land use patterns. The high level of unemployment and the need for development add additional pressure. Ecological arguments are perceived by some as mere delay tactic: "Ecology is the new class enemy!"

Introduction

LENKA in Norway is a collaborative project aiming at integrative regional and coastal development. A Swedish national research program "Sustainable Coastal Zone Management" (SUCOZOMA) focuses mainly on coastal fisheries and mussel farming, but also draws attention to the implications of marine reserves. Some lessons may be learned. The tourist and fishing industry are of particular interest for the East German coast. As the ecological situation of the Baltic Sea worsens because of pollution resulting in eutrophication, those who fish for a living are forced to work harder to maintain their standard of living. This is reminiscent in particular of the situation in Kalmarsund in southeastern Sweden. Aquaculture has come to represent a risk for coastal ecosystems with the installation of sea trout production units. A few years from now, the situation could resemble that of today's Himmerfjärden in the Stockholm area where fish feed inputs have been the source of eutrophication.

The human ecological research agenda explores the conditions for achieving sustainable coastal development that improves the well being of the local population, yet preserves nature and the landscape potential.

The Baltic Sea area: ecosystem and pollution

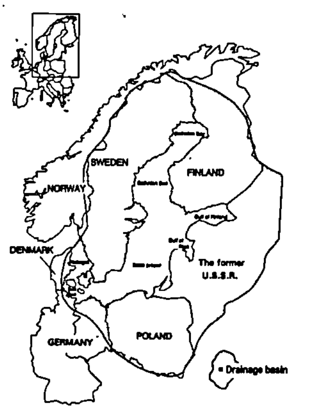
The Baltic Sea area is located in Northern Europe, surrounded by seven countries: Sweden, Finland, the former Soviet Union, Poland, Germany, and Denmark (see figure below). Parts of these countries constitute the drainage basin of the Baltic Sea area of roughly 1.65 million square kilometers, comprising a total population of 60 million people. Sweden, Finland, and Poland fall nearly completely within the drainage basin. The Baltic area consists of bays and gulfs, all draining into the North Sea: the Bothnian Bay, the Bothnian Sea, the Gulf of Finland, the Gulf of Riga, the Baltic Sea proper, and the Belt Sea (Rijsberman, 1993).

The Baltic Sea, with a surface area of about 400,000 square kilometers and a volume of 21,000 cubic kilometers, is among the world's largest brackish water areas. Its average depth is 55 meters (maximum 459 meters) which makes it an unusually shallow sea. Its ecosystem, due to the brackish quality of its water, is quite peculiar. The key to the specific character of the area is the shallow, narrow Danish Straits, which permit only slow water exchanges between the Baltic and the North Sea. As a result, the water in the Baltic Sea has a long residence time, 35 to 40 years, which leads to accumulating sediments and biota of discharged pollutants. The Baltic Sea is among the world's most seriously polluted seas, and the consequences will affect future generations (Voigt, 1983; Leppäkoski, 1980; NSEPB, 1987).

Temperature, salinity, and the growth period influence the Baltic (as other) living systems. Its marine ecosystem is species-poor, due to the growth period, which varies between four (north) and ten months (southern areas). There are 145 known macroscopic species in the southern part and 52 species in the north, as compared to 200,000 plant and animal species identified in the seas around the globe (Voipio, 1981).

Different species of fish, seals, and birds form the macroscopic fauna: six to ten in the Bothnian Bay in the north, 69 in the Kiel Bay in the south. In comparison, the North Sea contains 120 species of fish. The most important marine pelagic fish species in the Baltic are herring and sprat, others include garpike, stickleback, mackerel and anchovy. No less than 38 species of fresh water fish inhabit the Baltic Sea: they are not found in the open sea, and they do not form stocks as the marine fish do.

The Situation of the Baltic Sea Area



Source: OECD, 1993b, p.302

Environmental problems in the Baltic Sea are the following (Rijsberman, 1993: 287-288): Due to eutrophication and sedimentation, herring trapnet catches in major spawning grounds have fallen drastically. Oxygen deficiency in the deeper areas affects cod. This is associated with land to sea nutrient discharges. Cod liver oil was prohibited in Sweden as a result of PCB concentrations. Because of high mercury concentrations in fish, fishing in some Swedish coastal bays was forbidden. Reproduction rates of white-tailed eagles, ringed and gray seals decreased caused by toxic substances. Toxic algae in the Kattegat, foaming algae on the North Sea coast, and seal mortality had a negative effect on income from tourism in Denmark.

Eutrophication is the main problem in the Kattegat along the Swedish coast from south to north. Eutrophication from mariculture and fish farming is increasing. In the early 1980s, eutrophication concerns increased. Attention focused on agriculture as a major nutrient source (table 1). The high nutrient loads are linked with increased anoxic bottom conditions as well as with algal blooms. Eutrophication has caused algal blooms to become regular phenomena, particularly in the Kattegat. Along the Finnish coast of the Eastern Gulf of Finland, high nutrient concentrations have caused heavy bluegreen algal blooms in recent late summers and early falls. Nutrient and BOD sources are carried in the rivers from Sweden, Poland, and the former Soviet Union, also direct coastal discharges in Sweden, Poland, and Denmark. The river discharges

Table 1. Estimates of the nitrogen input from land into the Baltic Sea.

Country	N inputs in tons per year and in percent of Baltic total load							
	Direct Discharges From The Coast							
	Municipal		Industry		Rivers		TOTAL	
	T/y	%	T/y	%	T/y	%	T/y	%
Denmark	21,500	4.1	2,800	0.5	44,800	8.5	69,100	13.1
Finland	6,704	1.3	3,013	0.6	59,800	11.3	69,517	13.2
GDR area	1,395	0.3	—	0.0	2,250	0.4	3,645	0.7
FDR area	3,300	0.6	2,080	0.4	11,000	2.1	16,380	3.1
Poland	17,200	3.3	240	0.0	92,500	17.5	109,940	20.8
Sweden	12,240	2.3	2,916	0.6	114,300	21.6	129,456	24.5
USSR area	5,313	1.0	500	0.1	124,500	23.6	130,313	24.6
Baltic Sea Area		12.8		2.2		85.0	528,351	100.0

Source: HELCOM, 1987b; cited in OECD, 1993b, p. 305.

Table 2. Estimates of the phosphorus input from land into the Baltic Sea.

Country	P inputs in tons per year and in percent of Baltic total load							
	Direct Discharges From The Coast							
	Municipal		Industry		Rivers		TOTAL	
	T/y	%	T/y	%	T/y	%	T/y	%
Denmark	6,270	12.9	2,210	4.6	1,030	2.1	9,510	19.6
Finland	377	0.8	296	0.6	3,760	7.7	4,433	9.1
GDR area	195	0.4	—	0.0	180	0.4	375	0.8
FDR area	480	1.0	61	0.1	1,830	3.8	2,371	4.9
Poland	3,000	6.2	4,600	9.5	11,500	23.7	19,100	39.4
Sweden	1,021	2.1	1,060	2.2	4,770	9.8	6,851	14.1
USSR area	458	0.9	170	0.4	5,251	10.8	5,879	12.1
Baltic Sea Area		24.3		17.4		58.3	48,519	100.0

Source: HELCOM, 1987b; cited in OECD, 1993b, p. 305.

are caused mostly by intensified agriculture, the pulp and paper industry, by domestic sewage and effluents from other industries (Elmgren, 1989a and b).

Heavy metals are transported in rivers from Sweden, Poland and the former Soviet Union. Mining, the metal and steel industry, and the cadmium pigment use in different industries cause the discharges, along with fertilizer use and municipal waste. Zinc discharges in Sweden stem from mining activities. The airborne load of cadmium is eight tons a year. (The waterborne load, by comparison, is 6 tons per year.) Ore mining as well as the iron and steel industry cause the airborne load primarily. Refineries, the petrochemical industry and cars are the main cause for the discharge of oil and oil-like substances. The largest loads stem from rivers and direct coastal discharges in the former Soviet Union (HELCOM, 1987a and b).

LENKA[1] in Norway

Regional development policy in Norway aims at developing the county's least developed areas: trade, industry, and local communities. The general idea is to prevent imbalances in living conditions which includes social service standards. The Ministry of Local Government and Labor is responsible for regional development policy. The 1986 Regional Development Fund is the vehicle for regional assistance. Its primary objective is to increase employment and to strengthen the economic base for industry and business. Loans, investment grants and share subscriptions are the means to serve that objective. Recent aquaculture developments have been started classified as less developed and received assistance (Stewart *et al.*, 1993: 267).

ICZM "involves a balance of the competing forces for the use of the coastal, so that sustainable development occurs without increased environmental damage" (*op. cit.*, 268). LENKA was conceived and initiated in 1987 as "a standardized, efficient, integrating mechanism to provide coastal planners with an information base on aquatic capacity to aid in making choices as to the best use of the coastal zone" (*op. cit.*, 271; cf. OECD, 1993a). LENKA is a collaborative project which is supported by the Ministry of Fisheries, the Ministry of the Environment and the Ministry of Local Government and Labor. It includes the municipalities, the directorates and the government agencies at the county level.

LENKA is not a CZM system proper. Instead, it is a "planning tool to provide the information base on aquatic capacity to aid . . . rational choices among the many possible uses of the aquatic environment (Stewart *et al.*, 1993: 259). LENKA provides an element of integration by involving more than one of the sectors, namely fisheries, environment, and regional development. ICZM is thus encouraged by LENKA in that it promotes aquaculture in the northern regions and by discouraging it in the more populated south where other uses are prioritized, such as recreation. LENKA has encouraged the different level government agencies and the sectors mentioned to design a system to measure the coastal zone capacity which is accessible to the different groups of stakeholders. It also helped the municipalities and counties to improve their cooperation.

These achievements have been realized because of LENKA's autonomous status, which does not challenge the stakeholders' interests. Its budget has encouraged cost sharing with other participants. Its operation mode has encouraged a consensus approach because of its lack of

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[1] The LENKA acronym was developed from the following words: L = Landsomfattande, E = Egnethetsvurdering (av den), N = Norske, K = Kystone (og Vassdrage), A = Akvakultur (Nationwide analysis of the suitability [of the Norwegian coastal zone and freshwater] for aquaculture).

legislative power. These are lessons learned, which may be transferred to other coastal regions, such as the coasts in northern Germany.

What is lacking, on the other hand, are ways to incorporate additional sectors in order to develop LENKA more into a CZM tool rather than a fisheries management tool. Aquaculture needs to be balanced against holiday home development, navigation, port development, or agriculture. It may be impossible, however, to maintain LENKA's consensus approach if these additional tasks are included, i.e. if LENKA becomes involved in land and water use planning rather than in being restricted to the very neutral task of data collection and modeling efforts. The bottom line is that LENKA's non-involvement in resource decision making may be considered to be both, a weakness and a strength (Stewart *et al.*, 1993: 268-269).

LENKA contributes to CZM in Norway by strengthening the existing institutions (rather than creating new ones which is the alternative solution) and by creating an atmosphere of cooperation between aquaculture and CZM and by creating an information base. Still, there may be a constraint in the present CZM arrangements in Norway. An institutional reform, according to Stewart *et al.*, may include "administrative responsibilities, . . . administrative boundaries and . . . market mechanisms" in resource allocation. The conclusion for CZM is to decide whether it is an answer to pressing needs within the existing institutional arrangements or whether the management system itself needs to be reformed (Stewart *et al.*, 1993: 271).

SUCOZOMA in Sweden

The research program "Sustainable Coastal Zone Management" (SUCOZOMA, 1996, 1997, and 1998a and b; Krögerström, 1998; Glaeser and Píriz, 1998; Glaeser, 1998)[2] comprises twelve different research projects in different Swedish universities or research institutions. The project sites are found at the Swedish east and west coast. Particular attention is devoted to synthesizing knowledge comprehensively and to the implementation of results. We can thus speak of applied research, which is moreover aimed at its various users and the coastal stakeholders, such as government, NGOs, residents or fishermen, among others. The program is funded by the Swedish Foundation for Strategic Environmental Research (MISTRA). The total cost for the first four-year program period 1997-2000 is 45 million Swedish Crowns (10 million DM).

The Swedish coastal zone is an area of conflicts between many users, representing fishery, agriculture, industry, settlements, transportation, nature conservation and tourism. There is widespread environmental degradation, including loss of biodiversity, due to pollution and physical modification of the habitat. Important fish stocks are overexploited or have decreased because of pollution or habitat destruction. This state of affairs is largely a result of the failure to realize the importance of natural marine ecosystems and their services for society. The areas of low salinity and the highly productive archipelagos along the coasts of Sweden are unique in their character, requiring local solutions to solve the problems currently blocking sustainable development.

The SUCOZOMA research program aims at promoting the management of marine coastal ecosystems based on their real and sustainable contribution to society, in terms of ecological services. Among those are removal of excess nutrients, provision of suitable conditions for fishing, maintenance of the genetic diversity of marine organisms and flows of goods, such as fish and

[2] The following draws directly on the first two reports cited in this section, SUCOZOMA (1996 and 1997). Some parts of the original texts are reiterated here verbatim; others paraphrase closely the originals, with some minor additions, revisions or amendments.

shellfish. It is based on the conviction that a multidisciplinary approach must underlie sustainable coastal zone management, and that the immense value of the coastal zone for human quality of life must be fully recognized in economic and political decision making.

The program is divided into three parts. Subprogram 1, on conflict resolution, organizational structures and bioeconomic modeling, constitutes the common basis for the whole program and interacts with all other projects. Subprogram 2 evaluates the potential of mussel farming and environmentally responsive management of sewage discharges for reducing the impact of eutrophication and toxic algal blooms. Subprogram 3 focuses on developing a sustainable coastal fishery, through the creation of new fisheries, restoration of habitats for spawning and recruitment, and enhancement of high value stocks, while emphasizing the preservation of biodiversity and reduction of energy consumption.

As mentioned earlier the management of coastal ecosystems will be based on their real and sustainable contribution to society, including flows of goods, such as fish and shellfish and ecological services, like removal of pollutants and excess nutrients, provision of suitable conditions for fishing, aquaculture and recreation, and maintenance of the genetic diversity of marine organisms. Coastal management will use conflict resolution methods based on sound science, equitability and democratic user participation.

Living marine resources will be harvested by highly selective methods, and at rates that provide a margin of safety against the large natural variability in recruitment. As a result of changes in management frameworks and technology development, the economic value of the coastal fishery will have grown. Along the Baltic coastline, spawning and nursery areas for fish will be restored to their former productivity, or replaced by genetically correct supportive breeding of fry and larvae, to increase the biological diversity and the production of high-value species, of interest to tourists, local residents and professional fishermen alike. There will be greater public awareness of the value of marine resources.

This program aims at developing the concepts, evaluation instruments and procedures needed for resolving, on a basis of sound science and public participation, the many conflicts concerning the use and conservation of the natural resources of the Swedish coastal zone. Long-term sustainability is central, as is the effort to create local jobs in coastal communities, in activities that are ecologically and economically sustainable. Major goals include:

- to arrive at a multidisciplinary synthesis of coastal zone science, relevant for guiding future integrated coastal zone management in Sweden.
- to define and evaluate the most urgent conflicts over the use of the coastal waters, from the perspective of regional and local authorities, including environmental managers, and other coastal zone stakeholder groups, particularly those living from tourism and local living natural resources.
- to propose procedures for conflict resolution, based on democratic user participation, equitability and sustainability, suited for use in a wider ICZM framework.
- to understand the constraints and opportunities in the coastal zone management process, and to suggest improvements in planning and conflict resolution, starting with activities promoted by this program, e.g. in coastal fishery and mussel culture.
- to study Swedish coastal zone management in a regional Baltic Sea perspective, and propose improvements needed for sustainable coastal zone development in Sweden.
- to test the potential of mussel farms to reduce nutrient levels in coastal waters, and support mussel production in coastal areas through a full understanding of potential conflicts.

- to develop tools for managing releases of plant nutrients to the coastal zone in real time, particularly models that predict the local and regional water quality effects of different management options, and the attendant costs and benefits.
- to develop a bioeconomic model for marine Swedish fisheries and conduct research on the mechanisms needed to implement the model, in order to protect the long-term sustainability of existing and new coastal fisheries.
- to evaluate the potential for new fisheries of presently underexploited shellfish stocks along the Swedish west coast.
- to restore damaged recruitment areas and create new ones for perch, pike and pikeperch in the Baltic coastal zone, in order to strengthen fishable stocks.
- to evaluate the feasibility of enhancing Baltic Sea trout stocks, through habitat restoration and supportive breeding and early release of fry.
- to develop a general population genetics model of supportive fish breeding, for predicting effects on the genetic diversity of the managed stock.
- to develop technical solutions for an ecologically sound coastal fishery, giving catches of high quality and sale value. The fishery should be selective for target species and size class, and preferably give live catch, protected from seals. Energy use and damage to ethnic communities should be minimized, and by-catches of marine birds and mammals prevented.

Integrated coastal zone management in Germany: A federal initiative

What are the lessons to be learned for Germany? Until recently, coastal management was mainly confined to the level of Federal States (*Länder*), i.e. to the coastal states bordering the North Sea or the Baltic Sea. In the fall of 1998, the Federal Ministry for Education and Research (Bundesministerium für Bildung und Forschung) (BMBF) took the initiative to embark on coastal research. The draft version of a research concept was issued; this concept will be discussed with stakeholders during the course of 1999. Its preliminary state notwithstanding, some interesting features of the concept and organizations are worth noting. The stakeholder groups and institutions include the law system, private persons, economic interest groups, trade unions and churches, various administrations and various economic sectors, such as tourism, agriculture, fisheries, science and research. Scientifically, the program is meant to be interdisciplinary, including social and cultural, natural and planning sciences, and designed to follow a holistic approach, aiming at a strategy of social consensus. Three pilot projects will concentrate on three different types of coastal regions, one rural and agricultural, a second oriented towards tourism, and a third that is urban and industrialized. It is obvious that this German federal initiative, although "late" in one sense, can indeed benefit from prior experiences gained by other countries, including those in Scandinavia (BMBF, 1998).

Coastal potential and problems in East Germany

I will now attempt to use the coastal management experience in northern Europe, in planning and research, to draw conclusions for the north German coast, specifically for the Baltic region of Mecklenburg-Western Pomerania, formerly part of East Germany (GDR). The aim is to identify a research agenda.

Coastal waters ecosystems

Certain parts of the Baltic Sea are considered to be "death traps". The seabed profile, composed of deep sinks and shallow thresholds, prevents the more oxygen-rich ocean saltwater from penetrating. The ecosystem is extremely sensitive, and it is easily destroyed by anthropogenic activities, such as by agricultural, industrial or communal use. The coast of Mecklenburg-Western Pomerania is located in the more favorable region of the Baltic estuary where there is a more frequent water exchange with the Kattegat and the Skagerrak. In all areas, an increase of eutrophication has been observed during the past 30 years, its intensity depending on location and the speed of the water exchange (Holst *et al.*, 1994: 54-63).

The deterioration of the Baltic ecosystem affects coastal uses and users and includes summer guests, local inhabitants, and various economic interests. Among the different activities, tourism and fisheries deserve to be considered most closely. These two industries may serve as indicators for the bell-being and ecological health of the Baltic Sea and its coastal waters. They are affected more strongly by the ecosystem's degradation than other polluting industries. It may thus be necessary to impose strong regulating measures to ensure a sound environment as a major policy goal. This may imply to implement environmental quality standards, which are holistic; matter and energy related; and reflect local, regional and international extensions (Holst *et al.*, 1994: 64).

Biotic regeneration capacity is defined as the potential of individual species to sustain and reproduce themselves. In the Baltic coastal land regions, we find the following predominant types of vegetation: non-coniferous forests (potential, natural vegetation), wetlands, and agriculturally used areas. The latter use up most of the available space. All three vegetation types show a considerable regeneration potential. Stable food chains can be produced. The local fauna consists of 40,000 animal species and must be valued as species-rich. The fauna regeneration capacity is based on that of the flora. Planning measures to improve the ecosystem stability (Holst et al., 1994: 151-154) could still increase both.

Recreation potential

In principle, all landscapes have a potential for recreation, which means that they can contribute to the human physical and psychic regeneration. The basic natural recreation potential may be influenced and supplemented by cultural factors. This refers to anthropogenic landscape changes. Secondly, the users' demands determine how the recreation potential is valued. Local inhabitants and tourists may have different values.

The characteristics of the recreation potential in the research area are determined by the coastal situation between the Baltic Sea and the mainland. The coastal climate has positive health effects. Sand beaches offer bathing opportunities. Water sports, such as sailing, surfing, angling, diving, water or marsh hiking, are facilitated by the shallow waters and the rivers connecting the sea to the mainland. Culturally transformed landscapes are protected as national parks, nature protection areas, or biosphere reserves. They add to the natural recreation potential. Such are the favorable conditions that not only attract tourists but invite people to settle here. Environmental quality and quality of life factors not only determine the area's living space attractiveness but promote investments. The State Ministry of Economics advertises: "Work where others vacation!" (Holst *et al.*, 1994: 155-156). Recreational uses are systematized as follows (see table 3 below; based on Holst *et al.*, 1994: 157-158).

Table 3. Synthesis of Baltic coast recreational activities.

Seasonal Recreation			Seasonally Independent Recreational Activities		
Water Related	**Landscape Oriented**	**Snow Related**	**Cultural and Educations I Tourism**	**Health Activities**	**Sports**
1. bathing, swimming 2. sailing, surfing 3. wading, rowing, paddle boating 4. other water sport activities: angling, diving, etc.	1. hiking 2. bicycling 3. nature observation, bird watching 4. hunting 5. golf 6. other sports: jogging, horseback riding	1. skiing 2. sledding 3. ice skating 4. ice sailing	1. city tourism 2. congress tourism 3. general nature observation	1. health clinics 2. rehabilitation 3. health tourism	1. indoor: aerobic, swimming squash 2. outdoor: motor sport, mountain biking

In concluding, the coastal zone of Mecklenburg-Western Pomerania has a distinct capacity for recreation and tourism. The pure natural potential may not be sufficient, however, to guarantee tourism. In order to realize the potential some additional measures have to be considered. Sub-regional specific qualities have to pointed out and marketed. Infrastructural developments may prolong the tourist season. The local population should participate in brainstorming activities and in decision making. This may include acceptance questions, host mentality, and own recreation needs. It may also include job qualifications to work in tourism, in tourist administration as in hotels.

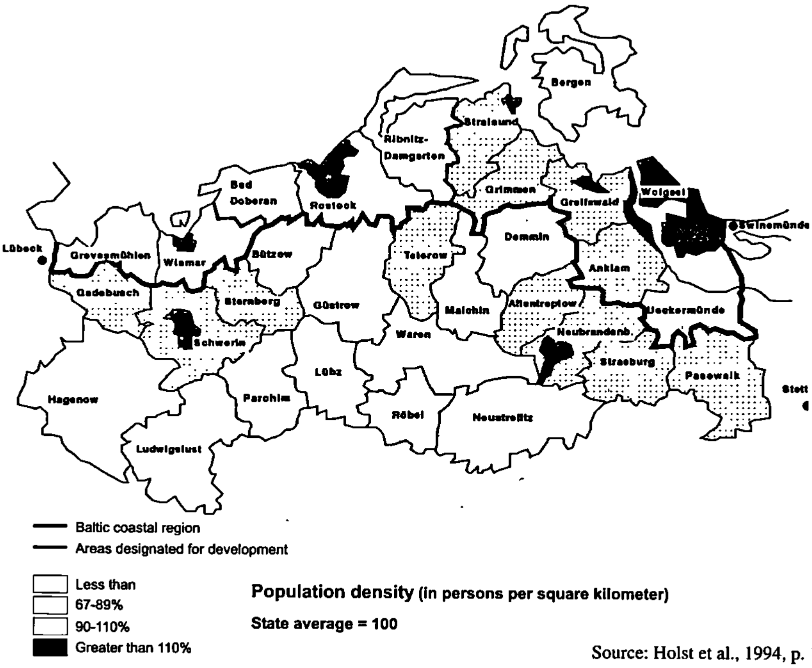
Conclusions and options

There are a number of competing uses in the coastal zone of Mecklenburg-Western Pomerania. They compete for space, and they compete with environmental landscape functions. These uses include population and settlements, economy and labor market (specifically industry and tourism), infrastructure (specifically traffic related, industrial sites, water treatment and waste management).

Mecklenburg-Western Pomerania is a significant domestic tourist and travel area due to its unspoiled nature, attractive landscapes, and the low population density. The Baltic Sea region, in particular, has had a long tourism tradition. "Curiosity tourism" after reunification was gradually replaced with a more stable tourism, beginning in 1992/93 when the number of guests approached five million, most of them during the months of July and August. The present situation could be described as that of a "sellers' market": the demand exceeds the supply side, there is hardly any competition, and prices are high.

The development potential of tourism is positive. In the year 2000, more than nine million tourists are expected, which corresponds to an annual growth rate of about 10%. They come from the "new" East German states as well as from the West German states of Berlin,

Schematic Diagram of Mecklenburg-Western Pommerania



Source: Holst et al., 1994, p. 180.

Schleswig-Holstein, Lower Saxony/Bremen, Bavaria and North Rhine-Westphalia. Foreign tourism is of less importance with the exception of the summer guests from Scandinavia.

If we differentiate between the subregions the following tendencies become evident. There is not only the usual coast-hinterland decline but also an east-west decline concerning the potential for tourism. In connection with the usual west-east decline as to the general economic potentials there is quite some pressure in favor of tourism related investments in the coastal zone. A multitude of investment projects in all planning stages range from hotels and condominiums to marinas, golf courses and rehabilitation clinics. These planning activities and developments induce conflicts with nature protection institutions, the planning authorities are overburdened.

The major challenge is to channel the appropriate investments, i.e. to develop instruments and procedures that accelerate environmentally sound and economically useful projects and that prevent all others. Only if this challenge is met can the touristic deficit be reduced and tied to the region's "nature pure" potential as the slogan goes. It should then be possible to compete in the long run with comparable coastal regions in Schleswig-Holstein, Denmark, Lower Saxony and Poland (Holst *et al.*, 1994: 204-216).

The labor market situation in the coastal Baltic region is deplorable. The tendencies are similar to those in Mecklenburg-Western Pommerania or East Germany as a whole. The rate of unemployment increased dramatically after the monetary unification, up to 17% in 1992, reflecting the economically wrong exchange rate between the East and West German currencies. For political reasons, the East Mark had been overvalued. This measure increased the immediate purchasing power of the population but the economic productivity was too low to be competitive.

Both industry and agriculture were affected. Unemployment is still around 20%; the situation is worse in the eastern parts of the region where people emigrated or commute to West Germany. In addition, birthrates dropped significantly after unification (Holst *et al.*, 1994: 222-224).

Employment improvement measures have absolute priority in the coastal region as in all of East Germany. Measures to improve the economic structure are needed. A viable option for the coastal region is tourism. The natural endowment is perfect in combination with the low population density: a paradise for bird watchers, hikers and other forms of "sustainable" tourism. Still, to keep the western clientele who can spend higher budgets and to be competitive with the neighboring West German and Danish coastal regions in the long run, hotel and other infrastructural facilities have to be improved. Investments are needed.

Infrastructural improvement includes accessibility. The road system needs further improvement if, in particular, the eastern parts of the coastal region are to be reached within acceptable time spans. So far the road density is low: roads take up between 0.4-0.8% of the space. NO_x emissions are correspondingly low: mostly below one ton per square kilometer.

Better accessibility could also increase conference and science tourism. Efforts have been made already to establish or stabilize research and technology, science and education in the region. There are universities in Greifswald and Rostock as well as a number of educational and technological centers. More emphasis could perhaps be put on regional or coastal specific subjects and topics. Rostock University, for example, focuses on research in areas like ecology, water related issues, ship technologies, biomedicine and agricultural technologies. More or additional emphasis could be placed on fisheries, eutrophication issues, marine biology and coastal management, among others. These and other fields of activity should include research and education; they should be linked with regional and local authorities.

Regional development in the Baltic coastal region will have to deal with the issue of harmonizing conflicting goals. Conflicts between economic and ecological goals materialize both when new institutional CM structures are built up and when old German Democratic Republic (GDR) related institutions are shut down. These conflicts appear in all land use patterns. The high level of unemployment and the need for development add additional pressure. Ecological arguments are perceived by some as mere delay tactic: "Ecology is the new class enemy!"

To assess and evaluate the natural potential of the coastal zone in the German State of Mecklenburg-Western Pomerania for landscape planning is still a task to be completed in addition to the data collection already done. Research is needed in the following areas:

- economic and social components that may be able to transform the structural crisis of the Baltic coastal region into a self-sustaining development;
- conditions for an environmentally sustainable coastal development in combination with the transformation of the structural economic crisis;
- the environmental sensitivity of landscapes depending on differing uses, including recreation and tourism;
- CZM concepts that include soil revitalization and other protection programs.

The bottom line is: Nature and natural landscapes represent a development potential par excellence for the East German Baltic coastal zone. Developing this potential, however, includes the chance to destroy it. The future research agenda ought to explore the conditions for achieving sustainable coastal development that improves the economic and social well being of the local population yet preserves the nature and landscape potential.

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Atmospheric Nitrogen Deposition to Marine Coastal Waters – how well do we describe source-receptor relationships

by

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Abstract

High nutrient loads to coastal waters may have considerable socio-economic impacts mainly on the local population. The environmental impacts may e.g. be loss of fish and benthic fauna, reduced species diversity in the coastal marine ecosystem and poor (bathing) water quality along the coastline. These effects may influence the health of the local population and the income for the region from fishing, tourism and all associated industries in these two sectors.

Atmospheric nitrogen deposition plays a major role for the nutrient loads of many European coastal waters. For the inner Danish waters the atmosphere has been estimated to contribute 30 to 40% of the total nitrogen load (Asman et al., 1994; Frohn et al., 1998).

The importance of atmospheric nitrogen loads on coastal ecosystems has often been overlooked, and the impact poorly determined. Therefore there is a considerable need for high quality and well tested model tools for determining the loads and performing scenario studies of source – receptor relationships and the impact of various emissions reduction strategies. The present paper gives an introduction to how precise we describe source – receptor relationships with present atmospheric transport-chemistry models. In this context the most important areas for future research are outlined. The most central of these include: to compile emission inventories with high spatial and temporal resolution, better knowledge concerning nitrogen in aerosol phase. The latter will include: field experiments to determine aerosol size distributions and how nitrogen compounds are distributed over the size range, field and laboratory studies of the heterogeneous processes taking place on the surface of and inside atmospheric aerosols, and finally developing aerosol sub-modules/models describing the main processes for implementation into present transport-chemistry models.

Introduction

High nutrient concentrations in coastal marine waters often lead to a large production of algae. In these waters, the algae growth is in general found to be the limited by the supply of nitrogen (Kronvang et al. 1993). Decomposition of dead algae in the bottom waters consumes oxygen, which can lead to substantial oxygen deficits. During the last few decades, oxygen deficits and the subsequent death of fish and benthic fauna has become a frequent phenomena in many European coastal waters. Another phenomenon has been the presence of high concentrations of algae that are harmful to the health of humans and animals.

The observed increase in the frequency of such phenomena is believed to be associated with an increase in the nutrient fluxes caused by anthropogenic activities. The Baltic Sea is one of the waters that have experienced such episodes. It has been estimated that over the period from the beginning of this century and up to the mid 1980's, the nutrient fluxes of nitrogen and phosphorous to the Baltic Sea have increased by a factor of 4 and 8, respectively (Larsson et al. 1985). Similar increases over this time period are likely to have taken place for many other European marine waters. Even though some smaller improvements have been observed e.g. for the

Danish marine waters over the 1990's, there is no doubt that at least in some regions further action to reduce the anthropogenic loads are needed.

Despite its clear significance for the overall nitrogen flux to most coastal waters, the atmospheric input has often been roughly determined and given little focus. The results from the Danish Marine Research Programme Sea90 show that for the Kattegat Strait between Denmark and Sweden, the atmosphere contributes 3040% to the overall nitrogen load (Asman et al. 1994). The significance of the atmospheric nitrogen loads is seen from the fact that similar figures have been estimated for other coastal waters. For the Baltic Sea about 50% of the nitrogen load is estimated to arise from atmospheric deposition (Rosenberg et al. 1990). The atmospheric nitrogen input is furthermore directly consumable by the algae.

The significance of atmospheric nitrogen deposition for total nitrogen loads to coastal marine waters is becoming increasingly recognised. Strategies for reducing the atmospheric nitrogen deposition are based on various impact assessment studies. The tools for these assessment studies are generally analysis of routine measurements from national monitoring networks in combination with the application of various atmospheric transport-chemistry models. The aim of the present paper is to discuss how well we estimate the atmospheric nitrogen loads and especially how well we presently determine the source-receptor relationships.

Socio-economic impacts of eutrophication of coastal waters

Atmospheric nitrogen deposition contributes significantly to the nutrient inputs to the coastal marine waters. The environmental impacts of high nutrient inputs can be eutrophication events with possible oxygen depletion in the bottom waters, poor water quality and blooms of harmful algae as the subsequent effects. These environmental effects may then have subsequent serious socio-economic impacts on the local population.

Oxygen depletion is a result of degradation of dead algae that have deposited to the bottom. In serious cases such events may lead to death of fish and benthic fauna. Loss of fish will of course have a direct impact on the local fishing. During eutrophication events, the concentration of phytoplankton increases dramatically within rather short periods of time. The high concentration of phytoplankton in the water column will in serious cases shade out the macrophytes and benthic algae at the bottom. Since macrophytes and benthic algae serve as an important habitat for small fish, this can seriously influence general fish populations in the region. A long term effect may therefore again be a general decrease in local fishing. Decrease in local fishing has of course strong socio-economic impact on the fishing community and the associated industries.

Poor quality of bathing water in the coastal zone may have strong negative impacts on tourism, and thereby also on the companies and communities in the specific region depending on the income from this sector.

Blooms of harmful algae may result from eutrophication events. In serious cases, harmful algae may cause health problems for the local population or tourists. Harmful algae can also affect fish and shellfish. Some years ago where salmon in Norwegian fish farms were killed by high concentrations of harmful algae. The specific type of algae sticks to the gills of the fish and thereby block respiration. A rather similar problem was observed in the Danish Limfjord system some years ago, where blue mussels consumed algae harmful to human health. In both cases these episodes had serious impact on the economy of local industries; in Norway they had to remove all fish from the ponds and sell them, despite many were supposed to grow bigger. In Denmark the blue mussel production was stopped for a long period of time.

Impact assessment

There is a substantial need for assessment tools aiming at evaluation of the optimal strategies for reducing the environmental impacts. The tools for such studies are coupled scenario models that describe the whole chain from nutrient fluxes to air and fresh water environments, over the transport to the marine coastal waters, and finally the subsequent responses in the marine ecosystems (see also the discussion in Geernaert et al. (1999), this volume).

The users of assessment tools for various impact reduction strategies may e.g. be EU, national governments, local authorities and local and international NGO's. Another group of users is those that reduction strategies will influence when the strategies are put in action. This group includes farmers, people in the tourist sector and industries, and their respective organisations, the local population and the local authorities dealing with handling of waste water etc.

Coupled scenario models may be constructed from combining a number of mathematical models describing the physical, chemical and biological processes in question. The full model system is not better than the weakest part of the chain. It is therefore important to evaluate the uncertainties of all these linked models, and perform a comparison of the performance. Main emphasis should be put on improving the weakest parts of the system, but barring in mind that the results depend highly on the time and space resolution, which is considered.

Monitoring atmospheric nitrogen compounds

Measurements carried out in national and international monitoring programmes are crucial for trend analyses, but together with intensive field studies and laboratory experiments also for our understandmg of the processes involved. In this context measurements from monitoring programmes are important tools for the evaluation of mathematical models used in various assessment studies. The resolution and accuracy in measurements in many ways sets the limits to how precise the model parameterisations can be made. Therefore there is a continuous need for refinement development of new monitoring techniques.

Atmospheric nitrogen reaches the marine coastal waters via dry and wet deposition. Measuring dry deposition of the various nitrogen compounds is a difficult and very resource-demanding task. Dry deposition measurements are therefore carried out as a part of research programmes, but they are generally not performed on routine basis as part of the ongoing monitoring programmes. However, air concentrations and wet depositions of atmospheric nitrogen compounds in Europe are monitored within various national monitoring programmes and e.g. within the European Monitoring and Evaluation Programme (EMEP). Based on local meteorological data, the dry deposition velocities can be determined. Applying these dry deposition velocities to the observed concentrations, the dry deposition of atmospheric nitrogen may be estimated. However, this procedure is constrained with considerable uncertainties, which will be discussed further in the following. As illustrations of loads and levels, some results from the Danish background monitoring programme are also presented in the following.

Air pollution monitoring of nitrogen compounds in the coastal and rural environment usually includes diurnal mean filter pack sampling of the gas phase compounds: ammonia (NH_3), nitric acid (HNO_3) and the aerosol phase compounds: nitrate (NO_3^-) and ammonium (NH_4^+). The filter pack method does not allow a good separation of nitric acid and nitrate, since nitric acid may deposit on the particle filter and nitrate may evaporate as nitric acid from the particle filter and deposit on the nitric acid filter (Andersen and Hilbert, 1993). Usually the sum of nitric acid and nitrate (in the following termed total nitrate) is therefore reported from the monitoring programmes, instead of the single compounds. A similar problem exist for ammonia and ammonium, but is generally found to give errors on the determination of single compounds less than 10% (Andersen and Hovmand, 1994).

The lack of a reliable separation between nitric acid and nitrate gives a considerable uncertainty on the estimated dry deposition of nitrogen. Dry deposition of nitric acid is a fast process that under normal meteorological conditions only is limited by the atmospheric transport down to the surface. A few hours are a common atmospheric lifetime for nitric acid. Nitrate on the other hand has a typical atmospheric lifetime with respect to dry deposition of 7 to 10 days.

Moreover, filter pack measurements do not provide information about aerosol size distributions. This is a crucial limitation for the estimation of nitrogen fluxes, since the dry deposition velocity of aerosols varies by 5 orders of magnitude over the typically observed size range (see e.g. Vignati et al. 1999). Results from field campaigns have shown that nitrogen compounds may be associated with aerosols in ultra fine fraction, fine fraction as well as coarse mode. Since this type of information is crucial for dry deposition estimates, it is likely measurements, which provide size specific information will be part of background monitoring programmes in the future. Until then, detailed information about the dry deposition of nitrogen compounds can only be obtained from designated field campaigns and from model calculations.

In the Danish background monitoring programme, the precipitation, gas and particle samples are analysed for the main inorganic compounds of importance for air pollution. This includes:

- Precipitation samples: nitrate, ammonium, chloride, sulphate, sodium, potassium, magnesium, calcium and phosphate (semi quantitatively).
- Gas and particle samples: ammonia, sulphur dioxide, the sum of nitric acid and particulate nitrate, particulate ammonium, particulate sulphate and a number of other elements.

It is crucial for the interpretation of the measurements, that the monitoring programme also includes analysis of sulphur compounds and various other compounds. The concentrations of these compounds provide important information about the history of the air mass. An example of results obtained in the monitoring programme is shown in Figure 1. The observed seasonal variation of the concentration of particulate ammonium is mainly due to seasonal variation of the sources in central Europe and the seasonal variation in the transport to Denmark. The sources of ammonia are mainly local agriculture and therefore the seasonal variation in ammonia concentrations reflects the local agricultural practice. The differences in concentration levels at the monitoring stations are caused by differences in the type of location; the monitoring station at Anholt is situated at an island practically without farming, while the monitoring stations at Keldsnor and Tange are placed in agricultural areas.

The annual average concentrations vary significantly from station to station and from year to year (Figure 2). No clear trends are observed for ammonia and for the sum of nitric acid and particulate nitrate. In contrast there seems to be a clear decreasing trend for ammonium during the time period 1989 to 1996 (see Ellermann et al. 1997 and Frohn et al. 1998 for further details).

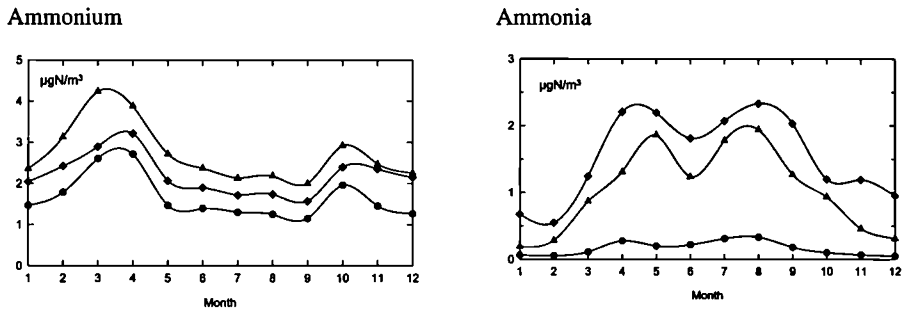

Figure 1. Seasonal variation in monthly average concentrations of ammonium and ammonia during the time period 1989 - 1996, derived from filter pack measurements at the Danish background monitoring stations at Anholt(●), Tange(■) and Keldsnor(▲).

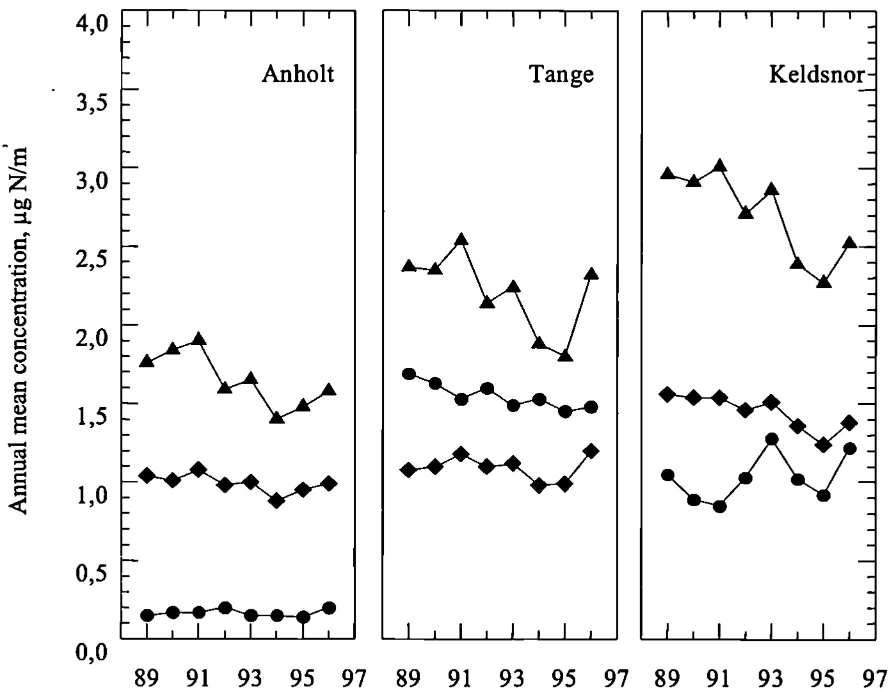

Figure 2. Annual concentrations for the time period 1989 to 1996 of ammonia, particulate ammonium, and the sum of nitric acid and particulate nitrate measured at the monitoring stations at Anholt(●), Tange(■) and Keldsnor(▲).

Modelling nitrogen loads of marine coastal waters

Various types of mathematical transport-chemistry models are presently in use at the European research institutes. In the following some examples are given from the applications of the Atmospheric Chemistry and Deposition (ACDEP) model (Hertel et al., 1995) at the Danish National Environmental Research Institute (NERI).

The ACDEP-model (Hertel et al., 1995) is a variable scale Lagrangian transport-chemistry model which is e.g. used for routine calculations within the Danish Background Monitoring programme (Skov et al., 1996; Ellermann et al., 1997; Frohn et al., 1998). For this purpose, model calculations of air pollution concentrations and nitrogen depositions are performed for 233 receptor points in a 30 km x 30 km grid covering all Danish marine waters (and land surfaces). Based on geographic information, nitrogen depositions to more than 100 different Danish waters have been determined from the results on the receptor net for the entire period 1989 to 1997.

The ACDEP calculations have showed that for Danish marine waters, typical annual atmospheric nitrogen loads are in the range from 0.8 to 1.5 tonnes N/km^2. The highest atmospheric loads are for fjords, creeks and bays and the smallest for the more open waters like the Danish part of the North Sea, the Kattegat Strait, the Danish part of the Baltic Sea etc. (see Figure 3). The calculations show that the higher nitrogen loads are associated with high dry depositions of ammonia from local agricultural activities. Generally emissions from agricultural activities (depositing in the form of gaseous ammonia and ammonium containing aerosols) contribute to between half and 2/3 of the total atmospheric nitrogen load of Danish marine waters. The model calculations have shown that for the more open waters like the Kattegat Strait, the contribution from atmospheric sources is up to 30 to 40% of the total nitrogen load, despite the atmospheric load per surface area is smallest for the open waters (Hertel et al., 1996a). For these open waters the main part of the atmospheric load arise from wet deposition of nitrogen containing aerosols.

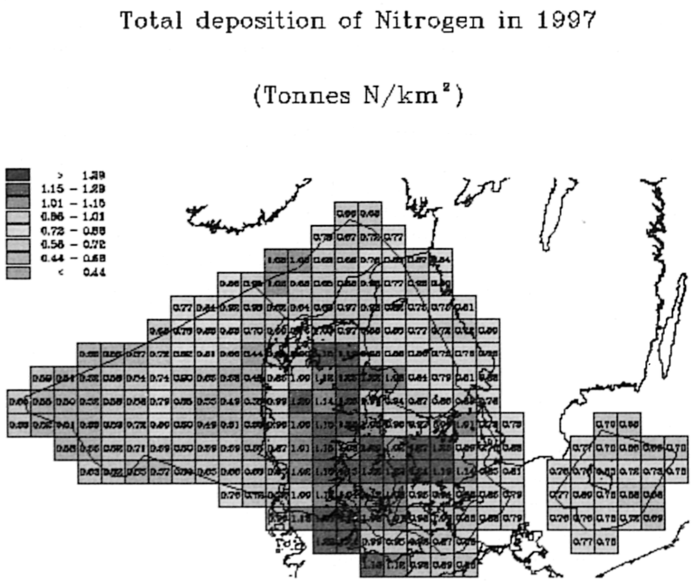

Figure 3. Example of calculated nitrogen deposition to Danish marine waters. Calculations performed with the ACDEP-model and for the year 1997.

Comparing results obtained from model calculations performed with and without emissions from a specific region or country, the contribution from the sources in this specific region or country may be estimated. Such calculations have been performed to determine the contribution from Danish source to the deposition to Danish marine waters. The results shown that in average for all Danish waters, Danish sources contributed during the period 1989 to 1995 by 14 to 19% of the atmospheric nitrogen load (Hertel and Frohn, 1997). For the fjord systems, creeks and bays the contribution is nearly half of the total atmospheric nitrogen load. For these waters the dry deposition of ammonia from local Danish agricultural activities contribute by more than 40% of the total atmospheric nitrogen load.

Deposition of particle bound ammonium contributes significantly to the atmospheric nitrogen load. Current model calculations indicate that ammonium mainly is associated with sulphate containing aerosols (Hov and Hjøllo, 1994; Hertel et al., 1996b). It is very difficult from standard monitor data to evaluate the actual association of ammonium with sulphate, nitrate or chloride containing aerosols. A crude estimation for Danish conditions indicated that more than 80% of the ammonium was associated with sulphate containing aerosols (Hertel et al. 1996b). However, more recent analyses show that this figure may be considerably smaller (Vignati and Hertel 1999; non published results). These analyses indicate that for specific days there may be cases were practically all the ammonium is associated with nitrate. On monthly average these analyses indicate that the fraction associated with sulphate may be 60 to 70% rather than more than 80%.

Implications of model results

The results show that in order to bring down the atmospheric nitrogen loads of Danish marine waters initiatives towards emissions reductions on European scale are needed. Similar results are likely to apply for many other coastal waters. It is evident from model calculations that Danish atmospheric emissions have only little (less than 20%) effect on the atmospheric nitrogen loads of Danish marine waters compared to the contribution from long range transport. The emission reduction protocols are expected to have a pronounced effect on the long range transport of atmospheric nitrogen compounds and thereby also on the nitrogen depositions.

Atmospheric nitrogen depositions contribute significantly to the nitrogen loads of the main Danish waters. For some waters the atmospheric contribution is 30 to 40% of the total nitrogen load (e.g. the Kattegat Strait). Atmospheric nitrogen deposition takes place in a form, which is directly available for algae. For coastal waters, the atmospheric nitrogen deposition may contribute eutrophication and subsequent oxygen depletion and turnovers. Especially in summer and autumn, the contribution from atmospheric nitrogen deposition is significant compared with the runoff (Conley et al., 1999). In these seasons, the atmospheric deposition seems to be larger than the runoff and can contribute significantly to growth of hazardous algae types.

Deposition (mainly wet deposition) of aerosol phase ammonium contributes significantly to the atmospheric nitrogen load. Current monitor data do not provide information about to which degree ammonium is associated with sulphate, nitrate and chloride containing aerosols. The distribution of ammonium on sulphate containing and other aerosols is important for determining the transport processes in the atmosphere. Ammonium associated with sulphate containing aerosols is fixed to the aerosol phase, whereas ammonium nitrate and ammonium chloride may evaporate to gas phase as ammonia, nitric acid and hydrogen chloride. The later three compounds have high dry deposition velocities and may therefore have considerably shorter atmospheric lifetimes than the ammonium sulphate.

Many of the current transport-chemistry models are applied operationally, therefore particle size resolution and the associated processes must be parameterised in a way that is not too time consuming but still account for the main processes. In such models, time steps are usually larger than the characteristic times of some of the processes involving aerosols. Therefore fast processes, such as gas condensation, must be carefully implemented. Implementation of schemes with many particle classes is highly time consuming, and hence the class number must be reduced to the minimum required that allows to resolve the effect of various processes. Coagulation is a very time consuming process and the numerical implementation is difficult. Fortunately, these processes are important only in the presence of high particle concentrations. At atmospheric concentrations, the effect is usually visible only on the scale of days. Therefore, coagulation can be neglected in most applications. When the effect of coagulation becomes important, for instance for simulations of days, it can often be substituted with condensation of gasses on internally mixed particles. The implementation can be based on analysis of the characteristic time scales for the various aerosol processes, or by use of parameters that determine in which conditions a process is important.

Uncertainties in current models

There are naturally many uncertainties in current model estimations of nitrogen depositions. Skov et al. (1996) estimated from comparisons with monitoring data, that the uncertainties on the annual nitrogen loads to Danish waters were in the order of 40% for the open waters and about 60% for the coastal waters (fjords, bays and creeks). These uncertainties are mainly constrained with,

- the emission inventories that are still coarse and highly uncertain. The typical uncertainty estimate is 30 to 40 percent on the annual emission on 50 km x 50 km grid,
- the highly simplified parameterization of aerosol phase compounds,
- coarse resolution and uncertainty in meteorological inputs, especially the precipitation that is highly local.

The uncertainties may be decreased by application of higher resolution in the input data (main the meteorological data and emission data) and by improving the description of compounds in aerosol phase. However, in order to verify that the model performance actually improves with the applied changes in input data and physical/chemical description, new field experiments are needed.

Needs for future research

In order to assure high quality model calculations with low uncertainties for various scenarios, new a considerably more detailed emission inventories for Europe are needed. These inventories need to have a spatial resolution of a few kilometres and temporal resolution of hours. Work of this type has been initiated within the EUROTRAC project GENEMIS.

Another area where more research in needed concerns the model description of aerosol phase compounds and heterogeneous chemical transformation. New models and sub-models with better parameterisations of the main features of these processes are needed. Some work has been initiated (Vignati, 1999; von Salzen, 1999), but there is a considerable need for detailed field experiments dedicated for improving our understanding and parameterisation of these processes. These field experiments should include measurements of particle composition in size fractions (e.g. sampling using 10-stage impactor). Information on the chemical composition of the different size fractions will reduce the uncertainties involved with determination of salts on the particles and the calculation of the dry composition of the different salts. Moreover, the chemical and physical transformations of the particle in the atmosphere depend both on the size and chemical composition of the particles.

Atmospheric transport-chemistry models should be linked to models for river run off and marine ecosystem models to constitute an integrated assessment tool for ecosystem responses to various emissions reduction strategies etc. These integrated assessment tools should in turn be used in combination with economic tools to provide socio-economic analyses of the various strategies. Therefore there is a considerable need for carrying out tests of linked model systems in future research programmes.

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Methodologies for Integrating Modelling and Analysis in the Coastal Zone

by

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Introduction

All countries with a coastline have an interest in the sustainable management of the coastal resource systems. The task of sustainable management, defined here as sustainable utilisation of the multiple goods and services provision generated by coastal resources (processes, functions and their interrelationships), is likely to be made more difficult because of the consequences of global environmental change, including climate change (Bower and Turner, 1998). Coastal zones are currently experiencing intense and sustained environmental pressures from a range of driving forces (Turner, Subak and Adger, 1996). Responsible agencies are seeking ways of better managing the causes and consequences of the environmental change process in coastal areas.

The coastal areas interface between the continents and the ocean is comprised of a continuum of aquatic systems including the network of rivers, the estuaries, the coastal fringe of the sea, the continental shelf and its slope. These interdependent systems are characterised by very significant biogeochemical processes e.g. primary productivity generation, organic matter and nutrient sinks etc. Significant inputs of nutrients to the coastal zone arrive via rivers, groundwater, and the atmosphere. The major flux of nutrients from land to sea occurs through river transport, via the drainage basins network. The network contains various 'filters' (e.g. wetlands) retaining or eliminating nutrients during their downstream passage to the sea. The effectiveness and selectivity of these filters depend on the strong biogeochemical coupling existing between carbon, nitrogen, phosphorus and silica circulation and they are also affected by hydrology and land use/cover (Howarth et al., 1996). Nutrient fluxes have been increased by human activity, and in addition, the N:P:Si ratios of these inputs have been perturbed and many coastal management practices exacerbate these perturbations.

The coast is a difficult place to manage, involving a dynamic natural system which has been increasingly settled and pressurised by expanding socio-economic systems. Although exact numbers are a matter of debate due to definitional differences about what constitutes a coastal zone, it is currently estimated that in excess of 37% of the global population (> 2.1 billion people) are living in coastal areas (Vitousek and Mooney, 1997). The biogeochemical limits to this development process may now be being reflected in symptoms such as the over-exploitation of fisheries, loss of coastal habitats, deleterious effects of land-based contaminants and eutrophication (Botsford et al., 1997). There is strong evidence of impacts arising from these changes in areas of restricted water exchange (Jickells, 1998). Coastal areas now need to be viewed as the spatia land temporal context for jointly determined socio-economic and ecological systems on a co-evolutionary development path (Turner, Perrings and Folke, 1997).

Understanding the interactions between the coastal zone and global changes cannot be achieved by observational studies alone. Modelling of key environmental processes is a vital tool that must be used if coastal management is to achieve its overall goals and objectives, particularly in view of the fact that many of the uncertainties in global carbon flow models may represent unquantified processes occurring within the coastal zone. For any group of researchers wishing to investigate and model a particular local coastal system (or aspects of that system) for subsequent up-scaling into larger models or wider regional estimates, there are initially two types of information required:

- estimations of biogeochemical fluxes in the system as it is now, for eventual incorporation into global estimates of flux through the coastal zone; and
- dynamic simulations of processes in the coastal system which can be used to explore the consequences of environmental change, and produce forecasts of future fluxes.

The second type of information set will require the integration of socio-economic and natural science data and models in two basic analytical contexts:

- to provide an understanding of the external forcing effects of socio-economic changes such as, for example, population growth, urbanisation, and other land use changes on fluxes of C, N, P and sediment; and
- to assess the human welfare impacts of flux changes due to the consequent process and function changes in coastal resource systems. Such assessments of the social costs and benefits involved will provide essential coastal management intelligence based on social science and possible resource and value trade offs.

The second analytical context poses a more formidable research task, not just because of the data requirements and the integration problem involving data which differs in form and in spatial and temporal scale, but because the long term goal is the development of an integrated prognostic assessment capability.

The assessment of the impact of changes in the coastal zone on human use of resources (wealth creation) and habitation (quality of life aspects) requires the application of socio-economic research methods and techniques in the context of coastal resource assessment and management. A particular contribution of socio-economic research is the incorporation of evaluation methods and techniques, which can be applied to specific resource damage and utilisation situations (projects, policies or courses of action which change land use/cover, alter or modify residuals from point and non-point sources etc.) because of C, N & P flux changes and related consequences, including loss of functions and even habitats. Again most of these valuation studies will be at a local/regional level and the same scaling-up problem presents itself. However, the transfer of economic valuation estimates (known as benefits transfer) across time and geographical and cultural space is controversial.

Management of the coastal zone must not only deal with anthropogenic pressures and impacts but also with the implications of future uncertainty regarding climate change, accelerated sea-level rise and changing storm patterns. Under natural conditions the form of a coastline is an optimal, but ephemeral, morphodynamic response to changing sea level and the impact of wave and tidal energy. The placement of fixed engineering structures (for resource exploitation, sea defence and coastal protection reasons) within this constantly changing system has in many cases reduced the 'resilience' capacity of coastlines to respond to the stresses and shocks of environmental change. Loss of intertidal habitats through land-claim and coastal squeeze (the increasing confinement of the intertidal zone between sea-defences and rising sea-level) is both a symptom of, and contributing factor to, this reduction in coastal resilance. It is associated with a loss of nursery areas for fisheries, biodiversity, coastal defence functions, carbon reservoirs, and buffers to regulate nutrient fluxes (Jickells, 1998).

The last 20 to 30 years has seen the gradual evolution of a strategy aimed at an integrated assessment of environmental science, technology and policy problems. A multi-disciplinary tool kit has been presented which, for example, global climatic change researchers have tapped into (Schneider, 1997). The integrated assessment framework must include coupled or integrated models (biogeochemical and socio-economic) but it is not limited to just this. According to Rotmans and Van Asselt (1996) integrated assessment is "an interdisciplinary and participatory process of combining, interpreting and communicating knowledge from diverse scientific disciplines to achieve a better understanding of complex phenomena". The critical importance of making value-laden assumptions highly transparent in both natural and social scientific components of integrated assessment models (IAMs) needs to be highlighted, practitioners now argue that incorporating decision-makers and other stakeholders into the early design of IAMs greatly facilitates this process. Valuation in this process is more than the assignment of monetary values and includes multi-criteria assessment methods and techniques in order to identify practicable trade-offs.

Modelling procedures

Three overlapping procedural stages can be identified in the process by which more integrated modelling and resource assessment can be achieved:

- Scoping and resources audit stage
- Actual modelling stage;
- Evaluation stage

(a) Scoping and audit

Initially the problem needs to be formulated i.e. the significant issues to be included in the system study need to be identified in order to fix the scope of the research to be carried out. More specifically, the problem formulation should result in:

- definition of problem owner and problems
- identification of system boundaries
- inventory of constraints
- identification of objectives
- identification of decision criteria and values

The best starting point in any overall modelling strategy is to generate a basic description of the particular coastal system being studied (including the socio-economic activity levels present and predicted [the pressures]). In some cases it may be possible to compare the system to be studied with similar systems that have already been well described and understood. The answers to the basic scoping questions will influence the type of model to be used, data collection/ analysis and impacts evaluation requirements. They will also inter-alia raise 'scale' issues, including the problem of defining system boundaries and the temporal scale.

The P-S-I-R (pressure-state-impacts-response) framework is a useful device for the scoping of coastal science and management issues and problems. The objective in this approach is to clarify multisectoral inter-relationships and to highlight the dynamic characteristics of ecosystem and socio-economic changes. The P-S-I-R framework provides a way of identifying the key issues, questions, data/information availability, land use patterns, proposed developments, existing institutional frameworks, as well as timing and spatial considerations see Figure 1 (Turner, Lorenzoni, *et al.*, 1998).

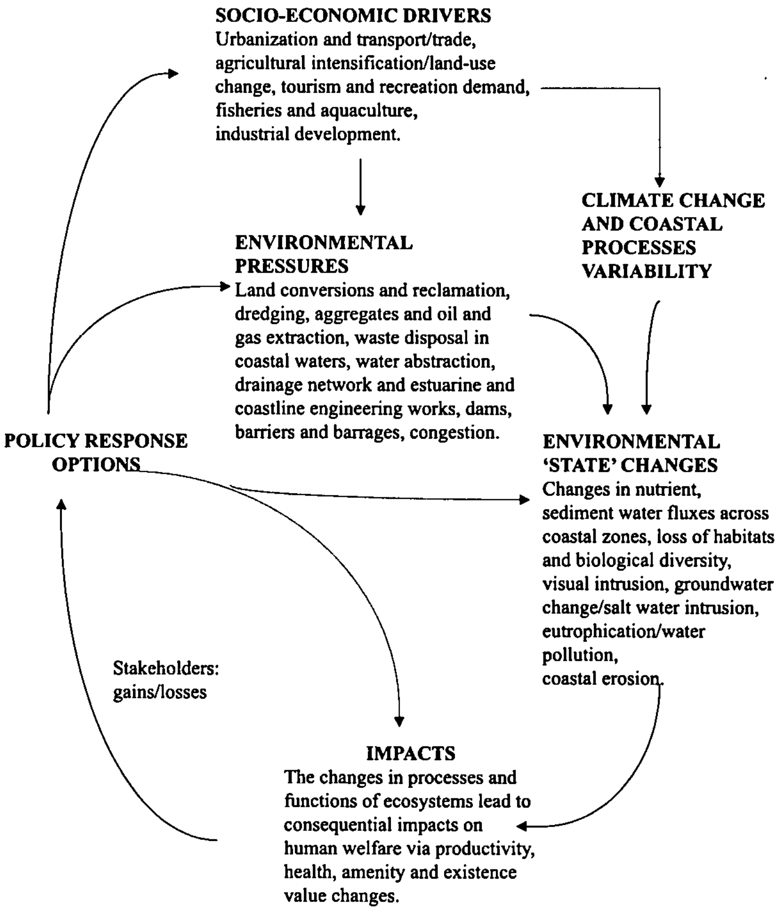
For any given coastal area (defined to encompass the entire drainage network) there will exist a spatial distribution of socio-economic activities and related land uses – urban, industrial mining, agriculture/forestry/aquaculture and fisheries, commercial and transportation. This spatial distribution of human activities reflects the final demand for a variety of goods and services within the defined area and from outside the area. Environmental pressure builds up via these socio-economic driving forces and is augmented by natural systems variability, which stimulates changes in environmental systems states.

The production and consumption activities result in different types and quantities of residuals, as well as goods and services measured in Gross National Product (GNP) terms. Thus the concern might be, for example, the role and extent of changes in C, N, P and sediment fluxes as a result of land use change and other activities. Conceptually what we have are a multiplicity of input-output (I-O) relationships, with the outputs being joint products (combinations of goods and services and non-product outputs or residuals, which if not recycled become waste emitted/discharged into the ambient environment). I-O relationships will operate at the individual industrial process/plant level, though population settlements, agricultural cropping regimes/practices, and up to regional drainage basin scale. These residuals estimates will then serve as the input to the natural science models such as nutrient budgets. Environmental processes will transform the time and spatial pattern of the discharged/emitted residuals into a consequent short-run and long-run time and spatial ambient environmental quality patterns.

These stage environmental changes impact on human and non-human receptors resulting in a number of perceived social welfare changes (benefits and costs). Such welfare changes provide the stimulus for management action, which depends on the institutional structure, culture/value system and competing demands for scarce resources and for other goods and services in the coastal zone. An integrated (modelling) approach will need to encompass within its analytical framework the socio-economic and biophysical drivers that generate the spatially distributed economic activities and related ambient environmental quality, in order to provide information on future environmental states.

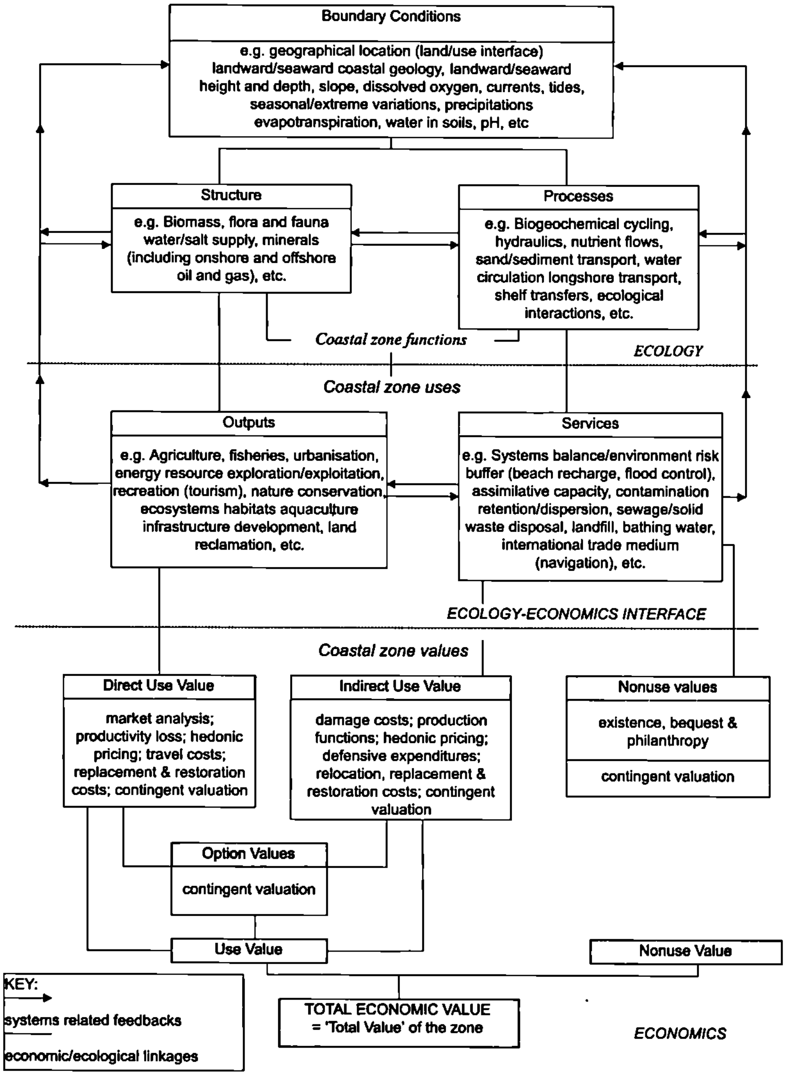
At the core of this interdisciplinary analytical framework is a conceptual model, based on the concept of functional diversity, which links ecosystem processes, composition, and functions with outputs of goods and services, which can then be assigned monetary economic and/or other values (see Figure 2). A management strategy based on the sustainable utilisation of coastal resources principle should have at its core the objective of ecosystem integrity maintenance i.e. the maintenance of system components, interactions among them and the resultant behaviour or dynamic of the system. Functional diversity can then be defined as the variety of responses to environmental change, in particular the variety of spatial and temporal scales with which organisms react to each other and to the environment (Steele, 1991). Marine and terrestrial ecosystems differ significantly in their functional responses to environmental change and this will have practical implications for management strategies. Thus, although marine systems may be much more sensitive to changes in their environment, they may also be much more resilient (i.e. more adaptable in terms of recovery response to stress and shock). The functional diversity concept encourages analysts to take a wider perspective and examine changes in large-scale ecological processes, together with the relevant environmental and socio-economic driving forces. The focus is then on the ability of interdependent ecological-economic systems to maintain functionality under a range of stress and shock conditions (Folke *et al.*, 1996).

The scoping stage is also an appropriate time for researchers to consider the predictive capability of their analytical approach. From the pressures side, an element of prediction can be introduced by the identification of trends in GNP, population, land use/cover change, urban settlements etc. (trend scenario) and the feeding of these into N and P budget calculations. The trend scenario, once established, could then be compared with alternative futures scenarios e.g. low growth, medium growth, high growth variants. In studies of a more localised nature, e.g. bays or estuaries within drainage networks, different management strategies might be modelled and compared, as alternative change scenarios.



Source: Turner et al. (1998)

Figure 1. P-S-I-R Framework: Continuous Feedback Process in Coastal Areas.



Source: Turner, Lorenzoni et al (1998)

Figure 2. Coastal zone functions, uses and values.

In summary, the scoping/audit phase should raise, among others, the following fundamental issues/questions/problems:

- the need for, and feasibility of, a basic characterisation of the study area encompassing both natural science and social science (socio-economic activity patterns and drivers) data;
- the extent of scale, particularly the system boundaries for the proposed study;
- the modelling/analysis goals, the need for, and feasibility of, some predictive power in the analysis to be adopted e.g. via environmental change scenarios, management strategies;
- the contribution the chosen study can make to any scaling-up process.

(b) Integrated Modelling

From the social science perspective, progress towards a more integrated assessment of coastal systems should incorporate three forms of models: activity models, natural systems models and models with a valuation dimension. The social science terminology has been used here but essentially what is being proposed as an analytical strategy is not incompatible with the modelling strategy adopted by natural scientists. Thus activity models are the ways in which socio-economic drivers/pressures variables are related to C, N & P (among others) fluxes in drainage basic networks. They encompass residuals generation and modification activities (e.g. different agricultural cropping regimes and N releases; levels of sewage effluent treatment and consequent N & P releases etc.) across all relevant socio-economic activities within a drainage basic. The I-O (input-output) modelling approach can be usefully applied up to perhaps the scale of a regional (within country) I-O model, which could predict residuals generation (nutrients, but also sediments and other substances) for a geographical set of economic activities and population settlements, under a number of different economic growth scenarios.

Traditionally I-O models are limited by their lack of dynamic properties (they are based on comparative statics i.e. a snapshot at current time T (and fixed coefficients) versus some defined future time point T + 1 with new fixed coefficients). Nevertheless, combined with change scenarios they could provide useful initial research findings. Much more complicated regional computable general equilibrium models offer increased flexibility but at the cost of much increased complexity and computing capacity and expertise.

What social scientists have called natural systems models, scientists would call budget models through to numerical systems models. However, at the prognostic systems model end of the spectrum there is a further 'interface' between natural and social science. In flux change contexts, for example, information on dose-response relationships would indicate what the impacts and implications for habitats, ecosystems and human welfare were because of changed C, N & P outputs.

It is possible to conceive of a suite of nested models related to different stages in the P-S-I-R relationship - see Figures 3, 4 and 5, (Turner, Adger and Lorenzoni, 1999).

In the case of the "causes to fluxes" relationship (i.e. pressure to state relationship) the drivers are land use and water use, as well as industrial development and population change, causing flux changes and hence changes in the environmental state (Figure 3).

Cause → Flux relationship Pressures → State relationship	
Drivers	**Modelling technique**
Land use change	food supply and demand models and nutrient flow models
Water regulation management	physical run-off models, etc.
Industrial development	input-output models, etc.
Population change	housing supply and demand models, infrastructure impacts

Figure 3. Drivers and modelling techniques inherent in the pressure to state relationship.

Some of the drivers shown in Figure 3 have spatial elements while others do not. In the flux to impact relationship, the drivers and modelling techniques are outlined in Figure 4.

Flux → Impact relationship State → Impact relationship	
Drivers	**Modelling technique**
Changes to water quality/quantity	health impacts (dose/response models, health impact models); recreational demand models
Changes to nutrient loading and primary productivity	fisheries stock models couples to fishing effort models
Changes to coastal geomorphology	recreational demand models physical risk and hazard assessments

Figure 4. Drivers and modelling techniques inherent in the state to impact relationship.

Finally the impact to response (cause feedback) relationship is characterised by the drivers and modelling techniques outlined in Figure 5. These are primarily social science models (often normative or policy driven models). It is extremely difficult to control any of the drivers in the impact to cause feedback (response) relationship.

Impact → Cause feedback Impact → Response relationship	
Drivers	**Modelling technique**
Demand and taste changes	demand for water quality, productive and recreational use of coastal resources
Policy process (political lobbying/decision-making)	stakeholder assessment/participatory planning, political economy approaches
Economic constraints	cost/benefit analysis

Figure 5. Drivers and modelling techniques inherent in the impact to response feedback relationship.

In social science (and in terms of benefits to resource managers and policymakers) a prognostic model should have a specified and explicit objective function, which relates to aspects of human welfare. The function will include ambient environmental quality indicators either in the function itself or as constraints. The policy goal of sustainable development of coastal resources is one such objective function in this context. Finally, because of the needs of policymaking (in which relative valuations of costs and benefits and trade-offs are inevitable) social science analysis is concerned with the development and application of criteria for evaluating strategies.

But information about environmental effects (physical, chemical or biological) and information about the value of ecosystem functioning need to be better linked than they have been so far. Quantitative information about increases or decreases in an ecosystem service can be a necessary prerequisite to valuation, but values may also determine which effects are chosen for measurement in the first place. Information about environmental effects requires a systems perspective, a focus on appropriate models, the adoption of relevant measurement endpoints and appropriate temporal and spatial scales (Bingham *et al.*, 1995).

While the fields of ecology and toxicology have advanced to a relatively high degree of accuracy in predicting the effect of some actions on particular ecosystem attributes, the sheer complexity of ecosystems still poses an immense challenge to analysts seeking to predict system alterations resulting from human actions. The variety of ecosystems and their attributes have not been completely catalogued and not all crucial relationships are known. Bingham *et al.* (1995) conclude that joint modelling exercises are required in order to review what information existing ecological models accept and in what form information is generated; and to explore ways in which the ecological models need to be adapted or better serve policy or valuation purposes.

Russell (1995) has argued that an ecological-economic modelling project undertaken in the 1970's (the Delaware estuary study, Spofford, *et al.*, 1975) has a number of important lessons to offer. Real collaboration requires investment in substantial up-front time, a process, which can be facilitated by the use of a mathematical model of the problem to be investigated. Bockstael *et al.* (1995) have reported progress in such a collaborative effort investigating ecosystem functioning and change in the Patuxent rive basin in Maryland, USA.

The linking of individual discipline models is very much restricted by the model type (Turner *et al.*, 1997). If the theories and concepts of ecological and socio-economic models fit a general systems frame then they may be incorporated within a unified model structure, where modules might represent the various original models, and the derived outputs of each model feeds into the next. However, given the different modes of thinking (across temporal and spatial scales) typical of different disciplines it is not always easy to link models directly. For instance, if both the ecological and economic models systems are represented in the form of programming or optimisation models then several options are available: look for a new aggregate objective; adopt multiobjective or conflict analysis framework; or, when possible, derive multiple sets of optimality conditions and solve these simultaneously. However, when the ecological and economic systems are represented by different model types, it is difficult to suggest how they can be linked to one another. Where economic models have an optimisation or programming format and ecosystem models a descriptive format direct technical integration seems feasible, otherwise heuristic approaches are needed.

Model classification can be described in many ways. For instance, Costanza *et al.* (1993) distinguish between economic, ecological and integrated approaches on the basis of whether the optimise:

- generally: characterised by simple theoretical or conceptual models that aggregate, caricature and exaggerate;

- precision: characterised by statistical, short-term, partial static or linear, models with one element examined in much detail; and
- realism: characterised by causal, non-linear-dynamic-evolutionary, and complex models.

(c) Evaluation Stage

Once environmental values have been elicited, indicators have provided 'clues' to the state of the environment and models have quantified to some extent the consequences of various possible management scenarios, there is a need to evaluate the different options and feed this information into a decision-making process for coastal areas.

Environmental appraisal is a generic term relating to the identification, measurement and assessment of environmental impacts. Assessment refers to a procedure for determining the importance of any impact. In cases where large projects or policies are being assessed it is not possible to trace out all of the linkages between economic, social and environment sectors via a quantified 'model' of the working of the ecological and economic systems. More pragmatically, judgmental assessments of the likely consequences are all that are possible, of ten accompanied by a degree of residual uncertainty (DETR, 1998).

Appraisal techniques all try in different ways to order information so that gains and losses can be placed in a comparative evaluative framework. Environmental impact assessment and cost-effectiveness analysis are fundamental to all coastal resources management issues. No appraisal can take place unless the environmental impacts are known with some degree of accuracy and any appraisal ought in principle to seek 'value for money' i.e. the costs of a policy are no higher than they need be related to any given stated goal or objective. Risk analysis is also relevant in a number of coastal contexts e.g. flood defence and coastal protection policies and is often combined within an overall cost-benefit analysis. (See Figure 6).

In any multiple resource use problem context, it will be necessary to identify the complete range of stakeholders present and their pressure impacts and influences. Multiple stakeholders translate into multiple worldviews and potential values conflict. One way of conceptualising this value conflict problem over time is via the formulation and analysis of environmental change scenarios. For this approach to produce meaningful results a trend scenario (i.e. the implications of current trends remaining substantially unaltered until some chosen terminal date in the future) need to be contrasted with the results derived from one or more alternative futures scenarios.

The stakeholder/revenue conflict situations that may be identified in any given coastal zone could be assessed and evaluated via multi-criteria evaluation methods which encompass both monetary and non-monetary valuation procedures (see Figure 6).

Financial Appraisal	Economic Appraisal	Multi-Criteria Approach
Based on private cost and benefits in cash flow terms.	Based on social costs and benefits, expressed in monetary terms, including environmental effects.	Based on non-monetary and monetary estimates of a diverse range of effects, social, political and environments.
Analysis is related to an individual economic agent, i.e. farmer, householder, firm or agency	Social costs/benefits = private cost/benefits + external costs and benefits	Scaling and weighting of impacts.
Typical techniques: discounted cash flows and balance sheets; payback periods and internal rates of return.	Typical techniques: cost-benefit analysis, extended cost-benefit analysis, and risk-benefit analysis.	Typical techniques: impact matrices, planning balance sheets, concordance analysis, networks, and trade-off analysis.

← less comprehensive/less data intensive — more comprehensive/more data intensive →

Environmental evaluation methods

Environmental Impact Assessment	Financial Analysis	Economic Cost Effectivenes s analysis	Economic Cost-Benefit Analysis	Modified Cost-Benefit Analysis	Multi-Criteria Decision Methods
quantification of a diverse set of effects on a common scale, but no evaluation; or misleading composite index scores	financial profitability criterion; private costs and revenues; monetary valuation	'value for money' given a fixed budget and multiple options to achieve a stated goal; does not measure the worth of the stated goal itself	economic efficiency criterion; social costs and benefits; monetary valuation	sustainable development principles; economic efficiency and equity trade-off; environment al standards as constraints; opportunity costs analysis	multiple decision criteria; monetary and non-monetary evaluation combination s

Figure 6. Spectrum of appraisal methods.

Evaluation and scaling problems

Because policy decisions are required relating to a range of spatial and temporal scales and different socio-economic and political levels, several broad assessment categories need to be distinguished (Barbier, 1993).

The choice of resource valuation approaches will depend on the spatial extent of the cause and effect relationship subject to assessment. Three levels of analysis can be defined:

- impact analysis: related to identified impacts generated by nutrients flux changes and other state changes usually within a restricted spatial area, but sometimes requiring drainage basin-wide data/analysis;

- partial valuation analysis: of given ecosystems, their functions and valued outputs, normally requiring more extensive spatial area analysis; and
- total valuation analysis: of a defined and perhaps very extensive coastal marine

It might be the case that a given change in nutrient flux and land use changes impose a particular impact on an individual coastal resource or set of resources, e.g., due to discharge from an industrial plant, oil spillage from platforms, storage facilities or during transport, sewage disposal from urban areas. Thus in this impact analysis category, a specific environmental impact is assessed via the valuation of the environmental state changes in the coastal resource(s) connected to the impact. The valuation requires an estimate of the consequent net coastal resources production and environmental benefits effects. The total cost of the impact (P_c) in social welfare terms is the forgone net benefits (NB_{fe}); so $P_c = NB_{fe}$.

The forgone net environmental benefits related to a pollution impact, for example, can then be compared with a range of alternative pollution abatement options and their cost (e.g. product and process design modifications for waste minimisation, end-of-pipe treatment and 'safe' disposal etc.). Table 1 summaries some relevant environmental state changes and related economic valuation methods.

Table 1. Coastal environmental impacts and valuation methods. (Adapted from Turner and Adger, 1996; and Turner, Adger and Lorenzoni, 1998.)

Effects Categories	Valuation Method Options
PRODUCTIVITY: e.g. Fisheries, agriculture, tourism, water resources, industrial production, marine transport, storm buffering and coastal protection.	Market valuation via prices or surrogates Preventive expenditure Replacement cost/shadow projects/cost-effectiveness analysis Defensive expenditure
HEALTH	Human capital or cost of illness Contingent valuation Preventive expenditure Defensive expenditure
AMENITY Coastal ecosystems, wetlands, dunes, beaches, etc., and some landscapes, including cultural assets and structures.	Contingent valuation/ranking Travel cost Hedonic property method
EXISTENCE VALUES Ecosystems; cultural assets	Contingent valuation

A second assessment category, partial valuation, encompasses situations, which require the evaluation of alternative resource allocations or project options. A planned large scale project (or extension of an existing project) such as a residential/recreation housing complex, or port and harbour facilities, might require the conversion of coastal wetlands and mudflats with significant biodiversity and other functional values. So the net benefits (NB_c) of the wetland conversion would be the direct benefits of the project (B_D), minus the direct costs of the project (C_D = capital and operating costs), minus the forgone net production and environmental benefits of the conserved wetland:

$$NB_C = B_D - C_D - NB_{fc} > O.$$

In some cases the estimation of only some elements of the valuation expression above is necessary to prove that the development project is uneconomic, provided that the on-going utilisation of the natural system is at a sustainable level. An analysis of the opportunity cost of wetland conservation (i.e. forgone project direct net benefits), for example, might show that $B_D - C_D$ is only marginally positive (some past agricultural conversion schemes have actually been shown to be negative).

As long as the conserved wetland yields a flow of functional benefits, storm buffering capacity, fish and other product outputs etc., the positive valuation of only some of these outputs and services will be enough to tip the economic balance against the large-scale project.

On the other hand, the development project may generate significant employment and regional income benefits and be seen as part of a regional development policy strategy. Increasing employment and reducing regional income disparities may therefore be interpreted as pre-emptive constraints on the cost-benefit analysis and such benefits may be heavily weighted by policy makers.

A third assessment category covers the evaluation of protected areas schemes involving restricted or controlled resource use. Such marine park or coastal nature reserve schemes, for example, might be a required compensating shadow project element in a large scale project programme approval process; or alternatively might preclude the existence of any given project altogether. The precise circumstances will depend on how 'weakly' or 'strongly' sustainability standards/ constraints are interpreted and imposed by planning/management authorities. The on-going loss of coastal wetlands might have reached such a stage that regulatory authorities were seeking to impose a "no net wetland loss" rule on all future development activity in the coastal zone (a pre-emptive environmental policy constraint on Cost Benefit Analysis.

In situations where there is a direct choice between a development project and a marine park or similar conservation scheme, or where compensating environmental shadow project possibilities are not available, it may be necessary to use the total valuation approach. The analysis would seek to determine whether the total net benefits of the protected area kept in a sustainable 'natural' state (Nb_p) exceeded the direct costs (C_p) of establishing the protected zone and necessary buffer zone, plus the net benefits forgone (NB_{fd}) of alternative development uses of the protected area. The conservation zone plus buffer zone set-up costs may include costs of relocating or compensating existing users:

$$NB_p - C_p - NB_{fd} > O.$$

In the context of regional or area - economic development, the objective of coastal management, interpreted using cost-benefit analysis, can be expressed as follows.

Maximise the present value of:

$$GRP - C_p - C_{cm} - D + B - C_a$$

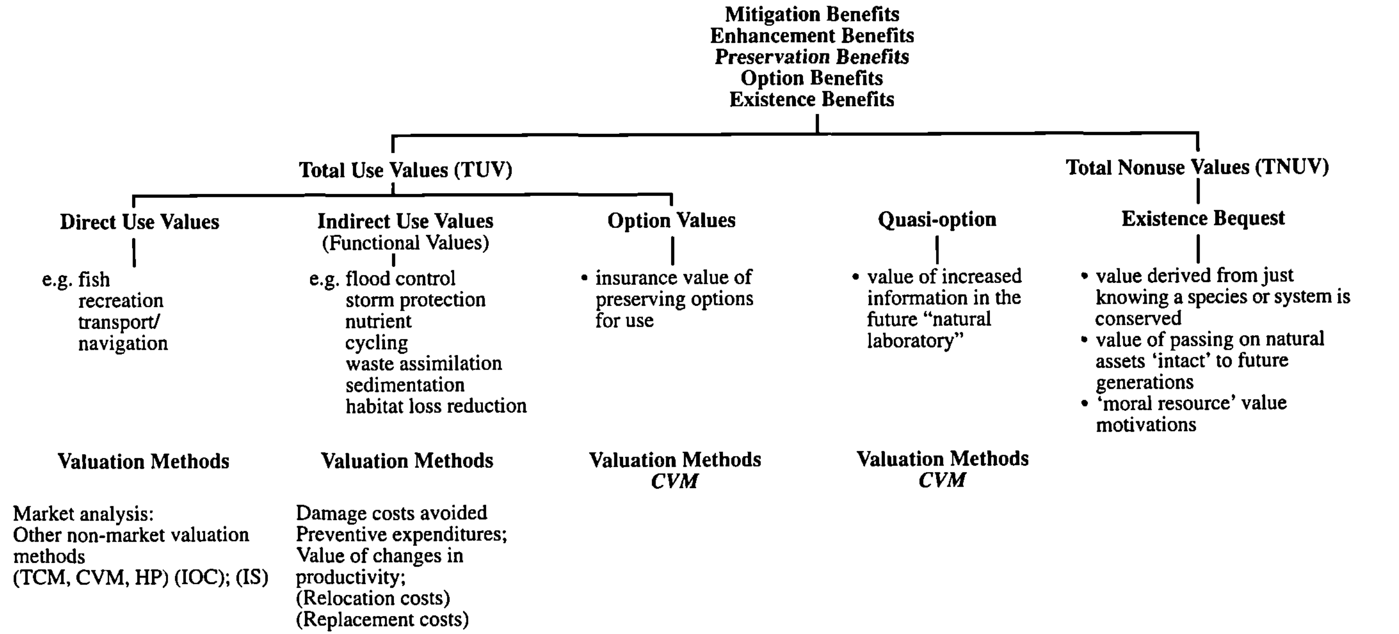
where

GRP = gross regional product;
C_p = normal production costs;
C_{cm} = net coastal management costs, e.g. discharge reduction costs/beach replenishment costs/coastal protection costs;
D = remaining damages;
B = benefits from improved environmental quality; and
C_a = administrative costs of ICM

Figure 7 summarises the methods and techniques available to value the range of benefits of coastal management before they are compared with the costs involved.

Given an integrated approach to coastal management the CBA economic efficiency criterion will have to be supplemented by other conditions such as equity, regional income/employment targets etc. (Bower and Turner, 1998). Multi-criteria analysis methods seek to offer appraisal guidance when policymakers are striving to trade-off gains and losses against multiple policy objectives (Janssen, 1994).

While there are limits to the economic calculus i.e. not everything is amenable to meaningful monetary valuation, economic valuation methods and techniques can and should play a significant role in the project, programme and policy appraisal process which leads to the setting of relative values (including environmental assets values). Costanza et al. (1997) controversially estimated the current economic value of seventeen ecosystem services on the biosphere-wide basis at between US $ 16-54 trillion (10^{12}) per year, giving an average annual value some 1.8 times the current global Gross National Product. Table 2 summarises the functional values for two typical coastal zone assets, coral reefs and mangroves.



Notes: **Market Analysis**: based on market prices; **HP** = hedonic pricing, based on land/property value data; **CVM** = contingent valuation method based on social surveys designed to elicit willingness to pay values; **TCM** = travel cost method, based on recreationalist expenditure data; **IOC** = indirect opportunity cost approach, based on options foregone; **IS** = indirect substitute approach.
The benefits categories illustrated do not include the **"indirect"** or **"secondary benefits"** provided by the coastal zone to the regional economy, i.e. the regional income multiplier effects.

Source: Adapted from Turner (1988), Barbier (1989) and Bower and Turner (1998)

Figure 7. Methods for valuing coastal zone benefits

Table 2. Composition of value elements for selected ecosystems

Coral reefs		Mangroves $ per hectare per year	
coastal protection	2750	coastal protection	1839
waste treatment	58	nutrient cycling	6696
food production/biol. control	259	food production/biol. control	
recreation	3008	recreation	658
TOTAL	**6075**		**9990**

Source: derived from Costanza et al., 1997.

The rationale behind this valuation exercise could be based on a number of arguments:

- Due to a lack of adequate market price data (or absence of data), together with inadequate (or absent) property rights regimes which ensure that resource values can be practicably appropriated, ecosystem services are assigned too little or zero value and weight in policy decisions;
- Some important environmental science research and debate, together with related policy-making (i.e. international agreements and conventions) necessarily takes place at the global scale. There is a need therefore for social science research to 'engage' science and policy at this scale. But such an engagement must, encompass analysis which will show clearly why globally aggregated social science estimates are often not meaningful, if the objective is to move beyond mere dialogue towards a more rational policy process;
- It is important to prove how valuable ecosystem services really are and to formulate mechanisms by which such function-based values can be realistically captured. Such capture must be relevant for everyday socio-economic and political activity and decision taking, through national income and resource accounting and project cost-benefit appraisal, down to the grass roots level in developed and developing countries.

Costanza et al.'s study goes some of the way towards meeting the arguments set out above. Their paper has engaged environmental scientists and policy makers, but the global, biome scale, economic value calculations risk ridicule from both scientists and economists. On the basis of the data and methods cited in the article and supporting inventory, the conclusion that the value of the biosphere services really is, on average US $ 33 trillion per year, is not supportable. Apart from raising policymaker, scientist and citizen awareness about the environment's economic value and the possible significance of the loss of that value over time, the global value calculations do not serve to advance meaningful policy debate in efficiency and equity terms, in practical conservation versus development contexts. Such calculations with their 'single number' outcomes shroud a number of fundamental 'scaling' problems to do with valuation contexts i.e. the temporal, spatial and cultural specificity of economic value estimates. Such values can also only meaningfully be assigned to relatively small ('marginal') changes in ecosystem capabilities (functions/services). The practical problem is that determining precisely what is and what is not a discrete and marginal change in complex ecological systems is not straightforward.

The issues of relative scarcity and basis of value are generic and serve to constrain the transfer of site-based function and system services economic values across time and geographical and cultural space. It is not being argued that all such benefits transfer is invalid, but we do believe that such procedures must be handled with extreme caution and have real limits. Many value estimates will not be amenable to legitimate aggregation beyond local to 'regional' (defined bio-geographically and including cross-national boundaries where necessary) scales. Further research to more precisely define these limits and to formulate a robust validity and reliability testing protocol is an urgent requirement.

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Specifying User Needs for Global Change Science in Coastal Zones

by

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Abstract

Coastal areas are getting continuously under increasing pressure for human settlement, use of natural resources and spilling waste. There is no other type of ecosystems that undergoes such dynamic and hardly to forecast changes than coastal areas do. One expects that currently more than 60 per cent of the world population are sustained by the coastal zone (Lange, 1999). With a view on spatial, food and material resources provided by the earth coastal zone environments this seems to be a rather conservative estimate. However, no matter what the exact figure is the pressure on this global domain continuously increases due to growing demands first of all caused by a growing world's population. This development will obviously cause substantial changes in the structure of coastal areas and their functioning. The increasing pressures will cause changes in environmental as well as social states of both the environmental as well as the social system. These changes are related to a magnitude of foreseeable and unforeseeable impacts to the natural and social environment that will require appropriate response. Human response to such changes bases on decisions that should safeguard a development that eventually has to support sustainability. However, it is still quite the exception rather than the rule that humans use their environments in a sustainable way presently.

Moreover, the way indigenous people live in sustainable economies that base on a day-to-day subsistence not on market economy driven by individual interests may only serve as a model for a sustainable economy. The economy of indigenous people was determined by limited wants that offered unlimited means with regard to limits in population growth (Ponting, 1991; Gowdy, 1998). Social and economic pressures on coastal structures and ecosystem functioning are mainly related to drivers such as rise in population number or commercial use of resources such as fish, seaweed or gravel, land transformation, agriculture, transportation or industry including tourism. The concurrent development drives into an impasse that needs concerted action of analysis, science and spatial planning (Turner and Bower, 1999, Fig. 1.3), which in the sense of ICZM (Integrated Coastal Zone Management) leads to application of non-static management strategies and thus to sustainable delivery option for goods and services. In practice this IZCM implementation means to redirect economy, planning for urban and agrarian development, to mitigate environmental impacts, to safeguard social development and to involve stakeholders in decisions that may support sustainability.

Human's action bases on decisions. Humans do their decisions in a world that only allows in part foreseeing or predicting consequences of decisions. Uncertainty, unpredictability and surprise are constitutional parameters of decision-making systems therefore decisions call for support systems that allows at least to reduce uncertainty (Köhn, 1997; Kremer, 1998a, van der Weide and de Vrees, 1999). Decision support systems mainly base on experience from past decisions but increasingly and complexity driven they rely on scientific advice. Social and biophysical sciences may ideally supply a set of different decision supporting systems that in one case more than another involves stakeholder experience. Big scientific programs like the IGBP/LOICZ (International Geosphere Biosphere Programme / Land Ocean Interaction of Coastal Zones Programme) and ELOISE (European Land Ocean Interaction StudiEs) are asked to put increasing effort in a user oriented synthesis. Not only should they cover those issues seeking scientific advice but also broker their respective deliverables to the various client groups continuously. Obviously a deliberate identification of users' needs against their different issues and the deliverables matching these needs is obligatory.

This paper will in particular reflect on the subset of potential deliverables of global and regional environmental change projects like LOICZ and ELOISE. It addresses questions such as: What are the issues, e.g. relevant uses that need decision support? Who are users involved in such decisions? What are their interests? What do users need to decide what? Why users should be involved in science and vice versa? When and how users should be involved in doing sci-

ence? When and how should science be involved in decision-making? What are the user expectations from science and when is scientific advice required and for what purposes? What should science deliver to properly address the numerous physical, geographical, temporal and administrative scales of issues in overlapping systems? What are experiences that may be useful for ICZ? In conclusion we are trying to combine the scientific innovation cycle with decision-making by designing a perpetual information cycle that based on mutual interests and participation may support decision-making in coastal zone management.

Introduction

Science especially applied science is committed to assist understanding and managing regional and global programmes that are designed to deal with environmental, social and political change or to resolve conflicts. Therefore, science is asked to provide a better and systemic understanding of the earth systems functions and the role of humans in these processes. This is why we are trying to capture and synthesise increasing amounts of (scientific) knowledge for different guiding questions related to issues such as climate change, environmental vulnerability and diminishing biodiversity (Köhn, in prep.). At the same time, market economy progressively substitutes for subsistence based economy even in many pristine parts of the globe that are managed by local people in a way that bases on traditional rather than scientific knowledge (Keohane and Ostrom, 1995; Berkes and Folke, 1998).

Consequently pressures exerted on the earth systems increase continuously and information needs of those whose interests are at stake are changing as well. In order to meet the challenge of safeguarding a functional earth system dynamic socio-economic and political responses are required to handle respective state changes and to mitigate impacts to the environment and the socio-cultural systems. One response – the AGENDA 21 of the UNCED (United Nations Conference on Environment and Development) summit in Rio 1992 – pulls together a comprehensive package of potential measures, which on a scientific level can be summarised as a logical shift from curiosity driven to issue driven science. In other words, a 'sustainability science' emerges that underpins decisions necessary to implement integrated management systems. In our case it is integrated coastal zone or integrated coastal area management (ICZM or ICAM). Integration in this connection not only means to put together the different issues in a relevant areas. It also means to encompass the different stakeholders including sciences (for instance, in global/regional change programmes), resource users, the general public, the policy makers, NGOs (Non-Governmental Organisations) and coastal zone managers, e.g. land use planners and administration.

Needs of users

Introductory remarks about users/stakeholders

Identification of the respective multi-users involved in certain coastal zone management issues and their interests is very important for addressing the outcomes of research in a proper 'language', that is a language and argumentation every stakeholder can understand, follow and synthesise for plans or action, and levels of detail. Equally important for the mediation or brokering process between producers and users of knowledge and know how are tools and measures allowing for successful participatory approaches. Crossland and Jordao et al, elaborate on this topic in detail (this publication).

User interests – recent sociology uses the term stakeholder instead of users – are different in many aspects. Users such as scientists from pure and applied science, technology developers, public authorities and decision-makers, public and private households, tourists, fishermen, private firms, and military services use or consume coastal resources or functions directly or indirectly. In tendency the intensity of uses for market economies grows faster than for subsistence purposes. Thus, resource use today often has to ensure maximisation of deliveries for a spot or regional or even global market instead of assuring lifelong supply for those people depending on these or complementary resources of a specific coastal region only.

A question of scaling

Furthermore, considering pressures on coastal zone systems from a stakeholder perspective requires to distinguish between offsite and onsite uses of coastal resources, structures and functions (Köhn, 1996). Turner and Bower (1999) suggest three different areas of interest in the coastal zone to be considered for integrated management purposes

1. politically designated management areas,
2. ecological areas,
3. demand areas, which can exert distant pressures on local or regional resources.

All coastal areas are already naturally under high evolutionary pressures. Physical and biological processes and on top anthropogenic driving forces add in magnitude and number to coastal change processes that physical sciences just begin to understand to an increasing extend. Both, naturally and socially caused pressures frequently do not originate in the coastal zone itself but are results of processes in the respective drainage basin that affects a certain coastal strip (Costanza and Greer, 1995). This applies for example to nutrients and pollutants that had been accumulated upstream. Such offsite effects perturbate the ecological balance of the coastal zone, which is in an 'end of the river catchment' position receiving various impacts caused by distant system changes. ICZM therefore calls for concerted action not only addressing coastal zone but also integrating the catchment area into the management efforts to reduce runoffs. This was described by Odum (1969) and has recently been elaborated further in the context of impacts on Continental Aquatic Systems, CAS, by Meybeck (1998) who has summarised among others the coastal relevance of upstream processes (Tab. 1). IGBP in response recently established the 'Water Group', a cross programme initiative of the BAHC (Biospheric Aspects of the Hydrological Cycle), LOICZ, PAGES (Past Global Changes), LUCC (Land-Use/Cover Change) and GCTE (Global Change and Terrestrial Ecosystems) core projects indicating the transboundary character of coastal process changes and their links to the CAS. The table below summarises the state – impact relationships and lists the global issues involved.

The LOICZ project increasingly contributes to this IGBP approach through its 'BASINS' concept, which highlights the human dimensions of flux changes to the coastal sea. Addressed are for instance, drivers of change and residual production (C, N, P, sediments and pollutants) as well as environmental quality aspects in terms of capacity – load relationships. These projects also pay more and more attention to threshold theory (Salomons, 1998).

To employ integrated management in this process and to build up a broker function of organisations and institutions requires advisory scientific consultation in such a way that coastal managers and resource users including in particular communities and the private sector upstream may realise and own responsibility for a healthy coastal zone environment. However, the process of ICZM has to provide both, the broad scale options addressing the whole system of pressures, states and impacts as well as options to deal with individual conflicts to enable appropriate response for action on the various scales.

Table 1: Important global threats on Continental Aquatic Systems, CAS, and related issues (adapted and supplemented from Meybeck 1998).

Environmental State Changes	Major impacts on the Coastal Zone	Global Issues						
		Human Health	Water Availability	Water Quality	Carbon Balance	Fluvial Morphology	Aquatic Biodiversity	Coastal Zone Impacts
1 Climate Change	• Changes in Soil Erosion			✓	✓	✓		✓
	• Extreme Flow Events		✓			✓	✓	✓
	• Changes in Wetland Distribution	✓	✓	✓	✓		✓	✓
	• Changes in Chemical Weathering				✓			✓
	• Develop. of Non-Perennial Rivers		✓	✓	✓	✓	✓	✓
	• Salt Water Intrusion in Coastal Groundwater		✓					✓
2 River Damming	• Carbon and Nutrient Retention				✓			✓
	• Retention of Sediments and particulate Matter				✓	✓		✓
	• Creation of new Wetlands	✓		✓	✓		✓	✓
3 Land-Use Change	• Wetland Filling or Draining			✓	✓		✓	✓
	• Change in Sediment Transport			✓	✓	✓		✓
	• Nitrate and Phosphate Increase	✓		✓	✓			✓
4 Irrigation and Water Transfer	• Partial to Complete Decrease of River Fluxes					✓	✓	✓
5 Release of Industrial and Mining Waste	• Persistent Organic Pollution	✓		✓			✓	✓
	• Salinisation	✓		✓			✓	✓
	• Heavy Metal Increase	✓		✓			✓	✓
6 Release of Urban, Agricultural, Domestic and Ship Waste (incl. Ballastwater)	• Eutrophication	✓		✓	✓		✓	✓
	• Persistent Organic Pollution	✓		✓			✓	✓
	• Develop. of Waterborne Diseases, e.g. through transfer of pathogens and non-indigenous species in ballastwater (Gollasch 1996)	✓					✓	✓

To give an example, long-distance transportation of nutrients along atmospheric trajectories reflects an additional potential for long-term and diffuse impacts originating from anthropogenic drivers as well as naturally caused global change. The Helsinki Commission (1996), for example, reports that 30 to 40 per cent nitrogen and ammonium input into the Baltic Sea originate from atmospheric deposition encompassing all sources in Western, Northern and Central Europe. Thus targeting a clean Baltic Sea environment requires concerted action in emission abatement strategies throughout Europe.

In conclusion, environmental state changes in coastal zones, which are externally forced across numerous physical and social boundary conditions require increased consideration of response options covering various interest, spatial and temporal scales. Science must account for this demand and underpin the decision support needed through understandable and issue driven information for all levels of scales. This scaling exercise must be properly executed and applies to the formulation of the scientific issues, the respective cross-sector client questions as well as the research deliverables (Köhn, 1998). It is a crucial task for larger synthesising experiments like ELOISE and LOICZ if they really claim being responsive and thus acting as brokers.

Response to user needs requires holistic views

There is no doubt that geo- and biophysical sciences significantly contribute to improved understanding of environmental pressures on and states of ecosystems. However, applying holistic views for the description of certain local or regional demonstration sites needs strong efforts to further elaborate on impacts and responses on the level of human systems. Westley (1995) thus calls for enhanced integration of socio-economic science.

It is for sure that at present a lack of interdisciplinary understanding is a major obstacle to sustainability. Parson and Clark (1995) and Michael (1995), therefore, argue for designing processes of social learning in a turbulent human ecology. Their pleading applies very much to the socio-ecological, socio-economic and political economy of sustainability in coastal zones (Köhn, in prep). Designing interdisciplinarity and co-operation is the task ahead we are facing in the scientific community in order to provide tools for decision-making. It is also the key need in issue driven science that is expected to enable the translation processes needed to match individual client demands for scientific advice. Executed continuously from the beginning interdisciplinary and participatory science helps finding a common language that facilitates understanding and joint ownership of issues and actions during the process of transfer (see Crossland, this volume). In some cases of course, the more scientific discussion may stay with the scientific community to avoid confusing the public.

As a bottom-line for understanding and concerted action may serve an overall acceptance of the dynamic and interacting co-evolution of the two groups of – natural and human –systems (Turner and Bower, 1999). This is absolutely pivotal for generating a clear vision of the advisory demands of heterogeneous client groups, and how they may benefit best from scientific products. This is essential for successful ICZM implementation. Making a long story short: We are lacking holistic thinking and systemic scientific approaches (Cable and Cable, 1995) allowing for decision-making towards sustainability in terms of its advisory deliverables.

However, besides transferring information for a public or political understanding to initiate appropriate action science may not forget to recombine information for an (eco-) system-oriented handling. This is in many cases not as easy as it seems to be. Van Ierland and Schiemann (1999), for instance, reported that reducing a single pollutant caused increasing impacts of another and therefore made the situation even worse. In summary benefits of options, gains and losses of different management strategies and trade-offs need to be highlighted from both the physical and social science perspective (Burbridge, 1999; Turner and Bower, 1999). This also is a major client expectation to holistic scientific approaches.

In order to cope with all these interdependent needs and expectations the application of a holistic descriptive framework to different coastal settings is a recommendable platform. Van der Weide and de Vrees (1999) and Turner and Bower (1999) give detailed insights on how such a scheme can be used. They illustrate a framework that enables understanding and acting from a systemic perspective. It includes socio-economic drivers and creates a link to state changes affecting the cycling and fluxes of carbon, nitrogen and phosphorous, sediment fluxes as well as stocks and resource use, goods and services.

The pressure-state-impact response, P-S-I-R, framework

The framework as outlined in more detail by Turner and Pirrone (this volume), Turner et al., 1998a; Scialabba, 1998; Turner and Bower, 1999; Van der Weide and de Vrees, 1999) tries to capture the variant aspects of external forcing of coastal change regimes comprehensively. Certainly this means natural changes caused by e.g. climate and sea-level change, vegetation cover etc. but equal effort is directed to include impacts of anthropogenic origin like land use and cover changes as for example urbanisation and aquaculture, expanded tourism or transport respectively.

Integrated modelling built on scenario descriptions that derive from PSIR framework application will allow both, future scenario building and reconstructing the interactions of drivers that caused past time events. Resulting peer reviewed scientific deliverables may prove beneficial when applied to management of coastal areas. By including those socio-economic **'drivers'** than referred to as **DPSIR** framework solid answers against the major issues coming from coastal resource usage can be derived. Their inherent hind- and forecasting capacity D-PSIR site descriptions may lead to dynamic modelling that features the human dimension of coastal change and facilitates decision-making.

The D-PSIR framework is a tool that captures the different forcing functions and levels in coastal change regimes in a way that should allow appropriate scaling of scientific work. While **drivers** refer to the socio-economic forcing factors – sectoral pursuit of stakeholder interests through the exploitation of one or a limited number of environmental functions, goods and services –, **pressure** refers to forces and interactions that are likely to change the coastal system. The **state** parameters of the coastal system represent the boundary conditions of significant functions of the system that may be affected by these pressures. Changes to this state may lead to **impacts** that may affect both environmental and economic processes (the human system) within the coastal zone.

Combined information on pressure, state and impact forms a basis for potential trade-offs between conflicting interests. This is particularly achievable if indicator functions can be allocated to the parameters measured (for LOICZ these are mainly the bio-geochemical cycles and fluxes of C, N, P and sediments). Hence, **response** describes the policy and management action and opportunities that are or can be taken to mitigate the undesirable impacts of pressures imposed on the state of a specific system. Employed in scenario building these results may elucidate alternative management strategies and their enabling policy instruments, which need to be applied to facilitate trade-offs in the light of relevant policy goals. Thus current 'response-performance' may also face some scientific evaluation. LOICZ, is developing tools for this purpose to fulfil its commitment to make science useful for coastal management (Pernetta and Milliman, 1995) in particular through its focus 4 (see below).

The LOICZ approach and deliverables

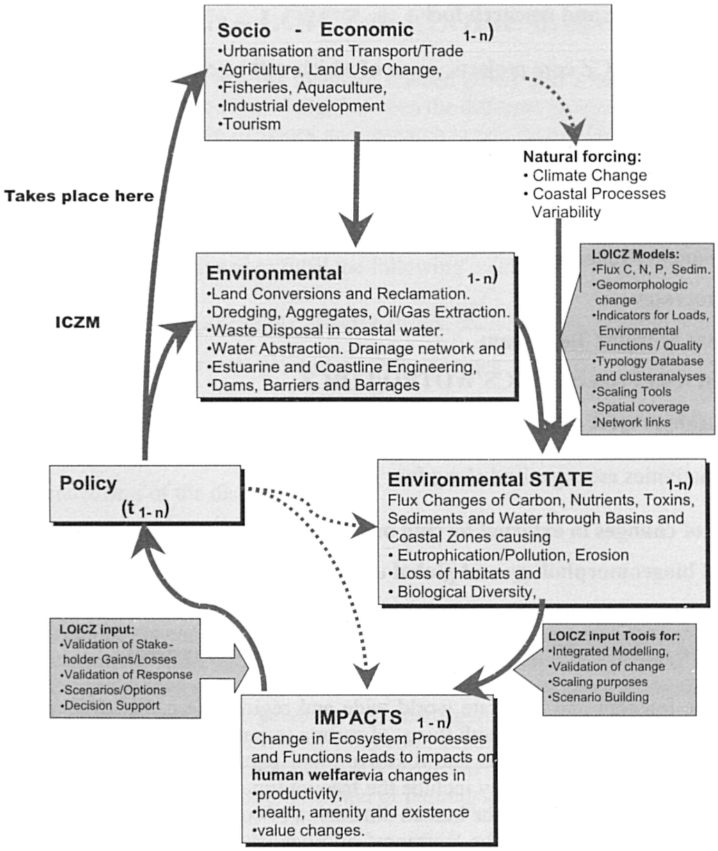
This section again refers to the D-PSIR framework while introduçing briefly the LOICZ Project and its relevant parts. LOICZ, which is one of eight IGBP core projects encompasses an array of natural and social science research to provide information on both anthropogenic and geocentric driving forces of coastal change to the global community. This information is designed to satisfy the needs of users like global decision-makers and coastal zone managers on different scales. The approach taken is to generate estimates of the fluxes of materials like C, N, P and sediments into, through, and from the world's coastal zone (Pernetta and Milliman, 1995). Increasing effort is being put on the human dimension of these flux changes i.e. how socio-economic **drivers** affect these fluxes through the coastal zone as a receiving body of transboundary transports.

In practice LOICZ supports the development of horizontal and, to a lesser extent, vertical material nutrient, pollutant and sediment **flux models,** which provide coastal sea bound budgets of nutrients, carbon and sediments. These models try to capture processes, which are influenced by or actively affect transboundary fluxes at the interface of the land/river drainage basin and the coastal environment as well as the atmosphere and ocean. They describe the **state** of the respective coastal compartment and doing so they consequently integrate material transportation throughout the whole water domain from the continental basins through estuaries and regional seas. Such biogeochemical process analysis and their time paths is fundamental for our understanding of coastal ecosystems and habitats.

Along with this biogeochemical approach LOICZ pays increasing importance to the human dimensions of fluxes (Kremer and Pirrone, 1999). The task is to identify those parts of biogeochemical flux changes in the coastal sea that can be attributed to peoples' activities referred to as **drivers** of change. Society **response** considers both types – the naturally and socially driven compartments – of changing regimes in system processes. This interplay makes the respective CZM process – if employed at all – look like an increasingly faster circling spiral, which ideally follows sustainable coastal zone management principles (Scialabba, 1998, part A). The difference between two "time shots" of D-PSIR scenario descriptions of a certain coastal site taken at T_0 and T_1 (see figure 1) may than be explained at least partly as management response(no matter whether effects seen are positive or negative at this stage).

If reviewed in the context of critical-loads reaching the coastal environment (Salomons 1998 and Salomons et al., 1999) flux changes are indicators for the **pressures** exerted on the system and the level of **impacts.** Critical fluxes induce or may induce changes within environmental systems that may have unexpected feedback on the social system. The database used to develop models of fluxes, budgets and their changes over time generate a set of indicators that allow for monitoring and detecting for anthropogenic and non-anthropogenic **drivers** on different scales. Consequently, these LOICZ outcomes deliver options for abatement strategies and **response** options. In other words, LOICZ science delivers tools for ICZM, which can match different user expectations. The spatial and time scale applied for proper science exploitation depends on the issues coastal zone managers must address.

Based on these different aspects LOICZ tries to employ the **pressure, state change, impact** and **response** scenario description to enable dynamic pictures of how natural and socio-economic forcing functions interact and impact coastal zone processes on various spatial and temporal scales. Relevant for users is to improve of the predictive capacities in the modelling approach. Thus while single models still remain approximations by capturing different scales and historical data one may continuously improve forecasting.



The suffix (t_{1-n}) indicates the change (between investigation at time 1 and n) in the interrelations of the elements at one demonstration site, as consequence of natural effects and/or response action taken. This means that after one 'coastal management' action, no matter whether it is success or failure the driver – pressure – state –impact scenario may look different. The circle can be applied again. In fact it becomes a three-dimensional spiral rather than a single layer projection. Of course on e must be sure to be able to distinguish between natural from human forcing of change observed.

The LOICZ structure and research foci

The major topical LOICZ core projects, some of which will be elaborated further in examples in this paper include:

- **Regional Basins (currently planned on EU level as EUROBASIN, in Latin America - Latin Basin – and planned for Africa, South and South East Asia)**
- **Coastal Typology**
- **Biogeochemical Modelling**
- **Deltaic Processes**
- **Continental Margins Task Team**
- **South East Asia Project SARCS/WOTRO/LOICZ**
- **ELOISE (this project comprises 29 EU funded research projects)**

The LOICZ activities are organised along four scientific foci:

F 1: Effects of changes in external forcing or boundary conditions on coastal fluxes;

F 2: Coastal biogeomorphology and global change;

F 3: Carbon fluxes and trace gas emissions;

F 4: Economic and social impacts of global change in coastal systems.

The Foci bring together and integrate world wide and regional (e.g. ELOISE) research programmes and assessments dealing with fluxes of carbon (especially CO2, with consideration of trace gases), nitrogen, phosphorous and dissolved and particulate matter into and between coastal basins and coastal seas. They include the forcing functions and boundary aspects mentioned earlier. In order to illustrate the human dimension of coastal change LOICZ has outlined a modelling approach, which uses the 'currency' of biogeochemistry and relates these to monetary and societal figures (Turner et al., 1998). This is aimed to generate a combination of physical and socio-economic indicators. Underpinned by economic science valuation studies and measures to price environmental goods, services and amenities may assist decisions of policy-makers. It will be an increasingly user oriented challenge for LOICZ and ELOISE to either put an economic value on biogeochemical fluxes or to find non-monetary indicators in biogeochemical parameters for the same purpose (Aguirre-Munoz et al., submitted). While the first may directly indicate sustainable or non-sustainable use of coastal resources (goods, services and amenities) the second tool provides indirectly for the same objective.

In addition LOICZ supports the development of coastal typology classification tools and methods. This research by setting up a natural and social science data set of 113 variables to one grade coastal squares tries to find a coherent approach and kit to resolve the up-scaling issue. Cluster and fractal analyses are employed to detect similarities and compare matching areas against different physical, biogeochemical or social sub-criteria, without necessarily starting new generic research everywhere. In this context LOICZ supports and contributes to the development of database-dependant key indicator monitoring programmes that particularly serve local and regional user needs (e.g. C-GOOS, the Coastal module of the Global Ocean Observing System of the Intergovernmental Oceanographic Commission IOC/UNESCO; see also section 6.1.4). Focus 4 tries to feed the indicators into the creation of if-then-scenarios superimposing the human dimension of changes along the D-PSIR framework for coastal zone management as a planning tool. If this effort results in a "D-PSIR" typology (Kremer, 1999) it may serve for developing coherent policy for clusters of coastal settings.

Addressing user needs – LOICZ & ELOISE brokering ICZM

When talking about ICZM as process planning science grows into a mediator role. Brokering the transfer of issues and related knowledge between the different groups involved will be needed to allow for joint ownership of issues and research action taken. This may foster extended peers discussions of users (Funtowicz and Ravetz, 1993) and eventually extended peers decisions. Extended peers are characterised by seeking consensus among stakeholders by exploiting best practise and best technological options to assure resilience for the decision-making and the succeeding implementation processes. Following Biesecker (1996) this only is possible when extended peers are designed to fulfil the following conditions:

1) the inclusion of all those potentially affected (users, stakeholders, property owners)
2) mutual acceptance to guarantee joint ownership of issues
3) the equality of the rights of all participants
4) the possibility of revising each position as well as the results
5) the open-endedness of the discourse
6) equal access to information
7) the absence of power (formal equity).

No matter that science is one key player (and stakeholder) in this concept it can play an important role by assuring the equal access to information for all parties involved in a way everybody can participate through understanding and sharing information. Under these conditions and provided an early involvement of the general public management achievements like for example new fishery management schemes, coastal protection strategies and technologies, master plans or projects are realistic. While operational on few local and regional scales (e.g. the Barrier Reef Australia, see Crossland this volume) this kind of participation is still vision along most of the global coast line.

As many others, also the Global Change Science Community of IGBP recently picked up the issue of how best to address the transfer of its results to users. Different scales from global (e.g. the International Framework Convention Climate Change, IFCCC) to smaller regional scales are touched in a pilot project on 'results transfer' run by BAHC and GCTE, which also receives European Union support. Common understanding to the programmes is to address two ways of science–user interaction, which are

a) based on the application of already existing science or, in other words, have science in place and than streamline and apply the results against the clients' needs;
b) generate an early involvement of policy and resource management throughout the research process; (IGBP., 1999; briefing documents 7.1, 7.2 for the 14 SC IGBP Feb. 99 in Estoril, Portugal – IGBP Secretariat, Stockholm, Sweden)

Both ways have to be considered today. To step into successful results transfer careful identification of clients, their interests and issues and how their interests may be addressed by science and vice versa, i.e. what the users' expectations are and how they understand science is one of the major objectives for a broker. LOICZ and ELOISE may serve as brokers (see figure 2, modified from Kremer and Pirrone (1999) when i) they evaluate their past current and future outcomes against those needs and ii) when taking a neutral position between the stakeholder groups either as part of management dialogue groups or as part or moderator of a coastal forum. The latter for example has been engaged in some of the elements of the ICZM Demonstration

Project of the European Commission (Directorate General DG) XI, (EU, 1999a, b) for example in the Dorset South UK part project.

Of course, following the outcomes of a recent conference on enhanced consultation between the EU research and development (R&D) administration (DG XII) and other executive parts of the Commission (Kremer 1999) this kind of brokering issue driven science to users has been accepted to be beneficial on the European scale for various users. The Commission itself should take the mandate and pursue this process actively. This also means for example to disseminate the findings made in course of the ICZM demonstration programme run by DG XI, link them to the science funded through R&D policy and provide for active involvement of advisory bodies such as the environmental management agencies like EEA. While a lot still needs to be done this discussion at least indicates increasing awareness to act towards the issue of science/user brokering in terms to enhance human welfare. Future will now have to show how this reflects in the practical willingness on different levels involved. However, besides serving as a mediator a crucial task of science remains to underpin the ICZM implementation through hard information, technology and prediction tools addressing functioning and interaction of natural and socio-economic systems, and to develop curricula for training and capacity building.

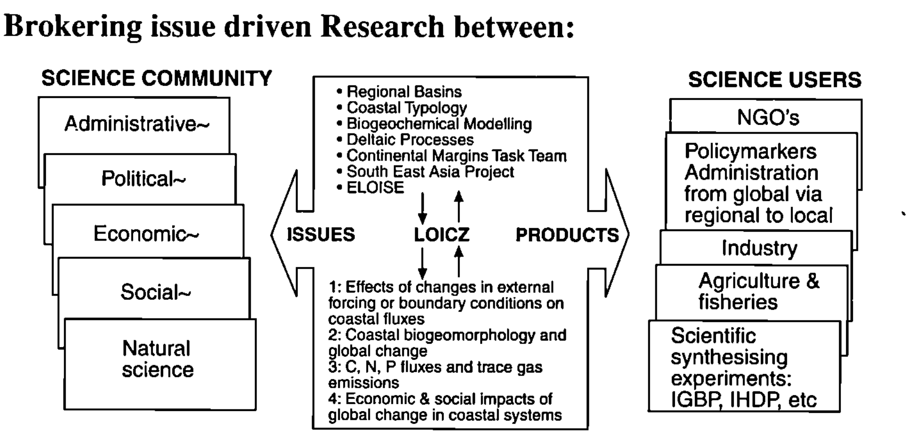


Figure 2. Projects like LOICZ aimed at global, regional, and local networking and synthesising to enhance multidisciplinary understanding of the coastal-catchment-ocean-atmosphere exchange processes and interaction in global change can take a vital role in brokering issues and deliverables between science and user groups.

The following chapter tries to enrol a first calibration of the contribution LOICZ and ELOISE might provide in form of science products to the decision-making and policy cycles related to coastal zone management. This will be outlined along examples for different clients making reference to the D-PSIR framework.

Users – examples for a multi-character group

Introductory remarks:

Stakeholders or users, we use the terms for simplification as synonyms here, in coastal zone management are individuals, groups, organisations or institutions claiming special interests in coastal zone issues. They may use coastal resources such as fish or minerals, draw benefits from space and functions such as the tourism industry (Sarda and Fluviá, 1999) or benefit indirectly from coastal zone economies by selling technologies for coastal protection etc. Users are also those who are engaged in nature protection, for spatial planning and decision-making in coastal zones. Eventually, the scientific community that focuses on coastal issues or working in basic science on coastal questions is a user. Along with the different user issues specific sets of questions can be identified, which seek advice needing targeted science exploitation.

The classical but partly paradox way for getting answers against current questions, as outlined by IGBP (see above), which is also valid for past and current LOICZ work, is trying to add value to already existing scientific results. This means to tailor available knowledge towards current and also future user needs, i.e. making '*old*' science responsive to future issues. However, new requirements of coastal zone management externally forced through for example global warming cannot rely on experience only. Therefore also new innovative ways of synthesising have to be designed for experiments like LOICZ and ELOISE, which respond to the user needs identified from the beginning in deliberate continuous consultation.

Relevant user groups and how LOICZ/ELOISE respond to their needs – A few examples

The science community

Slightly different from classical users not less important also the coastal science community comprising natural scientists, sociologists, economists, anthropologists and others is part of the heterogeneous group of coastal users. For example the disciplines and various institutes compete for limited funds. However, to gain a better understanding and explain the interrelationship between oceans, the coastal zone, the hinterland, the water regime and the climate as well as the spatial and time scales on which these compartments operate research programmes should communicate and interact as much as possible. For different science disciplines participating in one single programme it is in particular pivotal to accept that they are clients who mutually depend on each other results. Within LOICZ natural and socio-economic science may ideally interact across their special foci.

IGBP as an example:

A huge global synthesising effort like IGBP and its core programmes in fact use this kind of cross-discipline interaction as well. To fulfil its commitment to provide a comprehensive quantitative synthesis on global change issues in particular the biophysical processes that regulate the Earth's surface and its capacity to support life IGBP is the major client for the deliveries of its own core projects. Major motivation originates from questions around the risk of global warming or the related discussion on sea level rise and green house gas cycling searching for the missing one Gigaton of carbon (Smith et al., in prep.). How LOICZ on a global and ELOISE on a regional level may respond to this need is outlined here:

IGBP/LOICZ, and its core project ELOISE, provide science information to answer the generic question: "How will changes in land use, sea level and climate alter coastal ecosystems, and what are the wider consequences?" (see also . LOICZ recognises that the coastal zone, the place where land, sea, and atmosphere meet is not a line boundary of interaction but a global three-dimensional compartment. It is a significant domain, not only for biogeochemical cycling and global matter fluxes but also for human habitation, which on the other hand strongly influences these processes. In the major LOICZ questions (Figure 3) addressing coastal issues on a global scale one may easily recognise the generic IGBP task and get a good grasp on the user-provider relationship between the two huge experiments.

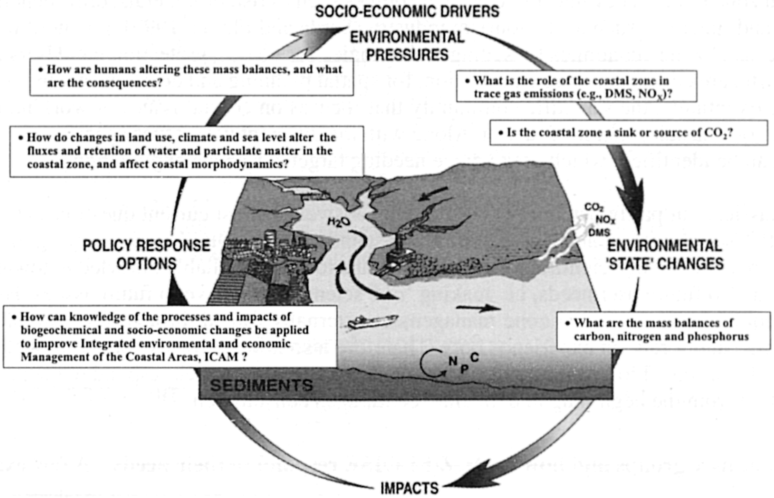


Figure 3. The six major LOICZ questions applied to the whole catchment-coastal sea-ocean margin water continuum. Transboundary modelling also covers exchange processes with atmosphere and bottom.

Products for the global change science community and IGBP

Evolving from the foci (Table 2) the own synthesis process LOICZ will provide different products, which also have high significance for the global IGBP syntheses.

Table 2: LOICZ deliverables against some key needs of global change synthesis (IGBP as a client).

LOICZ Focus	Deliverables	IGBP Needs
Focus 1: **The effects of changes in external forcing or boundary conditions on coastal fluxes**	• Regional synthesis estimating the catchment basin – coastal sea interaction including the critical link to drivers like land-use and cover change and climate change; • In co-operation with focus 3 and 4 quantifying models of anthropogenic residual C, N, P, sediment fluxes and change vital for use as indicators • Tools for global upscaling of the regional basins information captured here – feeding also in LOICZ focus 2	• Scientific input to the global "Water Group" Initiative • Assessment of the contribution of changes in catchments (e.g. damming) to coastal material cycling and hence exchanges with atmosphere, ocean and bottom • Scaled models for the respective transboundary flux changes
Focus 2: **Coastal biogeomorphology and global change**	• A coastal typology (objective typology of discrete coastal units serving as a sampling framework and to determine the appropriate weighting for preparing global syntheses, scenarios and models on the basis of limited spatial and temporal research data) Such a descriptive and dynamic system will allow grouping of the World's coastal zone into unit-clusters based on both natural and socio-economic features and processes. It will also serve as a basis for downscaling exercises needed in particular for management purposes. In summary the typology based grouping of coastal areas and processes may serve the establishment of appropriate indicator monitoring schemes on various spatial and temporal scales (see also IOC-GOOS, 6.1.4)	• Tool for global upscaling allowing the development of global scenarios and models based on clustering coastal zone areas of similar properties or against similar pressure state scenarios (without conducting empirical research everywhere) • Global picture of the 'human dimension' of coastal change (also serving the IHDP objectives) – see also Focus 4 • Operational links and exchange between different elements of IGBP benefiting from standard modularised descriptions of coastal units (typology)
Focus 3: **Carbon fluxes and trace gas emissions**	• Horizontal and, to a lesser extent, vertical material flux models (budgets) of Nutrients and Carbon; • a characterisation of coastal areas as netto hetero- or autotrophic systems serving as indicator for environmental quality and vulnerability; • Estimates of the ocean basin – coastal sea interaction captured through the joint JGOFS/LOICZ CMTT (Continental Margins Task Team – also Focus 1);	• Through respective up-scaling a global estimate of Carbon incl. CO_2 and Nutrient fluxes through the coastal zone and respective changes • A comprehensive picture of coastal functioning as a sink or source of the respective chemicals/materials
Focus 4: **Economic and social impacts of global change in coastal systems**	• Integrated modelling tools linking anthropogenic drivers to respective flux changes through the coastal zone and also defining the loop back from flux changes on the socio-economic system (human dimensions of flux changes – C, N, P and sediment residual production as currency for human action)	• Quantified description of the human dimension of global change, i.e. how economic action impacts the earth system and vice versa • Operational links and joint modelling efforts with LUCC and IHDP

Applied science / Technology developers

Basic science creates a pull- and push-effect to technological and tools development. On the one hand science needs equipment that industry may deliver, on the other hand, science detect resources, materials or methods that firms may be interested in or develop a new subject for entrepeneurship. It is a mutual dependence in a system that basic science, applied science and technology form or should form. Based upon scientific knowledge technology may create real innovation, instruments, materials and tools that can foster new market formation. Certainly some of these developments can lead to new direct or indirect (i.e. product and non product) pressures on the coastal environment (Van der Weide and de Vrees, 1999; fig. 4.4). New fishery technologies may serve as an example for affecting resources and the marine and coastal environment (Lindeboom and de Groot, 1998). Other technologies such as sewer management or farming that reduce erosion may assist coastal zone management schemes that protect the environment. It offers innovation and opportunities for using new materials and new technologies in agri- and aquaculture to mitigate impacts to the watershed and the coastal zone as a receiving body. In connection with global warming applied science responds to sea level rise and provides for coastal protection.

LOICZ and ELOISE combine an array of different scientific disciplines and approaches, which may provide for both the fundamental science and the more applied science and to both ends in form of data, guidelines for standardised investigations and modelling tools. A few examples are given in table 3.

Table 3: LOICZ/ELOISE approaches/products against the needs of some typical coastal management objectives, which seek to apply science; (compiled and supplemented from Salomons et al., 1999; Van der Weide and de Vrees, 1999; Scialabba, 1998).

Management Objetives Area/Sector	Applied Science User-needs	Science response (ref. to LOICZ & ELOISE)
• Coastal Protection, Flood Prevention; • Large Scale Constructions and (Port Management) • Aquaculture	• Geomorphological models; • Sea level change models; • Socio-economic modelling; • Indicators for water quality and health of the environment	• Flux-budgets and models including sediment transport and transboundary exchange processes; • Typology based on biogeochemical, geophysical and socio-economic parameters including rivers, fertiliser usage etc. • Tools for integrated modelling, hindnow and forecasting along PSIR, linking land and sea interaction to different pressures
• Waste Water Treatment	• Indicators for systems functions and health (state and performance) • Modelling tools for scenario simulation	• Basin Research (Integrated catchment/ coast) Approach incl. Load versus system capacity concepts • Flux-budgets; • Residual estimates of sectoral production of indicator fluxes (e.g. N, P)
• Water/Ecosystem Quality Assessment, EIA and • Monitoring Schemes	• Indicators for systems functions and health (state and performance) • Guidelines for standard comparable approaches at different locations	• Measurement Guidelines; • Critical fluxes/loads and change modelling; • Integrated modelling linking natural and social system components of coastal production processes; • Coastal typology to enable scaling of monitoring and CZM action against clusters of comparable coastal PSIR settings – not necessarily dependant on onsite generic research but allowing use of secondary data (see chapter 6.1.4)

Knowledge transfer, capacity building and networking

A crucial 'need' for successful science application has not been outlined explicitly in the table because it applies to all sectors and issues. What is meant here is the transfer of knowledge that is strongly dependant on interdisciplinary, multicultural learning and translation tools, which help to find common languages between the players and allow for the comparability of indicators (Kremer, 1998a,b; Mann-Borgese, 1997; Vallejo, 1996). Finally the effort of tool development and application has to be taken jointly by scientists and users in the field. Van der Weide and de Vrees (1999) distinguish four different phases of capacity building to be employed here:

1. Institute building,
2. Professional education,
3. Professional training,
4. Institutional support.

They have to be considered to various extends as in some cases institutions might already be in place whereas in others they are lacking. However, the levels described here are institutional (1,4) and individual (2,3), which are interacting complementary steps.

LOICZ tries to meet these needs through its active networking and co-operational links within the IGBP family and beyond with NGOs, IGOs (Intergovernmental Organisations) and regional institutions. Examples quoted in the same sequence are links to the LUCC (Land – Use and Cover Change) project focusing on integration of data on human drivers and the changes they induce in the socio-economic system more distant as well as close to the coast. The same applies to the joint participation of (among others) BAHC and LOICZ in the IGBP water group. Other operational links are with START (System for Analysis, Research and Training) as well as with the IOC (see section 6.1.4) and the regional Global Change Networks APN (Asia Pacific Network), ENRICH (European Network for Research In Global Change) and the IAI (Inter American Institute for Global Change).

LOICZ also currently employs continuous capacity building and training components in its global flux budgeting exercise funded by UNEP/GEF. Scholarship training for one of the participants allowing for deeper insights and capabilities to use the respective scientific tools will follow each regional workshop. Furthermore, in view of global up-scaling and synthesis LOICZ is committed to, the trainees are expected to function as regional mentors for future research and networking in their areas.

On the European level added value may certainly be generated through strong links to science users like DG XI and its Demonstration Programme on ICZM (European Commission, 1999a, b). Also other Directorates General like the Joint Research Centre, JRC, in Ispra (Italy), more classical users like the EEA (European Environmental Agency) in Copenhagen and European monitoring programmes may benefit from enhancement of science transfer, capacity building and application. On the other hand a wide-ranging application of science also means an invaluable test and verification of the LOICZ deliverables. In this area there is still considerable space for strengthening the links and stimulate the exchange of LOICZ/ELOISE outcomes with science users.

The economic/private sector and general public

The **Private sector** (companies and households) including the **general public** is closely involved in the process of ICZM and partly depending on its results since ICZM may directly influence their interests. Relevant stakeholders are private business, fisheries, tourist industry, home owners, farmers, service industry, construction industry, harbour and shipping industry, vacationers, local people, etc.

It is worth considering where decisions may cause changes in the coastal zone and affect these interests – the scaling issue again has top priority. 'Upstream decisions' may have serious impacts on the coastal zone and cause changes in water or material budgets, affect the groundwater level or nutrient loads. 'Downstream decisions' on increased urbanisation, large scale constructions, harbour business, tourism, intensive aquaculture causing for example salt water intrusion, diminishing of mangroves, etc. will directly affect the coastal environment. In conesquence the scale of the "coastal decision area" is an integrating over the whole water continuum including the catchments and expanding down to the continental margins.

It is exactly this system in which according to various uses the spatial range of 'coastal zones' is often defined closely along the limits of influence of interest groups or stakeholders. This sets the stage not only for the enormous extension but also the complexity and range of participatory processes aiming at deliberate sustainable use. Knowing these limits helps to identify the issues and expectations towards science that concern the stakeholders involved. Scialabba (1998) and Salomons et al, (1999) provide comprehensive overviews of scientific needs for sustainable cross-sectoral management of agriculture, forestry and fishery, whereas Barg (1992) and Sarda and Fluviá (1999) reflect on sectoral demands of fisheries and tourism (Table 4).

The table here concentrates on scientific data and deliverables providing information about sector related impacts. This has been done in order to underline the deliverables of the two synthesising projects LOICZ/ELOISE against related user needs in a simple and visible manner. Impacts outlined are affecting the systems functioning on environmental as well as socio-economic levels. Implications for human health and welfare are inherent. Most obvious institutional information, the legal and administrative framework and strictly economic backgrounds like market conditions have to be equally considered no matter that they are not mentioned here. We reiterate that most likely mutual benefit will be generated here from operational information exchange with IHDP (Int. Human Dimensions Programme on Global Environmental Change) and its subprojects.

Table 4: needs for scientific information (those, which will most probably find answers within LOICZ/ELOISE) of some sectoral socio-economic drivers (compiled and supplemented from Salomons et al., 1999; Sarda and Fluviá, 1999; Scialabba, 1998; Barg, 1992).

Sector	Scientific information needs for coastal management	Science response (ref. to LOICZ & ELOISE)
Agriculture	• Demography data; • Land-use change data; • Nutrient and pollutant losses from diffuse sources; • Nutrient and pollutant losses from point sources; • Agricultural sources of sediment load in surface water systems; (further points see under forestry)	Since there are a couple of deliverables, which may serve all the sectors mentioned to various degrees they are no longer divided by single sectors here: Obviously those are budget models of biogeochemical fluxes incl. sediments; fertiliser retention times; morphology and stability data of coastal land areas, and in particular again the coastal typology, which may also allow for clustering of information against comparable coastal settings of sectoral pressure; • However, the BASIN approach, which tries to cluster LOICZ/ELOISE science against management objectives in the whole water continuum covers catchment – coast interaction, critical loads etc. as well as the LOICZ/SCOR working group on Groundwater fluxes. The resulting data, guidelines and tools provide information against the various sectoral needs outlined. Emphasis must be put on the integrated scientific work like e.g. in LOICZ focus 1/4 (see above): Employing tools for integrated modelling to allow for involvement of socio-economic data aimed at: • Valuation of state changes and impacts as well as response options. Critical here is for example the approach taken in the South East Asian LOICZ project SWOL (see respective box): Residual calculation of C, N, P fluxes generated through the sectoral activities mentioned here may finally allow for successful marriage of biogeochemical change data and socio-economic as well as monetary figures. This tool also serves to achieve decision supporting accounting systems through applying for instance IO (Input Output) modelling, which finally may feed into Natural Resource Accounting, NRA, (Lange, 1999) on different scales.
Forestry	• Demography data; • Land-use change data; • Interrelation between the aquatic system and the supply of leaf litter, detritus and some silvicultural practices; • Effects of forest management on environmental quality of the coastal system (incl. other sectors like aquaculture, tourism etc.) and coastal geomorphologic stability; • Cross – sector impacts by other uses like tourism, agriculture etc; • Environmental impact on forest use strategies incl. land conversion; • Human impact through households, industry, use of water etc. • Impacts of changes in the catchment and/or coastal zone through large scale constructions (damming, filling or in general change in the horizontal flux characteristics)	
Fisheries	• Demography; • Land-use and cover change; • Biogeochemical and physical data (sediment and nutrient cycles and changes; i.e. is the system likely to shift from benthic to pelagic driven or vice versa); • Pollution; • Interaction with other sectors incl. aquaculture; • Hydrographical regimes and parameter changes incl. ENSO Events (El Niño Southern Oscillation); • Climate change;	

Sector	Scientific information needs for coastal management	Science response (ref. to LOICZ & ELOISE)
Tourism	• Demography; • Land-use and cover change incl. large scale constructions; • Biogeochemical and physical change data (in particular state changes of sediment and nutrient fluxes induced by waste production, land filling, dredging, water and sand extraction and changes); • Pollution; • Interaction with other sectors incl. aquaculture, fisheries, forestry, etc; • Coastal vulnerability to Climate change, erosion etc.;	

Intergovernmental bodies such as IOC/UNESCO

Intergovernmental organisations, IGOs, are clients since initiatives they conduct, mainly rely on existing scientific programmes in terms of pulling their results together to a new joint, often up-scaled approach. GOOS (IOC, 1998) may serve as an example. The major thrust for GOOS is in the fact, that since the majority of environmental processes are not simple cause – consequence processes, science has to enable proper monitoring of the systemic indicators and effects. Furthermore in service for coastal and ocean management this effort will have to be employed globally and to prove vitally applicable for policy and decision support. It may gain from standardised approaches, which translates into:

- pulling together fundamental science that is continuously conducted in most possible standardised manner without neglecting regional characteristics and with maximum global coverage to underpin the applied science on state of the art levels,

- setting up regional, system relevant indicator schemes for continuous monitoring; (Here in particular GOOS may act as a user of available indicative state and impact (critical loads!) parameters in existing research efforts like LOICZ. Consultation will also cover information exchange on upcoming new measuring systems. On the other hand LOICZ products receive invaluable validation through global application),

- employing a multidisciplinary coastal typology to gain maximum synergies in the implementation of coastal monitoring schemes also allowing similar approaches (including policy and management) for coastal pressure-state-impact clusters,

- underpinning this global effort through appropriate capacity building, and

- opening the outcomes and organisational links like for example to LOICZ for other GOOS modules like HOTO (Health Of The Ocean).

The enormous integrative force needed for getting such a programme off the ground is visible through the various international organisations involved such as IOC, WMO, UNEP and ICSU. GOOS in principle is targeted to advice a heterogeneous multi-user group in setting up individually issue driven measuring systems. Especially the efforts taken in the coastal module C-GOOS, which is committed to be strongly responsive to user needs, are direct clients for the synthesising experiments LOICZ/ELOISE.

The C-GOOS panel has divided the main client interests requiring scientific advice into four operational groups (GOOS Report No. 57, IOC-Paris in prep.):

1. Preserve healthy coasts,
2. Promote sustainable use of resources;
3. Mitigate coastal hazards;
4. Ensure safe and efficient marine operations.

How parameters investigated by LOICZ and ELOISE may fit into environmental quality monitoring may be seen in the chapter on indicators and in the Phillippine LOICZ case study (outlined in section 6.1.5). In the following we elaborate in some detail on the LOICZ typology effort, which also has been identified to be of significant scientific relevance for C-GOOS (IOC, 1998 and respective C-GOOS panel meeting reports not listed individually):

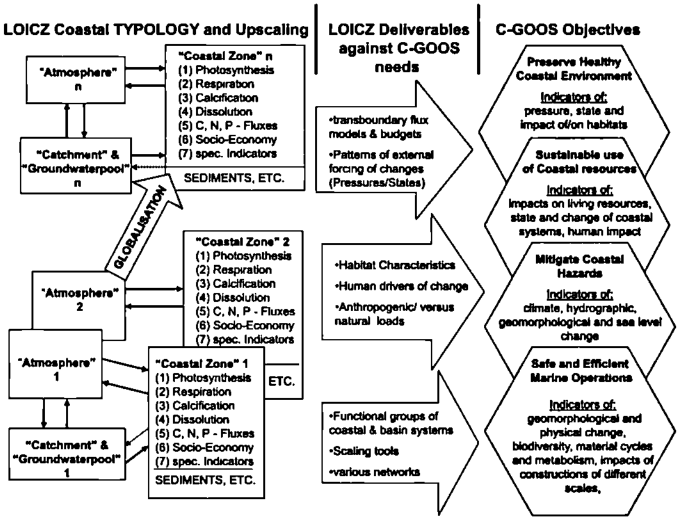


Figure 4. C-GOOS needs and deliverables from LOICZ research with special view on the LOICZ coastal typology core effort.

The LOICZ typology – a brief outline

All three C-GOOS panel meetings have identified the LOICZ typology to be a major need for the GOOS implementation phase. By mid 1998 the database comprises 113 physical, biological and socio-economic parameters at one degree pixel scale providing about 9600 coastal pixels in total. The typology database is a tool aiming to provide standardised scientific data allowing for analysis like clustering, scaling and modelling.

The sampling framework facilitates global syntheses through determining the appropriate weighting for, scenarios and models on the basis of limited spatial and temporal research data. A user including LOICZ itself can improve global up-scaling relying on the similarity patterns pulled out of the typology by cluster and fractal analysis while still keeping focused in key geographic coastal regions. To further enhance the applicability in particular for integrated modelling improvement of course will be needed for the partly still rudimentary subset of socio-economic parameters.

Furthermore a comprehensive global river basin database on e.g. river runoff, and catchment-size figures as well as one on fertiliser usage is available for investigation. All data are public domain and accessible through the LOICZ page (www.nioz.nl/loicz/). What is currently underway and interesting for a user like the C-GOOS?

Further work will continue to develop methodologies and tools for clustering and aggregating coastal descriptions, expanding and rationalising indicator parameters in the database, ways of linking to existing global data models, and seeking ways to link coastal with catchment typologies. The initial products are being posted to web-sites.

While there is still a lot to be done to refine a sound scientific and statistically proof approach for aggregating the pixels into a coastal classification the aim is to allow grouping of the World's coastal zone. Expected outcomes are clusters of discrete, scientifically valid units based on both natural and socio-economic features and processes. Similarities and differences can be pulled out easier and used to identify appropriate areas for comparative studies with secondary data. The LOICZ typology cells have already been used as spatial bases on top of which forecasting models of expected average temperature changes along the European coast until 2040-69 have been built. It was carried out by applying temperature models from the UK, Hadley Centre for Climate Prediction and Research, (and LOICZ page for more information).

It remains a priority to search for finer-scale resolution as well as to pursue the linking efforts with other typologies including IGBP projects such as on Land Use and Cover Change and in particular the BAHC typology efforts on river catchments. The 4th LOICZ Open Science Meeting 15-18 November 1999, Bahia Blanca, Argentina, will pick up this issue in a joint BAHC/LOICZ working group and respective sessions (see proceedings for results). Clients beyond GOOS and the IGBP Water Group are most likely to be found on EU level (see below). Linking catchment – coastal sea typologies serves directly the objectives of the FP5 in particular its Energy, Environment and Sustainable Development programme providing a cross-cut over various key actions with significant importance for No. 1 on Sustainable Management and Quality of Water and No. 3 Sustainable Marine Ecosystems.

In summary the Coastal Typology and the networking provided through LOICZ globally and ELOISE on a regional scale will be important contributions against the needs of Coastal- and other GOOS modules as well as the IOC-ICAM objectives. But as outlined in IOC (1998) it is also the validation of numerical models, which have been developed along the respective LOICZ guidelines which will provide a sound scientific basis for GOOS. The major LOICZ key parameters describing the carbon and nutrient cycles (Focus 3), sediment fluxes and changes across the boundaries of catchments down to continental margins (e.g. Focus 1) will be put in the context of environmental change to serve as indicators. This will be complemented through taking the socio-economic component into account in terms of integrated modelling (Focus 4), which again serves the FP5 goals in their generic action focussing welfare and human dimensions of change.

The operational link with C-GOOS will drive the combination of the tools, guidelines and data made available through LOICZ and ELOISE to an integrative product. This product employed by the GOOS monitoring effort will reach various end users (policy makers, coastal communities, international agreements etc.), and contributing to operational and sustainable management of coastal zones. The integrative needs of GOOS will including application of the modelling deliverables for environmental impact assessment and the valuation of response options and their effects on availability, economic value ranking (see also Costanza et al., 1997) and sustainable use of the coastal domain.

Public sector - The European level

CZM is based on multi-sectoral policy and decision-making seeking and considering scientific consultation on different international, national, regional and local levels. On a European scale the hierarchically highest level of legislation is the council of ministers; on the administrative (executive) level the Commission and the expert organisations like the European Environmental Agency, EEA, takes responsibility. Research and Development as well as economic and social policy is made, co-ordinated and evaluated here and has to consider all aspects of scaling interacting sectors etc.

In order to adequately address the difficult and often conflicting issues and interests in coastal zones including the influencing land based economic and social settings the Parliament in the early 90ies called for an Integrated European Coastal Zones Strategy. The DG XI has therefore launched a Coastal Zone Management Demonstration Programme (European Commission, 1999a, b) and DG XII through different programmes like MAST (Marine Science and Technology) as well as Environment and Climate has addressed a variety of 'wet' issues through its Research and Development policy. The biggest synthesising experiment pulling different related projects together is ELOISE. However, both, the shift of objectives that is visible when comparing the first four and the 5th R&D Framework programmes as well as the CZM-Demonstration Programme indicate that there is still a lot to be done to

a exploit the scientific know how successfully against the needs of various clients including the EU itself,

b to establish operational user involvement in scientific work on different levels from local community levels up to the establishment of links and continuous exchange between the Commission DGs (e.g. XI, XII, XIV, XVI, JRC Ispra etc.) and their associated organisations like the EEA or the EUCC on the NGO level.

FP5 in principle takes into consideration the various requirements of the decision-making process, which seek sound scientific underpinning and access to response options. However, it remains with the Commission's evaluation whether or not these integrative and cross-cutting objectives will reflect adequately in the selection of forthcoming European funded research and networking. Burbridge (1999) points out that insight must be provided in the potential risks and benefits of coastal management and the trade-offs, which are inevitable in cross sector management. Here the PSIR while taking changing demographic and socio-economic conditions into account together with use of resources like water, natural hazards etc. can help facilitate the development of **If-Then-scenarios.** Those combine experience with new scientific knowledge to increase the scientific certainty on which to built decisions. The user need covered in this way is enhanced prediction capacity of scientific results aimed at now-, fore- and hind-casting.

In response to these needs and in particular to the scaling issues of transboundary environmental process changes the EU took action in manifold ways. Examples are the water framework directive mentioned earlier, the WAtER Science Plan and the new problem oriented key action on 'Sustainable Management and Quality of Water', which aim at improved understanding of the complexity and to cope with a system like the water continuum in continuous change. The manyfold interactions of this key action with the other elements of the FP5 have been addressed in detail by the Environment-Water Task Force in its respective Freshwater report (European Commission, 1998).

Links and exchange will be needed in particular with the global and climate change activities as well as with the sectoral efforts aimed at enhanced sustainability and environmental health issues. The coast and thus the key action on 'Sustainable Marine Ecosystems' comes into focus addressing the receiving domain of the impacted land based water continuum and as a generator and buffer for global change processes. This again underlines the importance of joining land and sea based typologies for cross-cutting synthesis along this domain.

As sees it is most obvious that the private sector is a key player in this context and has to be involved in future research to make sure that science is targeted by issues and contributes to human welfare. This is elaborated further through the R&D generic activity "Socio-Economic Aspects of Environmental Change in the Perspective of Sustainable Development" and will become a crucial part also for LOICZ/ELOISE work to meet the FP5 objective of improved user orientation and providing problem solutions. From a user perspective FP5 is a profound tool to direct science against the urgent needs of sustainability science and human welfare. However, hope has to be expressed here again that this will adequately reflect in a policy that pursues integrated issue driven research in the Framework Programme.

For LOICZ and ELOISE to address properly the manifold demands for scientific deliverables arising from these needs is quite a challenge. However, this already takes place to various extents in the course of for instance:

- The joint **LOICZ/SCOR** (Scientific Committee of Ocean Research) **working group on ground water**. Here answers will be searched to the overall importance of groundwater fluxes as part of horizontal transports for the state and state changes of coastal systems. Methods will be developed and applied to model respective nutrient fluxes and their influence on the net biogeochemical behaviour of the adjacent systems (i.e. auto- or heterotrophic, pelagic or benthic driven) considering also the implications these characteristics might have for the coastal community and the aquatic resources.
- Other core projects like the South East Asian **SARCS/WOTRO/LOICZ** project that contributes considerably to create links between biogeochemical cycles and their states as systems characteristics and the anthropogenic driven production of residuals through for example agriculture, forestry etc. The box below gives a summary of the respective Philippine case study (adapted from McManus et al., 1999). It is most obvious that results produced here will touch the needs of policy makers directly. They seek and develop systemic indicator functions by taking bigeochemistry as a '**currency**' for human action. In view of the PSIR (see above) this may allow, at least in a later stage, for monetary and non-monetary valuation of change, scenario building and thus generating management or response options.
- The **Regional Basin (like EUROBASIN)** approach (Salomons, 1998), which aims at modelling the link between anthropogenic pressures on the catchment and the coastal zone, related state changes impact and response options. The main objectives are to derive from horizontal and vertical fluxes the loads, which have indicator functions that allow for appropriate decision support locally and upstream. Thus LOICZ by providing the respective Modelling guidelines (Gordon et al., 1996; Turner et al., 1998) adds value to the review of ongoing science as well as for the design of future action. Projects like MONERIS (Behrendt, 1999) and various ELOISE activities like METROMED, EROS etc. may thus provide directly against the needs of the EU for policy making on DG as well as subordinated levels like the EEA, or NGO level e.g. EUCC. It directly contributes to the outlines in FP5 and if put into a broader European synthesis may allow for input and valuation of the implementation of the water framework directive including coastal zones.
- The **LOICZ typology** effort, outlined earlier, which can deliver against the needs of monitoring approaches on various European scales and which could also be extended to a typology of coastal pressure – state – impact scenarios. Clustering "coastal zones" through standardised scientific data assessment, and along different scales of for example management

areas can provide a sound foundation for science – user interaction groups as coastal fora or cross sector user dialogue groups (see the Dorset Forum UK as part of the EU Demonstration Programme) or similar constructions. This helps to facilitate policy making and thus coastal management in a climate of joint ownership of issues and action taken by the different players including NGOs. Furthermore the typology if properly fed with socio-economic data on drivers and impacts will most probably allow finally the clustering of comparable D-PSIR scenarios on different locations (Kremer, 1999). A step in this direction even if not detailed enough yet for detailed scaling can be seen in the list of drivers as given in the report on lessons learnt from the Demonstration Program (European Commission, 1999b), which provides a simple 'driver typology' for European regions.

The following table summarises the outcomes of the recent review of various needs taken from observations made in the EU Demonstration Programme and potential deliverables and responses from the ELOISE/LOICZ side. The compilation strongly focuses on the needs for effective Integrated Coastal Zone Management:

Table 5: Information (i.e. processed data against certain issues) requirements as developed in the EU DG XI Coastal Zone Management Demonstration Programme (after European Commission, 1999b) and potential deliverables. The table concentrates on those requierements, which may already now or in the near future benefit from ELOISE/LOICZ achievements.

Issues and needs in the ICZM process	Available and recommended deliverables from LOICZ and ELOISE
Information Issues (information here means processed data)	
• Identifying and accessing available data	• Networking & brokering issue-led rather than curiosity driven science and transfer of products;
• Generating useful data to be turned into useful information;	• Data, modelling and tool products appropriate for temporal and spatial scaling and cross-discipline integration (holistic analysis) in a standardised manner
• Undertaking assessments;	• D-PSIR application allowing for impact assessment on different scales, valuation, accounting and benefit analysis (LOICZ-focus 4) and risk assessment based on standard natural – social science data and typologies
• Diffusion of information and knowledge;	• Networking with target groups and institutions on different levels and scales including science users; providing regular distribution tools, discussion fora and links to different data bases – all deliverables as public domain;
• Appropriate information management technology (improved communication between coastal managers and developers of information systems)	• Bridging the gap may be facilitated through the operational links LOICZ has to coastal management institutions, namely the Coastal Zone Management Centre, of RIKZ, The Hague; The Netherlands
Collaboration Issues	
• Identifying and ensuring the involvement of all relevant stakeholders;	• Improving regular links to clients on different levels either through programmes like in the Barrier Reef, Australia; • Generate respective workshops like the one treated in this monograph; • Strengthen institutional co-operation with science applicants (like IOC, EEA etc.); • Participating and supporting the steps taken by other parties like the EU DG XI/XII/XIV/XVI meeting on finding ways for a common strategy on coastal zones and management (July 1999);
• Cooperation across the land-sea boundary;	• Transboundary science as in the LOICZ BASINS concept and the IGBP Water Group delivers against the needs of transboundary users – enhanced stakeholder involvement will therefore automatically include institutions and authorities responsible for land and sea domains;
Legal Issues	• will have to be considered by both projects during science dissemination and communication as well as for proper scaling in.the model-design
Assessing the effectiveness of ICZM initiatives incl. policy performance	• the production line of biogeochemical flux budgets, change indicators, river loads versus threshold loads, calculation of residuals from human activity and integrated modelling drawing upon socio- economic figures, land-use cover change and addressing the whole basin will allow to set up indicators for • human impact, • gains and losses (benefits of current and future scenarios) • state-and impact analysis will enable valuation of responses taken by the decision makers • indicators of environmental and human welfare

Issues and needs in the ICZM process	Available and recommended deliverables from LOICZ and ELOISE
	in practice application of tools and appropriate synthesis from LOICZ and ELOISE projects for instance against the 'coastal' objectives of the Framework Directive-Water will generate a picture of both ecological and social systems functioning and performance including past and current policy; the same may apply to other CZM measures
Research and development to support ICZM among the various fields mentioned the two programmes have potential to respond in particular in terms of:	• developing methodologies and tools for integrated assessment (but they must improve the transfer into decision making and policy development) • deriving input conditions from observed concentrations (inverse modelling) – this is in particular addressed by the BASIN concept considering the loads of material in the coastal sea in relation to activities in the catchment – (this has been outlined earlier e.g. in the chapter reflecting on economic sector needs). Combined with multidisciplinary indicators this will provide the human dimension of fluxes taking the coastal sea as mirror for upstream processes; • to develop classification typologies, which will in particular be useful if clustering can rely on biogeochemical as well as socio economic settings – e.g. along the D-PSIR scheme

Of course these are only some pieces of the jigsaw not claiming to provide a full picture. On top of the single aspects mentioned there is an evident need for both projects to pay increasing attention to user identification, participation and thus to generate and distribute useful scientific information. Improvement is also recommended in the area of co-operation and co-ordination first to avoid duplication of efforts and second to enable continuous channelling of information to the users. The Commission can play an important part her in particular if this is executed on a Common Strategy level as recommended by the Council already in the early 90ies.

The following box gives a practical example of current LOICZ related science and provide an impression on how this may serve coastal management needs for indicators, and integrated modelling. From the four SWOL demonstration sites in Malaysia, Thailand, Vietnam and the Philippines the latter one is summarised here.

The impact of economic activities on biogeochemical cycling in Lingayen Gulf, northern Philippines: A preliminary synthesis
(after Talaue-McManus et al. 1999)

by

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Objective

This study attempts to determine how residuals derived from the waste production by land and water-based economic activities affects the cycling of materials and in consequence the health of the coastal environment in Lingayen Gulf, northern Philippines.

Study Area – Natural and Socio-Economic Structure

Lingayen Gulf is a u-shaped 2,100 km^2 wide and 160 km long embayment located on the northwest coast of Luzon, facing the South China Sea. The gulf has an average depth of 46 m, reaching a maximum of 110 m at its mouth. Its western section is dominated by about 200 km^2 of coral reefs and associated seagrass and algal beds. The bayhead has mostly a muddy substrate as it receives materials from the Agno River the biggest of six major river systems, which drain into the Gulf. Their total drainage area extends to 8,810 km^2 and annual aggregate freshwater discharge reaches 9,880 X 10^6 m^3. Agno River is the longest at 275 km, drains 70% of total catchment area and accounts for 70% of total discharge into the Gulf. Groundwater seepage into the Gulf was estimated to be 1 x 10^9 m^3/yr or 10% of total surface runoff. Flushing time is approx. 1.1 months.

From a total of 2.6 million people in 1990 in two adjacent provinces, population is expected to reach 4.6 million in 30 years at an annual growth rate of 1.45%, which is lower than the national growth rate of 2.3% per year. Inland areas are extensively used for agriculture and forestry and together with the fishery sector accounted for 43% of regional GDP while the service sector contributed 42%, and industry generated 15% in 1995. Most of the estuarine aquaculture areas with secondary stands of mangrove and nipa swamps are located here. The eastern section has a sandy substrate and its beaches provide for a moderately flourishing coastal tourism.

Approach

In this study, the contributions of nitrogen, N, and phosphorus, P, generated by economic activities were determined as major parameters in calculating nutrient budgets. Using the rapid assessment method developed by the World Health Organization (WHO, 1993), appropriate economic sectors were identified, and their respective residual production and environmental assimilation along its transport to coastal waters were calculated.

Estimates of waste loading were used in refining calculations of stoichiometrically linked water-salt-nutrient budgets. Preliminary budgets were made using the LOICZ Biogeochemical Modelling Guidelines (Gordon et al., 1995). Complete mixing of the water column was assumed and only annual means were considered. The influence of groundwater seepage was also taken

The important sources of P in terms of economic activities include household activities and agricultural run-off. Estimated total P input assuming an average assimilation rate of 80% as for N, was 2,400 mt/yr (77 x 10^6 moles/yr). Of this input, only 50% or 39 x 10^6 moles/yr were inorganic (DIP) (San-Diego McGlone in press) accounting for 33% of ambient DIP concentration in the Gulf (Tab 2).

The calculated P budget indicated that the Gulf is a net DIP source with (DIP being +0.001 mol/m^2/yr. Assuming that organic matter entering the Gulf includes plankton with C:P = 106:1 as well as organic waste material with a C:P = 47:1 due to partial oxidation, (prod.-resp., p-r) was estimated to range from –0.07 to –0.03 mol/m^2/yr. Overall, the small DIP flux and correspondingly low (p-r) values suggest that the system is nearly in balance metabolically as it efficiently recycles organic matter. However, the slight heterotrophy and a high initial estimate of (DOP at +0.09 mol/m^2/yr (almost 2 orders of magnitude higher than (DIP), suggest that **an increase in organic pollution could lead to changes in recycling efficiency and perhaps to a likely greater metabolic imbalance.**

The (DIN estimated for the Gulf was –0.1 mol/m^2/yr and which translated to a (nfix-denit) of the same rate. A net denitrifying state of the Gulf could be sustained by significant concentrations of DON and decomposition of organic matter.

Suspended solids derived from economic activities and that reached the Gulf were estimated to be 2.8 million mt/yr, 97% of which came from agricultural run-off (Table 1). This delivery could account for 37 to 100% of measured ambient concentration (Table 2). **Given this level of anthropogenic influence on the flux of suspended solids into the Gulf, changes in economic activities that increase delivery rates can have profound impacts. These may include changes in carbon fixation by and in the species composition of autotrophs and changes in sediment dispersal patterns and their consequences on bathymetry and coastal geomorphology, among others.**

Future Objectives – Modelling Change and Impact

Future studies in Lingayen Gulf will include the empirical measurements of concentrations and fluxes of the dissolved organic forms of nitrogen and phosphorus along a distance gradient from river mouths and point sources. The nutrient characterization of groundwater will also be done. With these additional parameters, net metabolic rates can be established along a distance gradient using disaggregated box models to validate if net autotrophy dominates near river mouths, and if net heterotrophy increases with increasing distance from shore. Simulations of changes in demography and economic activities can be made to determine first-order changes in nutrient concentrations, and their consequences on net metabolism at various levels of the gulf's assimilative capacity.

Table 1. Residuals from economic activities entering coastal waters of Lingayen Gulf (in metric tons yr^{-1})

Economic Activity	Nitrogen	*Phosphorus*	Suspended solids
Household activities	4,912	1,252	—
• Domestic sewage	4,467	563	—
• Solid waste	445	69	—
• Detergents	620	—	—
Urban Runoff	354	29	66,253
Agricultural Runoff	9,706	1,081	2,743,592
• Crop fertilization	5,097	973	—
• Cropland erosion	4,607	108	2,743.592
Livestock	83	14	2,687
• Commercial piggery	71	14	2,194
• Poultry	12	—	493
Aquaculture	62	11	66
Mining	—	—	20,732
TOTAL	*15,117*	*2,387*	*2,833,329*

Table 2. Total material concentrations in Lingayen Gulf and those contributed by economic activities

Material	**Ambient Concentration**	**Concentration derived from economic activities (% contribution)**
DIN	0.81 (mol/L	0.33 (mol/L (41)
DIP	0.12 (mol/L	0.04 (mol/L (33)
TSS	2.5 (4.5 mg/L	2.6 mg/L (37-100)

Coastal zone managers – The need for indicators

All groups mentioned above are users for scientific information and frequently but to various extents they are each other's clients. However, in as much as they are involved in steering coastal resource usage or take other influence on resources or people they are actively involved in coastal management. Policy makers often are also considered to belong to the coastal managers but mostly on a more distant level setting the legal, administrative and institutional framework, which without any doubt is one of the major pre requisites for successful IZCM implementation (Kremer 1998b, fig 1; Scialabba, 1998). There is no argument that the information needs on the different levels where coastal managers are active vary considerably but the common link for successful planning and implementation control (monitoring) can be found in a reliable set of indicators. The following chapter tries to review in more detail the question on what kind of indicators do users need and again in reference to the PSIR framework. For more detailed analysis of Coastal Zone Management strategies and needs please refer to Scialabba (1998), Cicin-Sain and Knecht (1998), European Commission (1999a,b) and Salomons et al., (1999).

The role of indicators

From a user perspective projects like LOICZ/ELOISE are expected to determine indicators that provide a quantitative understanding of the most important interactions between coastal subsystems (geomorphologic, biochemical and human or economic system) under changing external conditions. These interactions are steered by processes within the sub-systems, all of which can be characterised by a set of parameters. The challenge is to identify the triggers that mainly govern the processes and their characteristic features. Appropriate combinations of parameters may than serve as indicators for complex systems, the quality and (potential) development of coastal zones.

On the other hand generating a joint perspective of the issues among client-groups is depending on the identification of **user relevant indicators**. They form the bottom-line, from which clients will review the responsiveness of LOICZ products and from where more detailed discussions on issue driven science exploitation will depart. Indicators that sketch the human dimension of biogeochemical environmental change can be seen as the glue between the pressures and states description and the impact response side of the PSIR framework. In principle they can be seen as:

- parameters measuring the degree of sustainability in coastal uses and developments, which also help building bridges for the "public-private" partnership (clients are: public sector administration, private sector, coastal managers incl. advisory science (Kremer, 1998b), communities local people etc.),
- relevant for determining the state of environmental quality (clients are: EEA, EU-Commission, OSPAR, HELCOM, OECD, private sector, etc.),
- parameters relevant for modelling global change processes.

From the PSIR-framework as explained earlier three sets of indicators can be derived (OECD, 1994; Turner et al, 1998):

- **Indicators of environmental pressure.** They describe pressures from human activities on the environment e.g. energy, transport, industry, agriculture, fisheries, others.
- **Indicators of environmental conditions.** These indicators should be designed to give an overview of the situation (the State) of the environment and its development over time and not the pressures on it.
- **Response indicators.** Societal response indicators are measurements showing the extent to which society is responding to environmental changes and concerns.

In the framework of LOICZ these indicators are expressed in the form of

- Biogeochemical and physical fluxes of C, N, P, water and sediment (see the Philippine example above),
- Economic fluxes relating to changes in resource flows from coastal systems, their value and changes in economic activity,
- Social fluxes -e.g. food supply and price relating to food security, public health, welfare, flooding hazards.

The SARCS/WOTRO/LOICZ project as outlined in the box (section 6.1.5) gives a practical insight on how they can be investigated and linked to human activities. The major impetus which also poses the most complicated questions to the research teams involved comes from integrating science disciplines (natural and social and economic science). However, driven in particular through policy needs future developments will concentrate on this integration and economic modelling will receive increasing attention:

- putting values against biogeochemical flux changes and impacts;
- develop and apply appropriate indicators addressing the impact/response side within the PSIR framework;

These objectives already provide a major thrust for LOICZ but will need further consideration particularly in a review of past research and for the design of new work. They are also crucial for responding to the user needs as expressed in the 5th FP. It can be expected at least on the level of some demonstration sites that LOICZ will have such higher order modelling available within its lifetime (ending in 2002). However, since global synthesis required to that date can mostly be drawn out of simpler modelling exercises these higher order results will form a major legacy for future issue driven, management oriented coastal science to be run by either a new LOICZ period or a following successor experiment.

The role of science – Concluding remarks

Conflict management in coastal zones requires equal information access for all actors affected. The principle of mutuality also seeks all actors to supply to their information to the resolution process (Biesecker, 1996). However, the very specific processes governing coastal areas in terms of numerous cross-boundary forcing and therefore the complexity of decision-making users in coastal zones have to face put science in a challenging position.

Beside traditional knowledge, indigenous skills and experiences local people take from observation science is the main in many cases the only source of information. Nevertheless, the purpose of conflict resolution – the human – environment conflict as well as the 'between user conflict' is to foster equal and multidirectional exchange of information. This is to ameliorate situations perceived as being in conflict with user interests and which may in a short or long-term compromise future options for uses and living in the coastal zone by capturing a broader view of the players involved.

The sequence of deliberate advise and action science as a broker can support starts with identifying the issues and actors and their individual, joint economic and social interest in resolving the conflicts. Science as has been outlined has to engage its products and tools from its relatively neutral position to provide information on the gains and losses that may arise when users pursue their interests and to weigh them against environmental response. Hence, discourses, once set in motion, require various kinds of information and in order to resolve conflicts - a task also social scientists should be invited to assist at an early stage and contribute to the holistic thinking needed. However, it is principally important to get all stakeholders involved from the beginning. The initial step might be built up around:

- indigenous knowledge, skills and traditional practice of interacting with the environment
- local knowledge about the place and its development history
- experience acquired by trial and error before and during discursive processes (contextual learning)
- scientific knowledge

The following process of gathering and 'completing' information as well as sorting and applying tools for concerted action may do best if science sees its role in a dialogue procedure of mutual give and take. Positive as well less successful examples have been shown in the course of the European ICZM Demonstration Programme. The whole process needs interdisciplinary science and participation to generate joint ownership of issues through engagement of holistic views. This may assure that science speaks with in user oriented language to avoid confusion, which is pivotal for getting the process of ICZM going and keeping it alive. Moreover, this also assures that no scientist feels as appendix to another or that no user feels his interests being intruded in "wrong"directions by high flying scientific statements.

In designing future research programmes for resolution of coastal zone conflicts the complexity of the issues will no longer allow for separation in 'true' science and applied / social science. This means, concluding from the above, the main impetus for user involvement and responsiveness in projects like LOICZ and ELOISE must grow from engaging integrative research, analysis and modelling approaches. It also means to allow for appropriate capacity building and training in holistic, multidisciplinary scientific thinking, and science dissemination.

In other words the role of science in matching the needs of different clients mainly is to reduce the uncertainties involved in decision-making processes. However, there is no way to eliminate uncertainty completely. But since "(un)certainty reduction is costly and never fully accomplished" (Ostrom, 1990), dialogue strategies that see science as one player may reduce costs by forming or at least participating in dialogue relevant information (pools) involving all social players. The subsequent decision-making processes and the implementation of decisions into the social realm may also benefit from this.

Following Morgan (1993) the involvement of social science just from the starting point is even more important since "the only way to communicate risks reliably is to start by learning what people already know and what they need to know, then develop messages, test them and refine them until surveys demonstrate that the messages have conveyed the intended information". Morgan calls for informational support and assistance for discourses by science to overcome the fragmentation of knowledge. Although the social players involved will perceive and process information from and during the dialogue in their own ways. The dialogue however can keep scientists as well as users on track with the planning and implementation process of ICZM. This again comes down to a mediator or broker role of science in conflict resolution in IZCM, which can finally be summarised as follows:

- to assist the identification and dealing with the issues by analysing processes in natural and social systems (ecological, political, economic, technological, cultural, institutional change),
- to provide appropriate information and tools to deal with uncertainty,
- to offer options for action (scenario analyses),
- to contribute to and to communicate in discursive processes,
- to monitor implementation processes by means of appropriate indicator systems, and
- last but not less important to enable and provide for capacity building and training

In this paper we have tried to review the huge global change synthesising experiment LOICZ and its core project ELOISE on its current and future capacity to satisfy those needs. There is already a lot to be delivered against the various needs, which has to be pulled out of the bulk of information and transferred. But there is also quite an impetus needed to improve the responsiveness of the projects. The 5th Framework Programme of the European Union as well as the cross boundary initiatives like IGBP's Continental Aquatic Systems, the WAtER science plan (European Commission, 1996) as well as the water directive and, most recently, the huge UNEP/GEF effort GIWA (Global International Waters Assessment (GIWA, 1999) are examples for issue driven, cross boundary and resource (i.e. water) rather than spatial domain oriented approaches. One can expect that LOICZ and ELOISE through their efforts and syntheses will be able to generate significant contributions to these initiatives, while on the other hand they receive a comprehensive evaluation of their products through regional and global application by a large, multivariate user group.

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Improved strategies for linking coastal science and users

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Abstract

Globally, the role and place of science within the community is under increasing challenge. This challenge stems from scientists failing to communicate broadly their findings, failing to engage with users (or stakeholders) in describing and applying their enterprise, and a resistance to entering into relevant public debate and conflict. Scientists must actively address these issues by actively seeking and developing mechanisms that build links and activities with users and interest groups, especially in relation to the coastal zones and its "people pressures".

Efforts continue to be made in various part of the world to try and bridge the gap between science and the various users. There is no overwhelming "recipe" for success. Rather some win-win and effective outcomes have resulted that provide often small-scale successes from the matching of national and regional cultures and political systems with issues and conflict resolution. Where there have been successes in building bridges between science and users, these have had a strong dependence on the "people" factor – communication, mediation, collaboration. Successes have reflected the development of joint goals and actions through the identification of common agendas and recognition of both common issues and elements of conflict, for which there is a will between all parties to jointly resolve.

The key elements for success depend on building between all users and scientists: – a common understanding of the underpinning science and uncertainty, a common vocabulary and language, a development of trust between the parties, an explicit way to manage expectations (what science can deliver and what it can not), and establishment of "ownership" of the issues, science and approach for resolving the problems. This takes time and effort by all parties, and often scientists are uncomfortable with the sociological dimensions of establishing the effective dialogue and collaboration. Using a case example as a model, some key points and options for strategies of approaches can be drawn out which give guidance to building effective science–user bridges.

Introduction

Globally, the role and place of science within the community is under increasing challenge. This challenge stems from scientists failing to engage with users (or stakeholders) in describing and applying their enterprise, failing to communicate broadly their findings, and a resistance to entering into relevant public debate and conflict resolution. However, the wider community invariably acknowledges that scientific information is valued and that the information is crucial for decision-making across a range of issues and for technological development. Scientists must actively address this apparent paradox by actively seeking and developing mechanisms that build links and activities with users and interest groups. As a prime example, the issues and conflicts over resources use in the coastal zone urgently need effective scientific input to help in the development of sustainable options.

The coastal zone and its wise use

The coastal zone of the world is a heterogeneous and dynamic region, undergoing changes brought about by natural processes and human pressures. The coastal zone occupies less than 20% of the global surface, but provides about 25% of global primary production, more than 70% of global fish catch and it is where about 60% of human population lives (Pernetta and Milliman, 1995). Coastal populations and human uses are increasing, resulting in changes and impacts at various scales (local to regional), and increasing the conflicts over the allocation and availability of resources and space.

Coastal zone management is about managing people and resolving conflicts over their use of resources and actions in the coastal zone. The development of options for coastal zone uses depends on both value judgements, that reflect the community's needs and aspirations, and knowledge of the ecology and biogeochemical processes that underpin the natural functions of the coastal zone. To meet these needs, science can provide information about environmental processes, social and societal dimensions, economic factors and parameters, engineering and technological options, and integrated assessments of coastal practices (impacts and sustainability scenarios) (Doody *et al.*, in press). Clearly, effective management of the coastal zone requires mechanisms that bring together these scientific and the societal dimensions. Science research cannot continue to be conducted in isolation from users of the information, nor can it continue to be driven solely by the imperatives, goals and priorities of the researchers. There is urgent need for improved consultation and communication within society's constantly changing demands and expectations, in order to build end-user "ownership" of information especially by inclusion of all relevant stakeholders in the planning and processes of scientific inquiry and discovery.

Forging links

A framework for consultation, in the enterprise and management within the coastal zone is needed, and is often expressed within the rather fuzzy concept of "sustainability". While there remains argument about the practical meaning of the sustainability concept, the Rio Conference in 1992 (UNCED 1992) built further on the "Brundtland principles" of ecological sustainable development (WCED 1987). Many relevant principals and codes have been incorporated into the various policies of national and regional governments (e.g., ESD, 1992; Doody *et al.*, in press), and these contribute to a framework for coastal zone management and its strategies and planning (Cicin-Sain and Knecht, 1998). Irrespective of the details of these developments, there is a clear mechanistic requirement for both an access to knowledge and a process to integrate knowledge with societal values in order to determine viable options for sustainability e.g., sustainable use of the coastal zone (Scialabba 1998) (Figure 1).

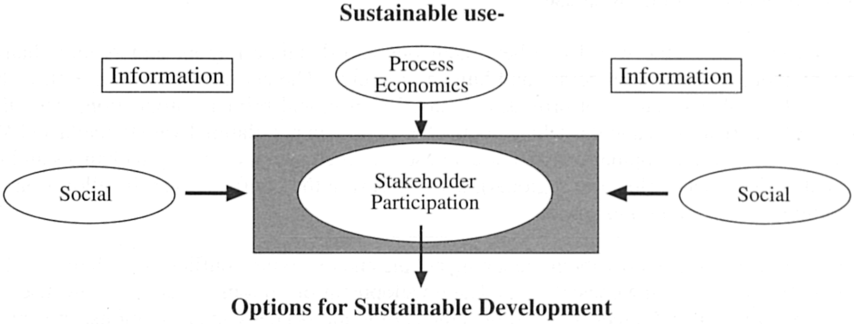

Figure 1. Model of information inputs into sustainable use decision process.

The key elements are:

a) putting in place mechanisms that readily provide access to and delivery of relevant knowledge from the plethora of information existing and able to be derived from natural science, social science and economics communities, and

b) integrating this with the needs and demands of the participatory process which includes the political dimension.

The form, level of detail, and relevance of the science information is important, often requiring skills and styles of communication for which science is poorly equipped. Moreover, the user or stakeholder groups may lack an understanding of key coastal process concepts, have limited ability to deal with uncertainty (risk management), and be unaware of the time frames inherent in gaining new and robust scientific information that may be required. Clearly, there is opportunity for improved dialogue and mutual education within an effective consultative mechanism.

Science information

What scientific information is needed? Most requirements will be issue or case dependent, as identified by the user or stakeholder group. It is likely that coastal zone managers will have a pivotal role in formulating the case-specific questions. However, industry, policy or community groups may have needs for direct and specific case information. The science community has a difficult role in providing a road map to the information, effectively communicating the information, and keeping ahead or responsive to coastal zone informational needs.

The general state of science being relatively disengaged from its users, reflects in part the change over the last 50 years in the way science priority setting has been carried out in much of the world. Cullen (1995) outlined the sequence of models (the researcher-led agenda and the user-led agenda) that has applied in Australia, and which has some applicability to the history of most national science agendas.

The researcher-led agenda (or "just-send-cash") characterised the period of 1950 to 1970's. Here researchers determined the problems, who might solve them, and the feasibility of the work. Scientific peer review imposed quality. While there were major creative products and scientific advancements, there was little attempt to consider *a priori* the benefits and attractiveness of the research. In this model the knowledge-producers determined the agenda with little or no cognisance of the knowledge-user's needs.

There developed an external perception – mainly from government and industry (i.e., the knowledge-users and resource-allocators) – that while Australia had high quality science it was not being transferred to or being "useful" for national economic benefit. This resulted in a shift to the user-led agenda, seen particularly in the 1980's with an impetus for economic rationalists and industry to set the research agenda. This reflected the view that those paying for the research (mostly community through governments) required greater accountability, "useful" results, and demonstrable national economic benefits.

Neither approach alone provides a functional model. The dichotomy of approach between the need for utility and "useful" knowledge (the user culture) and the internal validity of knowledge (the researcher culture) imposes a serious boundary for research.

Indeed, the current developments, in Australia and elsewhere, appear to be settling somewhere between these two approaches and into a context of an "Issues-led" agenda. The issue-led actions by the science community is becoming particularly noticeable in the arena of coastal science, where broad issue problems are being addressed by research teams of natural and socio-economic scientists. However, the direct engagement of science with the users is still in its infancy.

Many scientific institutions, organisations and individuals are actively working to build bridges and engage the users or stakeholders. Part of this reflects a culture change within science management, researchers and funding bodies with benefit and applicability of research outcomes being a significant project assessment criterion (e.g., EC 5th Framework, EU 1999). This does not imply that only applied research will be publicly supported, but does reflect the shift to greater relevance in scientific research to meeting community needs. It should be noted that in the case study described below, fundamental research is an integral part of the response to the science-user partnership requirements for information – and this factor is fully respected and accepted by the users.

Users needs

What are the issues? Undoubtedly, some are generic and some will be case-specific for sections of the coastal zone, as exemplified in Scialabba (1998), GESAMP (1996) and UNESCO (1997). The coastal zone managers usually have the role of "broker" between science and the wider community, and provide some level of institutional structure for interactive processes that lead to sustainable use options and practices in the coastal zone (GESAMP 1996).

Coastal zone managers face a range of issues associated with achieving their management goals (e.g., Crossland 1997). Managing the implications of these issues requires an awareness and understanding of scientific findings and consultation by industry and the managers with other management agencies and community interest groups (Figure 2).

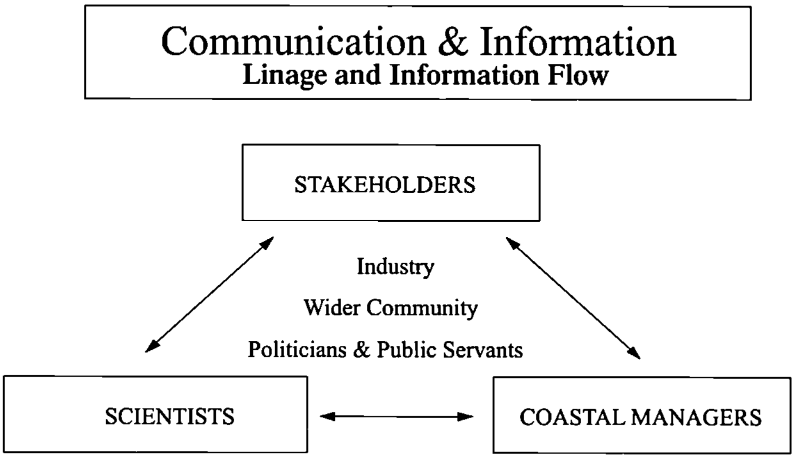

Figure 2. Dialogue model for consultation between coastal zone stakeholders.

The range and interest of users or stakeholders in coastal zone issues and respective global change science deliverables is addressed elsewhere in this volume (Kremer and Köhn).

Combining information and needs

Efforts have been made and continue to be made in various part of the world, to try and bridge the information transfer gap between science and the various users. These include approaches involving top-down and bottom-up consultation and planning, development of institutional and governmental arrangements and instruments, and the establishment of institutes and dialogues groups and foundations. These attempts are being made particularly in relation to the coastal zone and its range of uses for economic development and habitation, conservation, remediation and preservation. There is no overwhelming "recipe" for success. Rather some win-win and effective outcomes have resulted that provide often small-scale successes from the matching of national and regional cultures and the political systems with issues and conflict resolution. GESAMP (1996) and Scialabba (1998) outline potential and practical ways for engagement between science and coastal zone managers to work in a framework of integrated coastal management, and cite examples of successful working arrangements for community consultation.

Independent of the specific issues, it is apparent that effective science-user interaction depends on participation and partnerships, communication and trust, recognition of roles and responsibilities, and management of expectations. From evaluation of a range of case studies, it is clear that there are a number of features in information transfer and outcomes that are casualties in a poorly developed consultation process, including:

- a separation of science information from the users,
- lack of a mentor in the user group and loss of relevance of science information,
- often a mismatch between science research outcomes and the issues,
- limited recognition of the value of science information within the decision-making process,

- reduced trust and dialogue between the players and mis-directed debate,
- diminished liaison and follow up to evaluate the ecological and societal effectiveness of the derived use option, and
- limited ownership of the derived use option

Where there have been successes in building bridges between science and users, these have had a strong dependence on the "people" factor – communication, mediation, and collaboration. Here, success reflects the development of joint goals and actions through the identification of common agendas, and recognition of both common issues and elements of conflict, for which there is a will between all parties to jointly resolve.

The key elements for success depend on building between all users and scientists:

- a common understanding of the underpinning science and uncertainty,
- a common vocabulary and language,
- a development of trust between the parties,
- an explicit way to manage expectations (especially what science can deliver and what it can not), and
- an establishment of "ownership" of the issues, science, and approach for resolving the problems.

This takes time and effort by all parties, and often scientists are uncomfortable with the sociological dimensions of establishing the effective dialogue and collaboration. However, a "science forum" for discussion between stakeholders can provide a useful neutral ground in which to broker resolution of immediate coastal zone issues, and often to resolve wider coastal management conflicts.

CRC Reef - Science for sustainable use of the Great Barrier Reef

The Cooperative Research Centre for the Ecologically Sustainable Development of the Great Barrier Reef (CRC Reef) was established in 1993 as part of a federal government program (CRC Program, see www.dist.gov.au/crc) bringing industry, research and training together in key economic sectors. CRC Reef is a joint venture between Reef users (involving more than 1100 industry operators), Reef managers (federal and state governments) and research agencies. The partners work in collaboration to carry out research and development, training and extension in order to enhance opportunity for sustainable use of the Great Barrier Reef and to provide scientific information for Reef management. The Centre is run by an independently chaired Board with representation from the main Reef users, managers and researchers. The collaboration, a) brings together the best research and training skills in the knowledge-providers (researchers), and b) ensures participation and ownership in the identification of problems, setting of research goals and the use of research outcomes by the knowledge-users (industry and environmental managers). Other spin-offs are apparent from the collaboration between the different interest groups, including increased dialogue and trust, increased recognition of the context and constraints affecting each group, and efficient use of resources and facilities to support research and training.

The Centre addresses issues relating to tourism, fishing, and shipping and port uses of the Great Barrier Reef, and evaluates land-use impacts especially on Reef water quality. Research programs address the biophysical environment, social and economic values and use, and engineering design and technologies. The Great Barrier Reef is managed with multiple use planning, and resources use conflicts and land-use pressures are key concerns. Issues and priorities for research are guided, in part, by the 25 year GBR World Heritage Area strategic plan (GBRMPA 1994). Postgraduate training programs are key parts of the Centre's research activities with emphasis on joint supervision by appropriate industry and management personnel. This promotes the development of a cadre of skilled personnel aware of the industry and management problems and a focus on practical outcomes for their research.

A strong communication and education program has been developed as a major part of the Centre. The transfer of research findings in a readily understood form to the community, environmental managers and industry is not a trivial enterprise and is crucial to the Centre`s purpose. Extension of information into industry influences development of codes of practice and other elements of self-regulation. Environmental management agencies need to be appraised of new tools and support concepts that can affect planning options and best practice approaches.

The CRC Reef provides a new paradigm in the sustainable use of the Great Barrier Reef region of Australia. It has arisen to meet the joint needs of environmental management and industry and to assist in meeting the community demands for stewardship of the Reef. The commitment of public and private sector funding and resources for the Centre reflect these interests and the Centre is proving to be a unique and effective producer of relevant, useful scientific information to ensure wise use of the Reef.

[see www.gbrmpa.gov.au/~crcreef/new/]

Cases of interaction of science and users that have resolved issues and effected integrated coastal assessment and management have jointly and actively engaged in:

- using an issues-driven research approach to resolve problems (building common goals, understanding of concepts and time constraints),
- collaboration in research project design, implementation and data synthesis (mentoring and "owning" science outcomes, and understanding uncertainties),
- clearly confirmed ways that existing and new science can help and not help in resolving an issue (managing expectations), and
- maintained a frank and open communication about the knowledge base and problems (building trust and a common language, and public support).

There exists a multiplicity of frameworks (institutional and NGO) and models for consultation with the community of users or stakeholders, and for seeking their involvement in the implementation of coastal zone management options (see Scialabba, 1998). However, few models describe explicit ways for effectively accessing, researching and delivering scientific information. Coastal zone managers along with the community and other users suffer from information overload, and many consultant companies who contribute to coastal zone assessments and information use outdated information and concepts. Coastal zone management processes (often referred to as Integrated Coastal Assessment and Management –ICAM) to deal with and resolve issues are dynamic and iterative, including innovative options development, implementation, assessment and monitoring, which frequently leads to amendment of the selected management option. Consequently, there is need to establish mechanisms with structure and processes which have appropriate longevity, sufficient to meet the requirements of ICAM. Forums and liaison between science and coastal zone governmental agencies and NGO's are not uncommon. However, these alliances are mostly *ad hoc* and rarely have institutional arrangements to ensure continuity. Frequently they deal only with parts of the initial steps in ICAM. The lack of continuity is detrimental to building "ownership", mentoring and partnerships for necessary long-term information transfer between science and users of the coastal zone.

Globally, there are a few exceptions to the short-term institutional arrangements for information development and transfer. One successful example is the CRC Reef, which deals with science and management/users for the Great Barrier Reef region in Australia (see Text Box 1). The following discussion considers the evolving operational structure and processes that are ensuring that relevant science information is obtained and delivered to Reef management and user partners.

A Case Example – CRC Reef and the Great Barrier Reef

The key feature in the establishment of the CRC Reef Research Centre was ensuring that scientific work (fundamental, strategic and, in some cases, applied research) which built knowledge of Reef processes and human impacts was made accessible and transferred to end-users of the information – industry, environmental management agencies, community and policy arena.

Researchers and users were brought together in 1993 to develop an operational framework (Figure 3) that included:

a) mechanisms for consultation and development of issues-related questions, leading through a joint SWOT analysis and priority setting approach, and provision of regular for a for discussion of directions and new questions and research elements;

b) research implementation that aimed at involving end users, especially in research synthesis and operations (a project mentor associated with the chief investigator for each project),

c) communication and delivery of the results of the research; including progressive reporting, peer-reviewed communications (part of quality control), and technical and communications programs which put traditional, and often jargon-based research results, into plain language, and

d) ways to work with industry, environmental mangers and policy makers to "broker" science research input into conflict resolution and sustainable use option developments.

The interactive consultative and product model is idealised in Figure 4 and the process continues to evolve. Some five years on, the user-researcher interaction genrally has had good success but, at times, some failures. The latter have led to changes in the process, people involved, and ways of interaction. Maintaining the dynamic link takes time and effort, with the major stakeholders continuing to invest in the process. An important element is the stakeholder dialogue group that provides opportunity for progress review and mentoring both new issues into the science work, and timely transfer of information to meet the users needs.

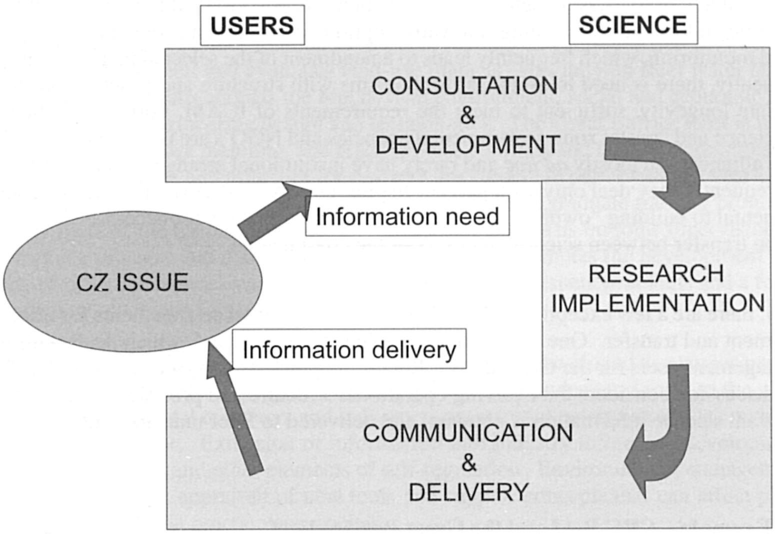

Figure 3. CRC Reef process outline.

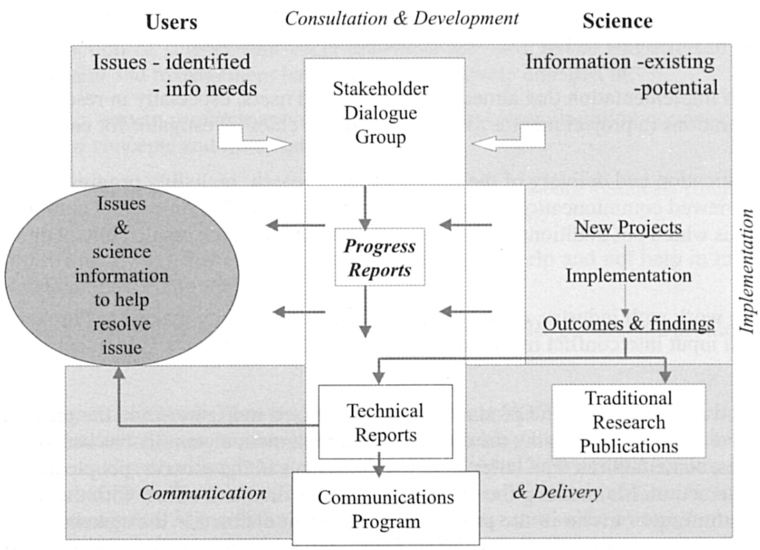

Figure 4. Idealised CRC Reef model for science user interaction.

Achievement of an effective structure takes time, effort and commitment from all players plus some funds – the latter usually can be achieved through a mixture of institutional arrangement (including the private sector) and from research project funding sources. The "benefits of research" are increasingly criteria for project proposals, and costs for communication processes are becoming acceptable and supported by many funding agencies. The required elements besides the science information (existing, developed and delivered) are people skills; some institutional structures with overt processes (involvement and consultation); communication and building of partnerships.

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Spatial and Dynamic Ecological-Economic Modeling for Sustainable Environmental Governance

by

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Abstract

The six *Lisbon Principles* – responsibility, scale-matching, precaution, adaptive management, full cost allocation and participation – form an indivisible collection of basic guidelines to achieve sustainable governance of environmental resources, namely the marine and coastal resources. These principles rely upon an integrated (across disciplines, stakeholders groups and generations) approach based on the paradigm of "adaptive management", whereby policy-making is an interactive experiment knowledge.

The application of the *Lisbon Principles* for sustainable management of coastal zones requires an integrated assessment of the biophysical and socio-economic systems, with their linkages, interdependencies and feedback. It also requires space-time modeling, as a basis for evaluation of tradeoffs among development alternatives and their impacts inland and offshore, and an on-going, participatory and open process involving all the major stakeholders groups.

In the light of *Lisbon Principles* and the general guidelines for their implementation, the ECOMAN Center, in collaboration with the University of Maryland, has been developing two projects in the Portuguese coast:

- the "Landscape Based Ecological Economic Model for Integrated Management of the Mira Estuary" and
- the "Mediated Modeling Project in Ria Formosa";

Both projects rely on the use of ecological-economic modeling as a tool for integrated coastal zone management, promoting participatory processes of policy-making. This paper focuses on a generic description of the working being carried out under this subject by the ECOMAN team.

Key Words: Integrated Coastal Management, Ecological-Economic Modeling, Participatory Processes.

Introduction

In 1998, a workshop in Lisbon, Portugal, sought to identify the principles for the sustainable governance of oceans. The six principles defined - (1) responsibility, (2) scale-matching, (3) precaution, (4) adaptive management, (5) full cost allocation and (6) participation – known as the *Lisbon Principles*, form an indivisible collection of basic guidelines governing the use of all environmental resources, including marine and coastal resources. Their definition relies upon an integrated (across disciplines, stakeholders groups and generations) approach based on the paradigm of "adaptive management", whereby policy-making is seen as an interactive experiment knowledge, rather than a static "answer" (Costanza *et al.*, 1997, 1998).

(1) *Responsibility Principle:* Access to environmental resources carries attendant responsibilities to use them in an ecological sustainable, economically efficient, and social fair manner. Individual and corporate responsibilities and incentives should be aligned with each other and with social and ecological goals.

(2) *Scale-Matching Principle:* Ecological problems are rarely confined to a single scale. Decision-making on environmental resources should: (a) be assigned to institutional levels that maximize information about the relevant ecological systems and recognize that ecological information needs to flow between them; (b) take ownership and actors into account; and (c) internalize costs and benefits.

(3) *Precautionary Principle*: In the face of uncertainty about potential irreversible environmental impacts, decisions concerning the use of environmental resources should err on the side of caution.

(4) *Adaptive Management Principle*: Given that some level of uncertainty always exists in environmental resource management, decision-makers should continuously gather and integrate appropriate ecological, social and economic information, with the goal of adaptive improvement.

(5) *Full Cost Allocation Principle*: All the internal and external costs and benefits (social and ecological) of alternative decisions concerning the use of environmental resources should be identified and allocated.

(6) *Participation Principle*: All stakeholders should be engaged in the formulation and implementation of decisions concerning environmental resources. Full stakeholders participation contributes to credible, accepted rules that identify and assign the corresponding responsibilities appropriately.

The need for integrated, inter and/or transdisciplinary approaches as core tools to pursue sustainable development in coastal zones was previously recognized by LOICZ (Land Ocean Interactions in the Coastal Zone) and ELOISE (European Land Ocean Interaction StudiEs), and settled down in the Agenda 21 for Integrated Coastal Management (ICM).

In that document, ICM is simply described as "*... depending upon knowledge and understanding deriving from both natural and social sciences*" still, this means the acknowledgment that questions related to the coastal zone and its management arise from the co-evolution of both the environmental and economical systems (Andrade, 1997). Thus, it implies that policy makers and managers must take into account both biophysical and socio-economic systems, as well as their linkages, interdependencies and feedbacks.

Within this scope, the adoption of *Lisbon Principles* can play a major role, promoting an integrated assessment between the systems, the evaluation of tradeoffs among development alternatives and their impacts inland and offshore, as well as an ongoing, participatory and open process involving all the major stakeholders groups.

This approach has been promoted by the ECOMAN Center, within two research projects focusing on the Portuguese coast:

- the "Landscape Based Ecological Economic Model for Integrated Management of the Mira Estuary", developed in collaboration with the University of Maryland;
- and the "Mediated Modeling Project in Ria Formosa", a joint project with the University of Maryland and the University of Algarve.

Both projects focus mainly on the *Participatory Principle* and use ecological-economic modeling as a tool to promote its implementation. The potential of modeling to promote ICM is discussed in section 2, and its application to the Portuguese coast described in section 3, as well as the main developments achieved in both case studies. Finally, in the section 4, some of the advantages and shortcomings from the experience gained are discussed, along with their implications for ICM.

Ecological-Economic Modeling for Integrated Coastal Management

Coastal areas are the result of, and are permanently being shaped by, a number of phenomena occurring at a wide range of both time and space scales. Coastal processes occurring at local, regional, national or global scales cannot be viewed as mutually independent. Even when local decisions and actions concern a wider scale of interest and consequences, this effect is further amplified due to the fluid nature of the marine and atmospheric environments interacting in the coastal zone, which allows for increased spreading effects (Andrade, 1997).

Alongside, the multiple conflicting interests between stakeholder groups, must be settled through clear cut management options, bearing in mind principles such as ecological sustainability, economic efficiency and social fairness. The sustainable management of coastal zones requires an integrated assessment and adaptive management (*Principle 4*), involving the direct participation of the major stakeholder groups in the several steps toward decision-making (*Principle 6*).

As emphasized by Funtowicz *et al.* (1997), dealing with complex environmental problems requires opening the analytical and decision-making process to broader categories of facts and actors than those traditionally recognized as legitimate. Considering also that both time and space have to be taken into account for sustainable resource allocation, few land use issues can be answered without taking into account landscape attributes and dynamics (Standford, 1996). Therefore, tools to support sustainable coastal zone management must deal with the entire landscape and be ecosystem oriented, trying to anticipate how activities in one area might affect physical, biotic and socio-economic properties of adjoining areas (Jordão *et al.*, 1999).

Among other approaches, this as been addressed in the field of ecological-economics via simulation models, through which externalities between various uses can be made explicit and trade-offs between specific scenarios can be analyzed.

Nevertheless, to be truly effective, models should not be seen as an independent component of the decision support framework in which they are used. In fact, their role can be enhanced when stakeholders actively contribute to their development (Costanza, 1997; Van den Belt *et al.*, 1997) as well as to the formulation of the scenarios to be analyzed. Then, models can play a crucial role, not by giving precise answers or prescribing optimal decisions, but by providing a tool for analysis and communication. Furthermore, they can bring up awareness of the possible impacts of proposed actions and respective feedbacks, so that it becomes clear how decisions by one not only have an impact on the environment, but also on the interest of others (Jordão *et al.*, 1999).

Thus, the participation of stakeholders in the modeling process is important not only as an analytical and communication tool but also as a knowledge elicitation instrument used to provide a better understanding of the systems upon which decisions are made.

Case Studies

Mediated Modeling Project in Ria Formosa

Description of the coastal area

The Ria Formosa is a highly dynamic coastal wetland subject to changes from physical forces. Located in the South of Portugal in the Algarve Region, the Ria Formosa is spread along 60 km of low-lying coastline (Figure 1). With its 18,400 ha, the Ria is a rich biological resource and a haven for many bird species, including many migrating species.

In order to promote an adequate use of its natural resources, this area was classified as a Natural Park in 1987, and included in the Portuguese Protected Areas Network. It is also regarded as an internationally important wetland area (as part of the International Conservation Network), and is considered in the Ramsar Convention and in the Special Bird Protection Area by Community Directive 79/409/EEC. Furthermore, Ria Formosa is also classified as a Site of Special Interest for Nature Conservation (Site 13 of the Portuguese preliminary list for the NATURA 2000 Network).

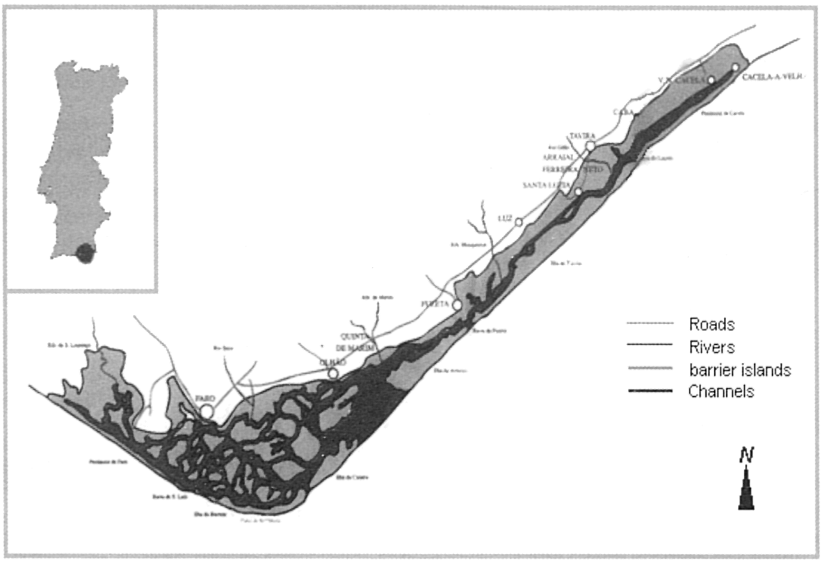

Figure 1. Map of Ria Formosa.

The conservation of Ria Formosa's natural heritage faces several obstacles imposed by the negative impacts of social and economic activities. Therefore, management of this system includes the regulation of human activities in order to promote the sustainable development of the area. The main pressures created by these activities include:

- the growth of urban and tourist developments in sensitive areas, such as the sandy barrier islands;
- high urban growth,
- the overexploitation of fish and shellfish stocks,
- the abandonment of salt marshes and traditional activities more in harmony with conservation objectives,
- the inadequate treatment of domestic and industrial effluents,
- the overexploitation of aquifers.

Model

The research project "Mediated Modeling in Ria Formosa" (van den Belt *et al.*, 1999) was developed with the objective of revealing the main interrelations between the natural and socio-economics sub-systems of Ria Formosa. During 7 days of workshops, a group of stakeholders examined this subject and constructed a model, based on the System Dynamics methodology, with the help of a facilitator, which yielded a broader and dynamic understanding of the issues involved in linking ecology and economics in the area. The developed model constitutes *a dynamic hypothesis, which describes the causal relationships between stakeholders' activities and its effects on the natural system, and how these further feedback and influence every new decision taken by the stakeholders involved in the Ria.*

The mediated modeling workshops consisted of building a computer model in a participative environment where the discussion between stakeholders was mediated by a facilitator and then translated into pieces of model structure, with the aid of the *STELLA II* software. All participants could follow the interactive modeling process on a big screen that was connected with the modeler's computer.

The resulting model is composed of four sectors: Land Use, Socio-Economic Activities, Natural System and Management. These four model sectors are related to each other by "information flows", as depicted in Figure 2. Specific issues within and among these sectors influence each other over a time frame from 1980 - 2020. From 1980 - 1998, the model tries to describe the observed historical behavior in the region. From 1998 - 2020, the model can run under a range of scenarios.

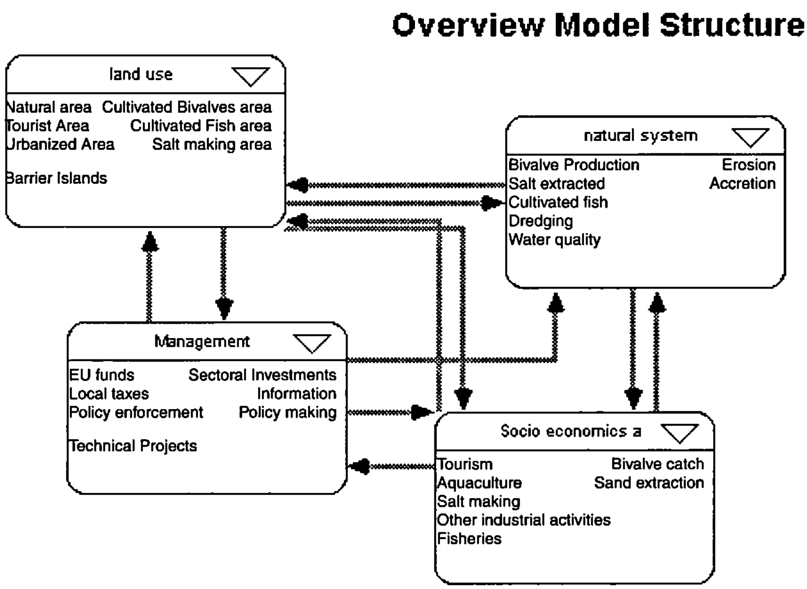

Figure 2. Model Structure Overview.

Results

The scoping model that was obtained for Ria Formosa represents a discussion about the main issues involved in conciliating the development of economic activities with the conservation of the terrestrial and marine heritage of Ria Formosa. This means that a group of stakeholders from a broad range of backgrounds (nature conservation, regional and local authorities, universities and economic sectors' representatives) interactively "scoped out" the linkages between ecology and economics (van den Belt *et al*, 1999).

The modeling process allowed for gaining new insights related with the existing environmental problems and the courses of action required to tackle them in an effective manner. Some preliminary conclusions were drawn and a consensus on those preliminary conclusions exists among the stakeholders involved. The following statements, grouped in different sets of problems addressed by the model, arose from the simulation of different management scenarios and their discussion among the stakeholders:

i) *Information to support integrated environmental management*

- Even though there is a realization that land use practices are important, there does not seem to be accessible information concerning land use practices over time or the effects of land use on water quality.
- Information and education is lacking on many subjects and links.
- Accessibility to information is lacking. There is a need to compile information and make it accessible for the broader public.

ii) *Valuation of the Ria's environmental resources*

- It is easiest to place a value on commercial activities, less easy to relate these activities to land use and very hard to value other ecosystem services derived from "un-used land".
- More effort should be put into the (e)valuation of ecosystem services.
- The total value of salt marsh is high compared to its current economic uses in the Ria. The total value of marsh is based on a global general value for ecosystem services of the marsh (Costanza et al., 1998). Dependent on the natural marsh available, there is a natural capital derived from the marsh.

iii) *Funding and "political will" as the main driving forces for management decisions*

- Environmental management depends currently on political will and outside funds.
- The EU funds are an important patch on the wound in terms of wastewater treatment and dredging in the Ria. The question remains if the Ria Formosa is economically and ecologically self-sustaining after the funds dry up.
- Limited funds can only be spent once. Coordination and cooperation of stakeholders' efforts need to go further.
- There is a need for economic instruments for environmental management to self-sustain the system on the local and regional level. An institutional setting (public and private) for redistribution of resources needs to be implemented.
- Decision-making should be based on integrated knowledge, rather than beliefs.

iv) *Economic activities development*

- Salt making is a decreasing activity due to the low profit margin. Licensing area to reduce salt marsh from being converted into salt pans will not have a large impact.

- Cultivation of bivalves and fish are increasing activities. If they are not licensed, they will steadily continue to grow.
- All economic activities (except tourism) are dependent on natural capital and just begin to capture the value of the natural area. Tourism is the largest source of income and in the model tourism is not negatively affected by the degradation of the natural area in the model.

v) *Future areas for investigation*

- Boating and bivalve aquaculture benefits from dredging of the channels?
- Sand and sediments from dredging should stay in the system?
- Does dredging make a significant impact during neap tide?
- How is tourism affected by the degradation of the natural area?

Landscape Based Ecological Economic Model for Integrated Management of the Mira Estuary

Description of the coastal area

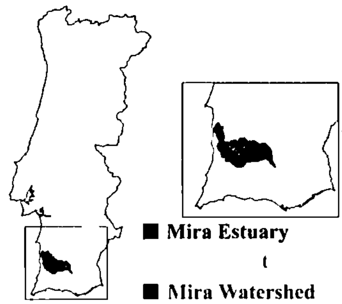

Figure 3. Location of the Mira Estuary and the Torgal Watershed.

The Mira Estuary (see Figure 3) is a small estuary in the Portuguese Southwest Coast. It is included in a National Park and has a great interest for conservation, being the Mira River is one of the less disturbed watercourses in Portugal. It hosts a great number of wildlife, among which a population of otters (*Lutra lutra*) living near the cost, a phenomena that has been described as unique in the European context, since these mammals hardly bear salt water. Their dependency on freshwater inputs from upstream is a major cause for the fact that, up to this stage, the project has mainly focused on the Torgal Watershed. This watershed is part of the estuary basin, and was included in the Portuguese national list of sites to be protected under the EU Habitats Directive (NATURA 2000. The Torgal stream drains an area of about 238 km^2 and flows through rolling hills for 28 km. Its headwaters are up to 300 m in Serra do Cercal, and it discharges at about sea level into the estuary.

Although very close to the coast, where development pressures are more intense, poor accessibility and infrastructure have lead land use in the watershed to remain related to agricultural and forestry activities. Even so, as synthesised in Figure 4, significant changes have occurred in the period between 1957 and 1995, for which accurate land use data is available. These refer mainly to intensification of forest related activities such as eucalyptus and cork oak forestry, at the expense of a strong regression of cereal fields and agroforestry areas.

Forestry with eucalyptus has been leading to changes in the hydrologic regime, reduced biodiversity, enhanced soil erosion, and has a low aesthetic value, providing also less products for local populations. There is thus the fear that, if changes continue in the same direction, the wetland area of the estuary may be affected, as well as the Mira River hydrologic regime.

Land Use Class	Area (ha) 1957	1995
Artificial / Urban	22	11
Annual Agriculture	96	265
Cereal	15338	5796
Permanent Agriculture	53	0
Olive Trees	368	61
Mixed Agriculture	238	1547
AgroForestry (A>F)	833	1753
AgroForestry (F>A)	5831	336
Forestry	13	217
Holm Oak	27	36
Cork Oak	1026	7825
Eucalyptus	12	5616
Natural Shrubs	584	999
Wetlands	12	0

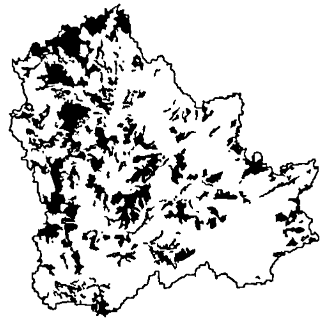

Figure 4. Land use changes in the Torgal Watershed, and their spatial distribution (in white).

Decision Support Framework

In order to address the issues associated with land use changes in the area, a generic decision support framework for watershed management has been developed (Jordão *et al.*, 1999) and is being applied to the area. As presented in Figure 5, together with information from external experts common to most management processes, the proposed framework relies on direct input from local stakeholders in all stages of decision support. These are basically aggregated in:

(i) the development of a modular ecological economic watershed model;

(ii) simulation under a spatial platform of the economic and environmental impacts of land use scenarios developed by the stakeholders;

(iii) assessment and evaluation of trade-offs between scenarios, for identification of common objectives and land use proposals;

To simulate the biophysical and socio-economic subsystems, a spatial ecological-economic watershed model is developed, representing the system under study. To achieve this, interdependent modules addressing each of the components of the system are constructed and validated stepwise.

Scenario development includes a "development as usual" base case scenario, relying on deterministic rules, assuming that changes in the area will follow a similar pattern to the historic one. This is assessed with transition matrices derived from land use data analysis, and may be extended in identify spatial variables that had significant influences in the transition process, so that they can explicitly be considered.

Further, with information obtained from interviews with stakeholders, "individual land use scenarios" are developed for each stakeholder, reflecting their own interests as direct users of the area. These can be seen as proxies of land use plans, that are developed individually for each stakeholder and consist on the identification, as maps, of the area that according to his viewpoint should be allocated to each specific use. The process of "individual land use scenario" development is a distinguishing feature in comparison to traditional decision support systems, where scenarios are generally defined by outside experts. It allows one to grasp stakeholder's different definitions of a problem, different ways of selecting and conceiving its relevant aspects, as well as different goal definitions.

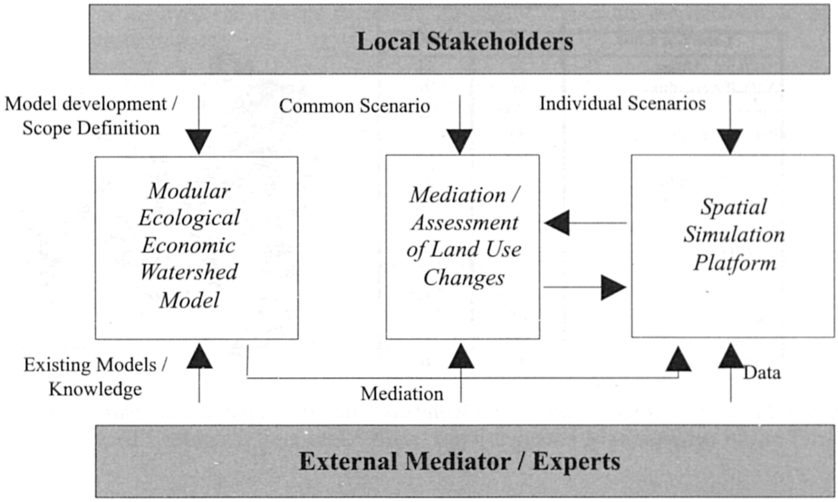

Figure 5. Diagram of the Decision Support Framework.

The environmental and socio-economic impacts of each "individual land use scenario", can then be assessed with the support of the spatial simulation model. For this, results from simulation of each alternative are combined in matrices of alternatives *vs.* impacts, which can be analyzed and discussed in detail by all stakeholders in a review workshop. Due to the spatial nature of the modeling process, results from simulation may include both aggregate indicators for the whole watershed, as well as maps with the spatial distribution of indicators for which the spatial component is relevant.

Results

As the project is still ongoing, final results are still not available. With information generated from first contacts with stakeholders and an extensive literature review, a draft outline of the biophysical and socio-economic modules to be included in the model of the watershed has been drawn (Figure 6). It is being used as a conceptual guideline for scoping and development of the structure of each of the modules.

As a general remark to the model structure, one can identify four groups of modules:

- '*ecosystem types*', roughly driven by socio-economic processes and constrained by climatic and geomorphologic conditions;
- '*biophysical processes*' that interact with the former since these are intrinsically related with the type of ecosystem existing in each land unit;
- '*socio-economic activities*', which drive changes in the watershed, but in turn are conditioned by biophysical processes and existing landscape elements;
- and finally, '*decision making oriented*' modules, that represent the state of the system.

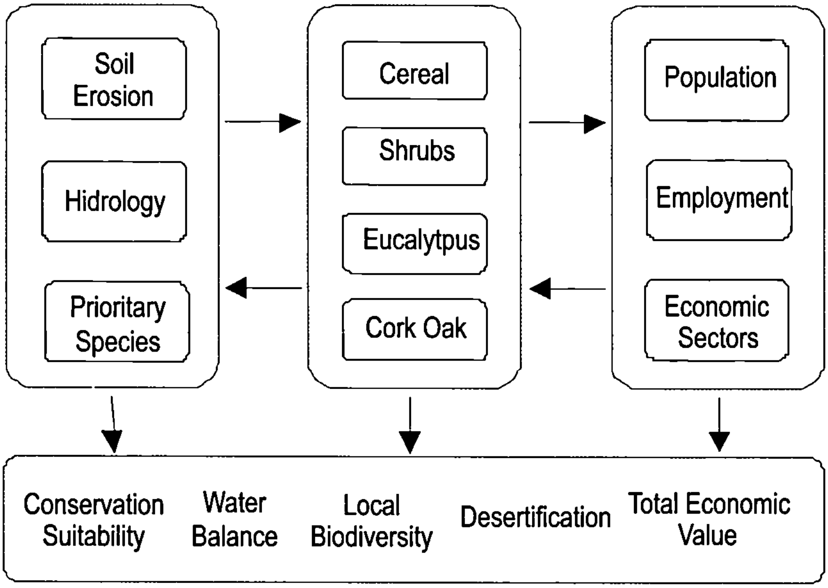

Figure 6. Overview of the model structure.

Individual interviews with most stakeholders were held in order to obtain a more clear idea of what are their current concerns and general objectives for the area. First results are summarized in Table 1, where one can already identify common objectives for the area. The most obvious consensus case is that of the possibility of breaking apart current properties into smaller units. Although with different ideas concerning the implementation of such objective in space and time, this common concern may act as a positive link to build consensus among different interest groups when one proceeds towards the impact assessment stages. On the other hand, one also identify probable emerging conflicts for the assessment stage, namely those associated with use restrictions of some habitats that are defended by the Natural Park as well as the intensive forestation of interior lands wanted by the County.

In the sequence of the individual interviews, questionnaires were prepared with the objective of refining stakeholders' definition of problems. This information is currently being used for the development of the individual scenarios, through a GIS based process of information overlay that is illustrated in Figure 7. Information concerning current land use by the individual stakeholder is first combined with "expert" suitability of land for that use, in order to identify potential areas where changes should occur. Then, with information from the stakeholders individual preferences, expectations regarding their future action in the watershed are accessed (expansion, maintenance, or contraction of the current area), in order to obtain preferable changes, under the suitability point of view. Finally, this information is combined with stakeholder's own decision-making variables and their relative importance, to derive a map showing where land should be allocated to that particular use.

Table 1. Preliminary objectives of use of the Torgal Watershed identified by stakeholders on the individual interviews:

● - *wanted* / ○ - *unwanted.*

	County	Parishes	Dir. Agriculture	Farmers	Natural Park	School
Restrict Urban Development in Coastal Fringe	●	○		○	●	
Allow Break of Large Properties in Smaller Units	●	●	●	●	○	
Allow Intensive Forestation in the Interior	●		○		○	○
Promote AgroEnvironmental Measures - EU 2078/92		●	●	○	●	
Promote Forestation with "Montado" - EU 2080/92			●	○	●	
Increase Intensive Recreation: Swimming, fishing…		●			○	
Increase Nature Based Tourism		●		●	●	●
Increase AgroTourism				●		
Promote Environmental Education Tracks					●	●
Increase Sustainable Hunting Activities		●	●		●	
Restrict Use of Important Habitats	○	○	○	○	●	
"Protected Islands" in Agricultural Fields				○	●	
Enlarge irrigated agricultural area				●	○	

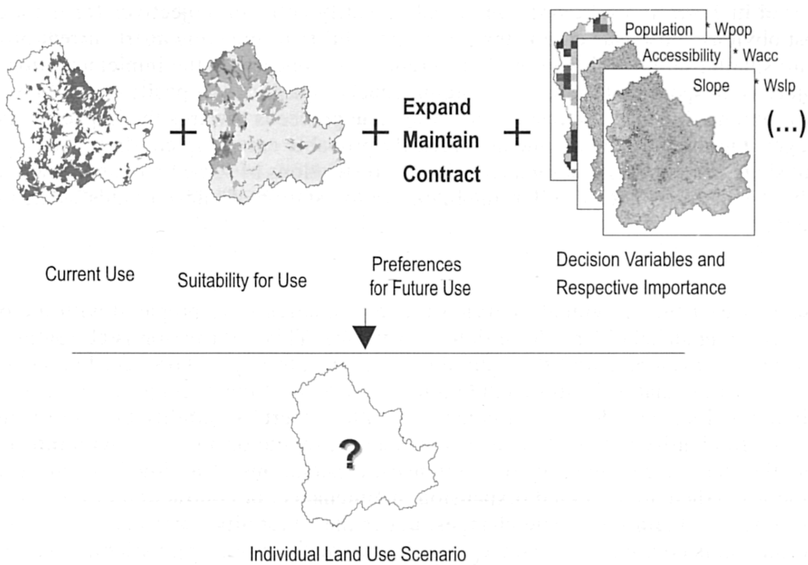

Figure 7. GIS overlay procedure for deriving "individual land use scenarios".

Conclusions

Using different approaches and methodologies for the sustainable governance of coastal areas, both projects being carried out by ECOMAN rely on the implementation of the *Lisbon Principles*. Whereas the Ria Formosa case study focuses on a scoping model that allows for an increasing awareness of problems among stakeholders, the Mira Estuary project focuses on a more decision making oriented process, where the spatial dimension cannot be neglected.

Nevertheless, both projects can be seen as an illustration of the practical application of the generic guidelines that were set up by the *Lisbon Principles*. They provide additional awareness on the interdependencies between the ecological and economic systems within the case study areas and, thus, contribute to their sustainable governance and development.

Acknowledgements

The work presented in this paper has been funded by Program PRAXIS XXI of the Portuguese National Research Foundation, through PhD scholarships BD/5469/95 and BD/13771/97 attributed to the authors Luis Jordão and Nuno Videira, respectively, and Project 2/2.1/MAR/1740/95. The project "Mediated Modeling in Ria Formosa" was funded by the Luso-American Development Foundation.

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B

Abstracts of other papers presented at the Workshop

Nutrient fluxes from land to sea in a European perspective

by

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The appearance of strongly elevated concentrations of nitrogen and phosphorus in major European rivers is normally considered to be a post-war phenomenon. In the 50s and 60s, point emissions of phosphorus increased with growing urban populations connected to sewage systems of low standard, and diffuse losses of nitrogen from agriculture increased with increased fertilisation rates. Long time series of data from rivers, such as the Rhine and the Daugava, confirm that the output to water of both nitrogen and phosphorus did increase at an unprecedented rate during the first decades after World War II. However, the relatively rapid water quality response to increased point source emissions and intensified agriculture does not imply that the reaction to decreased emissions will be equally rapid. Long-term fertilisation experiments have shown that important processes in the large-scale turnover of nitrogen in soil operate on a timescale of decades up to at least a century, and long hydraulic residence times in groundwater aquifers may cause substantial time lags in the response to changes in land use. In addition, model calculations have provided strong indications that the low nitrogen uptake efficiency in older agricultural practices caused a significant nitrogen loss to water. Finally, recently compiled data have revealed that in several major Eastern European rivers there is a remarkable lack of response to the dramatic decrease in the use of commericial fertilisers that started in the late 1980s. In Western Europe, studies of decreased phosphorus emissions have shown that riverine loads of this element can be rapidly reduced from high to moderate levels, whereas a further reduction, if achieved at all, may take decades. Together, the reviewed studies showed that the inertia of the systems that control the loss of nutrients from land to sea was underestimated when the present goal of a 50% reduction of the input of nutrients to the Baltic Sea and the North Sea was adopted.

The environmental state of a Mediterranean coastal area: Thermaikos Gulf / Greece

by

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Thermaikos Gulf is a semi-enclosed embayment in the NW Aegean Sea, with a strong ecological and socio-economical interest. It receives large amounts of fresh water through three major rivers, as well as domestic, agricultural and industrial effluents through the rivers and the sewage from the city of Thessaloniki mainly. The functioning and dynamics of this coastal environment is studied in the frame of the European Research Project "METRO-MED" (ELOISE) concerning "Matter transfer and biogeochemical studies in coastal systems".

In the framework of the above mentioned project, certain activities have been undertaken as:

- observations, measurements and data collection of selected environmental parameters concerning physical, chemical, biological and geological oceanography,
- mapping of the Thermaikos sea floor in order to evaluate the thickness of the upper sediment layer, which is influenced highly by human activities.

The collected data have shown the great amount of anthropogenic impact to the Bay of Thessaloniki resulting in severe eutrophication and even exceptional phytoplankton blooms and elevated concentrations of several pollutants.

This northern area of Thermaikos is characterized by intense eutrophic conditions in comparison with the oligotrophic Aegean ecosystem. Indicative parameters for the degree of the anthropogenic impact on this vulnerable ecosystem are the nutrient concentrations (phosphates 5.7, silicates 2.6, ammonium 5.9, nitrites 1.8, nitrates 1.7 times higher than the oligotrophic Aegean) and the phytoplankton biomass (as chlorophyll a 20 times higher) and primary production rates (as ^{14}C fixation rates) (200 times higher).

The distribution of heavy metals like Zn, Cd and Cu and organic load in the surface sediments show elevated concentrations. The concentrations drop to low levels a few centimeters below the surface. Similar behaviour is observed for the organic load.

Concerning oil pollution samples from Thessaloniki harbour were characterized by concentrations of aliphatic and aromatic hydrocarbons as much as 200 times higher than the value characterized as background concentration. In Thessaloniki harbour were 50 to 10 times higher than the normal.

The study of pesticides distribution revealed that concentrations of insecticides are in general quite low, except in the river estuaries. Chlorinated hydrocarbons concentrations (mainly DDT and its metabolites) were highest at Thessaloniki bay decreasing towards the gulf, but still detectable.

However, though the degree of pollution of the bay of Thessaloniki, according to the above described features is quite high, this area is characterized by two "advantages" acting in combination as a "self-cleaning potential" of the water masses, the general circulation of water masses in the NW Aegean and the dominating in the area northern winds.

In addition, the studies have shown that self-cleaning factors for the sea bottom also exist. These factors are: a) the existence of benthic nepheloid layer related to resuspension processes which facilitate the diffusion of the pollutants, b) the presence in the whole area of the annelids species *Maldane sarsi* (polychaete) inducing further physicochemical changes to the sediments by the bioturbation of them.

Concluding, according to the so far collected data the bay of Thessaloniki show a highly degraded ecosystem characterized by oxygen depletion, increased nutrients concentrations decrease of biodiversity, species elimination, azoic zones and also aesthetic degradation.

The immediate reduction of the pollutant loads entering the marine environment is proposed as an action for the improvement of the present conditions. The mechanisms of self-cleaning of the water and the sea bed are acting synergistically and in the close future will help the environment to react positively and finally to recover.

FAIR CT98-4399
A European database of indicator coastal communities

by

Oddmund Otterstad

FAIR CT98-4399 is a three years concerted action (starting January 1999) financed by the FAIR programme (EU DGXIV) and co-ordinated by the Norwegian University of Science and Technology (NTNU) in Trondheim. The main objective of the project is to bring together experts from different countries, academic disciplines and industry sectors, all persons who have been engaged in former projects with the aim of creating better and more policy-relevant planning instruments for European coastal areas.

Sub goals are:

1. to identify fisheries dependent areas in Europe and highlight those which are most economically and socially vulnerable;
2. to diagnose the most important macro processes (from fisheries policy, environmental change, technological change, etc) expected to influence these areas in the next decade;
3. to select a number of indicator coastal communities with fisheries dependence for comparative in-depth studies;
4. in this process, to use some of the harmonised indicators that have been developed for European rural areas with fisheries dependency, and
5. to assist those responsible for the management of the CFP with tools that will enable them more easily to assess the social and economic consequences of alternative management options

The main outcome of this project shall be a database material with special emphasis on the socio-economic conditions in European coastal areas with fisheries dependence. The structure of the database consists of three elements: a macro-material with aggregated numerical information, a micro-material with both statistics and other types of information and the "front-page": an Internet presentation.

The Internet presentation will be developed in both volume and complexity throughout the project. In the start of the project the Internet presentation will appear more like a framework with maps and national statistics. At the time of completion users from all over Europe will have access to a substantial material with both quantitative and qualitative information about the selected indicator coastal communities and the counties, regions and countries they belong to. The intention is that the database shall involve users in the collection of information and that this work shall continue even when this particular project has ended.

There will be two main processes following each other hand in hand throughout the three years project period, a "top-down" process developing the aggregated data, and a "bottom-up" process preparing in-depth materials for the selected indicator coastal communities. Within each of these activities there will be groups of researchers preparing the materials about fisheries dependent coastal areas, respectively from the macro and the micro perspective.

A third process is hardly distinguishable from the two first processes, as it integrates the two other activities by specific measures. In terms of the number of users, this third process will be the most important part of the database. Here selected information shall be made available for large groups of users. The goal of this third process is continuously to improve the public utilisation of the database material. The core element in this respect is the Internet presentation.

Mercury in products - a source of transboundary pollutant transport

by

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The purpose of this study was to estimate the contribution from mercury contained in products, to the total anthropogenic emissions of mercury to air and transboundary transport of mercury in Europe.

Products included in the study were batteries, measuring and control instruments, light sources and electrical equipment, all intentionally containing mercury.

In order to estimate the emissions of mercury from products, a simplified but systematic approach for the description of patterns of consumption and disposal of the different product categories was used. The estimated annual consumption of mercury in the product category of concern was assumed to be distributed to different "compartments" (i.e. incinerated, landfilled, re-collected, accumulated etc) from which emissions to air occur. The distribution into the different compartments was described using distribution factors, and the emissions to air from the compartments using emission factors. Separate calculations were made for each of the product groups concerned.

It was found that product-related emissions of mercury can contribute significantly to total emissions and transboundary transport of mercury in the European region. Consequently, measures to limit the use of mercury in products can contribute to an overall decrease of the environmental input of mercury in Europe.

It was concluded that:

- Mercury contained in products may be emitted to air during consumption, after disposal when incinerated or when volatilized from landfills. Mercury may also be emitted to air during recycling of scrap metal or when accumulated (stored) in society.
- The amount of mercury consumed in batteries and in measuring and control instruments has decreased since the late 1980's. The total use of mercury in light sources and electrical equipment has not changed significantly during the same time period.
- The contribution to total anthropogenic emissions of mercury to air in Europe in the mid 1990's was estimated to be <5% each for batteries and for measuring and control instruments, and approximately 10% for lighting and electrical equipment.
- Mercury in products leads to significant atmospheric emissions in Europe and results in increased wet deposition input of mercury in Scandinavia. The relative amount of the total deposition flux attributable to products was estimated to be 10-14%.

C

Workshop Agenda

Joint ELOISE/ LOICZ Workshop on

"Socio-economic Aspects of Fluxes of Chemicals into the Marine Environment"

organized in cooperation with the Norwegian Institute for Air Research (NILU) Kjeller, Norway, 8 – 10 March, 1999

Agenda

Monday, 8 March, 1999.

9:30 - 10:00	Registration, coffee

Session 1. Chairperson: Wim Salomons

10:00 - 10:30	Welcome Workshop objectives and structure Introduction of participants
10:30 - 10:55	Global Change: the LOICZ approach, invited paper by C. Crossland
10:55 - 11:15	Biogeochemical cycling and flux studies within ELOISE projects, by J.M. Pacyna
11:15 - 11:40	Effects of changes in external forcing or boundary conditions on coastal fluxes, invited paper by W. Salomons
11:40 - 12:05	Pressure factors having impact on the level of fluxes and the state of the environment, invited paper by N. Pirrone
12:05 - 13:00	Lunch at NILU

Session 2. Chairperson: Chris Crossland

13:00 - 13:25	Nutrient fluxes to the water column - accuracy requirements, measurement issues, model performance, and research needs, invited paper by G. Geernaert
13:25 - 13:40	Nutrient fluxes from land to sea in a European perspective, by A. Grimvall
13:40 - 13:55	The fate of nutrients from the source to the load into the sea: results for German river systems, by H. Behrendt
13:55 - 14:10	River to estuary fluxes in the UK LOIS Study - User's relevance and applications, by G. Leeks
14:10 - 14:25	The environmental state of Mediterranean coastal area: the Thermaikos Gulf/ Greece, by C. Anagnostou
14:25- 14:40	Consequences of mining and industrial activities for metal contamination in the Gulf of Cadiz (Southern Spain) and metal fluxes at the Strait of Gibraltar, by F. Elbaz-Poulichet
14:40 - 15:00	Tea/Coffee

15:00 - 15:15	Mercury in products - source of transboundary air pollutant transport, by J. Munthe
15:15 - 15:30	Coastal management and sustainability in Baltic East Germany: learning from Scandinavia, by B. Glaeser
15:30 - 15:45	Socio-economic aspects of atmospheric nitrogen loads to coastal marine waters, by O. Hertel
15:45 - 16:00	Transfer of scientific results to end-users: an example from Denmark, by B. Lomstein
16:00 - 16:15	FAIR CT-4399: A European database of indicator coastal communities. A comment to the theme of the ELOISE/ LOICZ Workshop, by O. Otterstad

Possible other contributions and general discussion

19:00 - Workshop Dinner

Tuesday, 9 March, 1999

Session 3. Chairperson: Nicola Pirrone

9:30 - 9:55	Methodologies for integrated modeling and analysis in the coastal zone, invited paper by T.K. Turner
9:55 - 10:20	Users needs with respect to the application of integrated assessment of environmental and economic consequences of fluxes of chemicals in the coastal zone, invited paper by H. Kremer, J. Köhn and M. Scheffers
10:25 - 10: 50	Building bridges: strategies for linking science with users, invited paper by C. Crossland
10:50 - 11:10	Coffee/tea
11:10 - 11:25	Ecological-economic dynamic spatial modelling for coastal watershed management, by S. Martinho
11:25 - 12:20	Introduction into the Workshop discussions, by J. Pacyna and H. Kremer
12:20 - 13:20	Lunch at NILU
13:20 - 15:00	Workshop discussions in parallel sessions
15:00 - 15:20	Tea/coffee
15:20 - 17:00	Workshop discussions in parallel sessions continue

Wednesday, 10 March, 1999

9:30 - 10:00	Summary of the discussions on Tuesday, short reports by rapporteurs in plenary
10:00 - 11:00	Discussion continues in parallel sessions
11:00 - 11:20	Coffee/tea
11:20 - 12:00	Discussion continues in parallel sessions, cont.
12:00 - 13:00	Final discussions, draft conclusions and recommendations, plans for publication of the Workshop proceedings (in plenary)
13:00	Closure of the Workshop
13.05 - 14:00	Lunch at NILU

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The main goal of the Workshop was to discuss the means of transferring knowledge from the Eloise and LOICZ projects on the impact of socioeconomic drivers and pressures on the coastal zone into policy-making procedures. The monograph includes a set of invited papers on socioeconomic and environmental aspects of fluxes of chemicals to the marine environment and the consequences of these fluxes, and short contributions from the workshop participants on their research related to the topic of the meeting. An important part of the monograph is a set of reports from the three working groups formed at the workshop to discuss the coastal science limitations and communication links between scientist and the users of the coastal zone science. This discussion resulted in a set of conclusions and recommendations, also presented in the monograph.

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