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Coastal Fluxes in the Anthropocene

The Land-Ocean Interactions in the Coastal Zone Project of the International Geosphere-Biosphere Programme

With 121 Figures

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Preface

In an ever-changing world, the global coastal zone stands out as an area of extraordinary changes. These changes are shaped by natural processes and phenomena that influence the Earth systems – on land, in the ocean, in the atmosphere, at their interfaces and at planetary scales – and ensure a dynamic coastal environment that has continued to respond and adapt biologically, physically and chemically in unique ways. Now there is a greater catalyst for change in the coastal zone – human society – impacting directly on coastal processes and systems and indirectly through modification of the natural processes and events.

The world's coastal zone is a long narrow feature of mainland, islands and adjacent seas denoting a zone of transition between land and ocean. Humans have lived in the coastal zone for millennia utilising its many and rich resources for their survival and socio-economic benefit. The coastal zone is the area where 25% of global primary productivity occurs, and it supplies about 70% of global fish catch. Some 50% of the people in the world live in this relatively small but highly productive, highly valued and highly dynamic domain which occupies 12% of the surface of the Earth. The density of coastal populations varies dramatically among different coastal regions, and there is a general trend of people moving from inland regions to the coast. The richness and diversity of resources found in coastal areas has long been recognised by humans, and there has been a corresponding concentration of human activities and settlements along shorelines and estuaries throughout the world. It is clear that the coast will continue to sustain the livelihoods of a very large proportion of the human population, both those living there and those living inland. The coastal zone is therefore an important asset to people worldwide.

At the same time, the coastal zone is a domain of constant change and one of the most threatened areas on Earth. Changing wave and current regimes, climate, morphological processes and fluxes of materials between land, atmosphere and oceans are causes of high natural variability which is still imperfectly understood. In the last several decades, with their increasing technological capabilities, humans have accelerated the rate of change and increased their influence on already highly variable ecosystems (Steffen et al. 2004). Pollution, eutrophication, changing sediment load, urbanisation, land reclamation, overfishing, mining and tourism continuously threaten the future of coastal ecosystems. Impacts on the coastal zone originate locally, regionally and globally, and an understanding of these impacts is now obligatory within the context of global change, including climate change. Although most impacts are addressed at local and regional levels, the scale of development and population growth along all coasts of the world is increasing such that it has become a truly global issue. Despite the rapidly increasing knowledge about coastal ecosystems, crucial questions on the causes of natural variability and the effects of human impacts are still unanswered. Although the perception of environmental managers of our coasts is shifting from one of mainly short-term economic approaches towards long-term economic, ecological and sustainable perspective, the need for this shift in management practice is often ignored or difficult to communicate to policy-makers. In particular there is a widespread ig-

norance among coastal stakeholders of the multiplicity of temporal and spatial scales across which coasts are affected including the continuum from river catchment to the coastal ocean (Meybeck and Vogler 2004). The major challenge that we face today is managing the human use of coastal habitats so that future generations can also enjoy the many visual, cultural, edible products and sustainable resources that they provide.

Sustainable use and protection of the Earth's coastal areas are now items high on international agendas. The increasing international instruments, such as the United Nations Convention on the Law of the Seas (UNCLOS), Rio Agenda 21, and the Conventions on Wetlands, Biodiversity and Desertification provide important mechanisms for coastal management.

The need for increased knowledge about global change and its ramifications for the functioning of Earth systems motivated the establishment by the International Council for Science (ICSU) in the late 1980s of the global research initiative – International Geosphere-Biosphere Programme: A Study of Global Change (IGBP) which aims "*to describe and understand*

- *the interactive physical, chemical and biological processes that regulate the total Earth system,*
- *the unique environment that it provides for life,*
- *the changes that are occurring in the system, and*
- *the manner in which they are influenced by human actions.*" (*http://www.igbp.kva.se*)

The Land-Ocean Interactions in the Coastal Zone (LOICZ) project was established in 1993 as one of eight core projects of IGBP, and was directed to provide scientific information to answer the IGBP core question: "*How will changes in land use, sea level and climate alter coastal ecosystems, and what are the wider consequences?*"

Fundamental to answering this question is the need to recognise that the coastal zone is not a geographic boundary of interaction between the land and the sea but a global compartment of special significance, not only for biogeochemical cycling and processes but increasingly for human habitation and economies. Also, the spatial and temporal heterogeneity of the world's coastal zone is considerable. Consequently, challenging methodological problems are associated with developing global perspectives of the role of the coastal zone compartment in the functioning of the Earth system. Clearly, a useful and practical knowledge of the globally heterogeneous coastal zone depends on harnessing an array of research from natural and social sciences and integrating with those both anthropocentric and geocentric forces of change. The LOICZ project is designed to encompass these elements in providing science information to the global community, which should then be of use to decision-makers and coastal zone managers globally.

The LOICZ Science Plan (Holligan and de Boois 1993) developed four overarching objectives to address the IGBP question:

1. To determine at global and regional scales: the fluxes of materials between land, sea and atmosphere through the coastal zone, the capacity of coastal systems to transform and store particulate and dissolved matter, and the effect of changes in external forcing conditions on the structure and functioning of coastal ecosystems.
2. To determine how changes in land use, climate, sea level and human activities alter the fluxes and retention of particulate matter in the coastal zone, and affect coastal morphodynamics.
3. To determine how changes in coastal systems, including responses to varying terrestrial and oceanic inputs of organic matter and nutrients, will affect the global carbon cycle and the trace gas composition of the atmosphere.

4. To assess how responses of coastal systems to global change will affect the habitation and usage by humans of coastal environments, and to develop further the scientific and socio-economic bases for the integrated management of coastal environments.

These objectives, however, do not imply that LOICZ is actively undertaking coastal zone management, but rather it is providing knowledge and tools that underpin options for alternatives in development and decision-making. A clear goal is to provide a sound scientific basis for future sustainable use and integrated management of the components of coastal environments, under conditions of global change.

Following consultation with scientists globally, the LOICZ Implementation Plan (Pernetta and Milliman 1995) identified the array of issues and science that needed to be addressed, recognising the large (and somewhat prohibitive) funding requirements for a global coastal research programme. Operationally, LOICZ focussed on gaining an understanding at global scales of the following questions:

- Is the coastal zone a sink or source of CO_2?
- What are mass balances of carbon, nitrogen and phosphorus in the coastal zone?
- How are humans altering these mass balances, and what are the consequences?
- What is the role of the coastal zone in trace gas (e.g., DMS, NO_X) emissions?
- 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?
- How can knowledge of the processes and impacts of biogeochemical and socio-economic changes be applied to improve integrated management of the coastal environment?

For the last decade, LOICZ has addressed these questions by focussing on horizontal material fluxes and scaling of processes through the application of environmental and socio-economic sciences. These activities have used results from research programs and contributions of individual scientists, and LOICZ has built a large network of researchers across more than 80 countries to develop collaborative and interdisciplinary projects to meet the goals outlined in the LOICZ science plan and implementation strategy.

This book provides a synthesis of the LOICZ work during its first decade ending 2002. It represents a milestone rather than a destination for the journey of collaborative inquiry into material fluxes and human interactions in the coastal zone. While compilation of the individual chapters have been the responsibility of the identified authors (see Authors and Contributors), the overall work represents an enormous amount of effort and research by many thousands of scientists who have contributed to the LOICZ enterprise. Some of these many contributions are found in LOICZ publications from workshops that have addressed regional and thematic coastal science (see Appendix A.1) as well as in the wider scientific literature.

This book addresses key elements of material flux in the coastal zone and indications of change, then draws together the biogeochemical information with an assessment of the influence of human society, before looking at future needs for targeted research and management actions in the coastal zone.

Chapter 1 provides a description and operational definition of the coastal zone. By discussing its spatial and temporal heterogeneity and natural variability, the authors differentiate between variability and change, and consider the dynamics of human population as a forcing factor for change. Changes in the intensity and extent of human drivers and pressures for change are outlined, along with a consideration of economic valuation of coastal resources and services. The challenges in assessing change at global scales and the approaches taken by LOICZ are presented, especially the new tool of typology.

Chapter 2 addresses the dynamics of a changing coastal boundary. Projections in sea level fluctuation are reviewed along with the implications for changed coastal and shoreline vulnerability. Changes in sediment and water fluxes to the coastal sea are undergoing major changes. The magnitude of the changes and their ramifications on coastal and estuarine morphologies are highlighted, noting especially the role of dams and reservoirs, other water impoundments and coastal water extraction. Submarine groundwater discharge is discussed, including new methods for assessment, the biogeochemical implications of these fluxes and the need for improved understanding and appropriate management of this regionally important freshwater resource.

Chapter 3 examines the biogeochemical fluxes of nutrients, especially carbon, nitrogen and phosphorus transport and transformations, within the coastal zone. The question of whether the coastal zone is a source or sink for carbon is examined. The role of estuaries and coastal seas as "incubators" of inorganic nutrients is assessed, including a system's capabilities as a region for net nitrogen gas release or retention. New estimates of inorganic nutrient discharge from river catchments are derived that show significant changes in loads to the coastal seas within the last 30 years. The typology approach developed by LOICZ is used to aggregate the many estimates of metabolic performance by relatively small-scale estuarine and coastal sea ecosystems to achieve global measures of nutrient and net metabolic changes, especially those related to nutrient discharges from the land.

Chapter 4 develops a broad picture of river catchment drivers and pressures and their impacts on coastal change. Where available, information on related governance response is provided. By looking at the river catchment-coastal sea continuum as a single system, the authors address individual catchment assessments and extrapolate information to regional or continental scales. Coastal change issues and related drivers are ranked, based on mostly qualitative information, including the identification of critical loads and thresholds for system functioning or geomorphologic stability. The regional difference in the relative role played by specific drivers in imposing coastal change, such as damming, intense agricultural, land use and urbanisation, are highlighted and expected trends are identified.

Chapter 5 provides a synthesis of major scientific findings determined in the first four chapters. It addresses the "So What?" relevance question by considering the ramifications of the findings for policy- and decision-makers involved in governance and management of the coastal zone. In so doing, the authors provide a glimpse of the remaining challenges and future directions for the next decade of LOICZ activities and the wider coastal community.

Text boxes have been used throughout the book to give both details on methodologies and examples of case studies which are referred to in the text. The Appendix includes a list of key LOICZ publications and abbreviations to assist the reader.

The LOICZ project is continuing into a second phase within IGBP, building on the findings and gaps identified here and responding to a new priority of issues that have emerged from discussions engaging the global scientific community and institutions. The new project has shifted in focus towards highlighting the societal and environmental management dimensions of coastal material fluxes (LOICZ II Science Plan and Implementation Strategy; *http://www.loicz.org*). LOICZ is expected to become the major contributor of interdisciplinary coastal science to the second stage of the IGBP and the International Human Dimensions Programme (IHDP), and to the Earth System Science Partnership of IGBP, IHDP, WCRP and DIVERSITAS.

Han Lindeboom

Chair, LOICZ Scientific Steering Committee 1997–2003

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