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## Foreword

## Vulnerability of intertropical littoral areas



The coastal zone is of very high importance for human development and human wellbeing. Half of the global urban population lives in the coastal zone, where it has access to both continental and marine ecosystem services and to maritime transport. These urban populations coexist with rural and traditional coastal populations, some of which still possess good traditional ecological knowledge of the coastal ecosystems. Marine biodiversity and favourable environmental conditions sustain fisheries and aquaculture, represent a source of inspiration for humankind and provide numerous opportunities for recreation and tourism. In addition, coastal areas provide nursery functions for juvenile fish and invertebrates, which is important for the fish and crayfish stocks exploited offshore. Located at the interface between marine energy and continental processes, the coastal landscapes are dynamic environments. Nevertheless, the destruction of habitats and the increasing exploitation of the coastal zone represent serious threats to the ecosystems. Moreover, human land use and modifications in the watersheds have strong impacts on the coastal zone primarily by contributing to their pollution and nutrient over-enrichment. Damming and creation of reservoirs upstream also heavily modify the hydrology of the watersheds and often dramatically reduce the delivery of sediments to the coastal zone. In addition to these regional and local anthropogenic impacts, the coastal zone is vulnerable to global change among which sea level rise and climate change are particularly important drivers. Many coastal zones extend along giant faults and subduction zones, which makes them particularly exposed to earthquakes and tsunami hazards. Other forms of natural hazards are caused by hurricanes and cyclones that develop at sea and whose trajectories often hit the coastlines.

The question on how to combine the conservation of the highly valuable coastal ecosystems and their sustainable exploitation with the strong socio-economic development in the coastal zone is a major challenge for humankind in the 21<sup>st</sup> century. This requires both a high degree of political will and appropriate governance together with

sound scientific knowledge. Hence, many international and national organisations for research and development work in the coastal zone to contribute to the objectives of sustainable development. The French IRD is one of them, as it develops research in tropical and subtropical countries in partnership with their respective national institutions.

This thematic issue provides a collection of results that illustrates the involvement of IRD, of its partners, and of other national and international groups working in the field of tropical and subtropical coastal environments. Overall, the objectives of the research include: (i) to identify the major forcing factors and drivers of changes and to understand the mechanisms involved, (ii) to examine the possibility of a harmonious existence between socio-economic development and biodiversity conservation and to study potential conflicts in the physical and biological systems as well as in human societies, (iii) to develop observables, indicators and techniques to monitor the coastal zones and the processes at play in order to alleviate the impact and threats of natural hazards.

For this purpose, the coastal systems' vulnerability is "instrumental". Vulnerability is a concept that relates to the extent to which perturbations, including hazards, threats, and disturbances, can harm a system and push it into a different and often undesired state. Hence, vulnerability provides a measure of the propensity of the system to sustain change induced by these perturbations. As such, it is related to the concept of resilience, which describes the capacity of a system to absorb a perturbation while maintaining its integrity in the long term, although it often goes through a temporary period of deviation. These concepts can be applied to geophysical and ecological systems. Moreover, when the objective concerns the interdependence of people and their surrounding ecosystems, it is appropriate to adopt the concept of socio-ecological systems for vulnerability assessment.

Three articles in this issue have a main focus on understanding the processes that drive coastal morphology and how these can be impacted by natural forcing.

Indeed, coastal erosion is a very important issue for coastal populations that may endanger their livelihood and survival. Besset et al. (this issue) analyse the impact of the 2008 cyclone Nargis on the geomorphology of the Ayeryarwady delta (Myanmar, formerly Burma) by using a combination of data including remote sensing, meteorological (precipitation, wind speed and trajectory of the cyclone) and measures of suspended particles. They show that the cyclone induced a strong erosion of the coastline that persisted two years after the event, thus demonstrating the lack of resilience of this deltaic system. Aucan et al. (this issue) characterise the different types of waves that occur in the coral-reef lagoon of New Caledonia. They discuss the possible impact of three different wave types on the local erosion and accretion of small islands in the lagoon. More work is needed to establish these links more precisely. However, they interestingly point out that the so-called infragravity waves, which form by breakage of low-frequency waves on the coral reef, may have a high impact on the islet erosion, in addition to the more common high-frequency waves generated by wind. Gratiot et al. (this issue) focus their study on the Mekong delta in Vietnam where damming across the Mekong River has markedly reduced the delivery of sediment particles. They argue that, to understand the sedimentation in the delta and its ability to counteract the coastal erosion, a sound understanding of the dynamic behaviour of sedimentary flocs in suspension is necessary. Using field studies and laboratory experiments, the authors determine the influence of sediment concentration, turbulence and differential particle settling on the flocculation process. They find that flocculation by differential settling is a predominant factor for siltation in quiescent environments. This process is evidenced in the inner mangrove fringe, where sediments are indeed currently depositing rapidly, modifying the equilibrium of the delta zone.

Five articles have a major focus on the impacts of anthropogenic drivers of change in the coastal environments, among which three address the impacts on the socio-ecosystems and two are more methodological. Duval et al. (this issue) focus on the changes in the deltas of the main rivers in Eastern Africa and Madagascar. By upstream damming in many of those rivers, the seasonal flooding has decreased or disappeared with a negative impact on the productivity and delivery of ecosystem services to the traditional local populations. The authors adopt a socio-ecosystem approach to analyse the various management models, and they highlight contradictory approaches between commercial hydroelectrical companies and conservation actors. They argue that these tensions could be eased by maintaining or restoring the natural hydrodynamics through managed flood releases. Mohamed et al. (this issue) analyse the water table in Nouakchott, the coastal capital of Mauritania, and show that, paradoxically, its water table has risen despite its arid climate. This is explained by large water importation from an external source (the Senegal River) to the city for human consumption, with this excess water eventually returning to the ground and filling the natural aquifer. The rise is documented by piezometric observations and its interaction with a saline intrusion from the Atlantic is studied

with chemical analyses and isotope data. The current increase in the water table causes regular flooding, damages the buildings and infrastructure, and creates human health issues. Araujo et al. (this issue) use Landsat satellite data to show the regression of the mangrove surface in the Sepetiba Bay, Brazil, over the last 30 years, and the concomitant increase in the urbanised area. In addition, they analyse the chemical composition of the intertidal sediment flats and document the pollution of the sediments by an ancient electrical plating plant. However, the metal contamination is relatively modest in the bay and the authors suggest that mangroves contribute, by absorption, to the abatement of the contaminant levels. The authors conclude that the ongoing decrease in the mangrove cover may enhance the pollution of the bay in the near future.

Two methodological articles focus on the problem of bacterial contamination in the coastal zone. Rio et al. (this issue) develop a “precipitation index” (API, based on the precipitation accumulated during the last 10 days), and use it as a predictor for the amount of faecal pathogen bacteria in the outflow of the tributaries into the coastal zone, and for their concentration in the coastal waters. Although this tool has been developed for a Mediterranean context (NW Mediterranean, Nîmes–Montpellier region), it is expected that it can easily be adapted and implemented in tropical and subtropical environments. Almakki et al. (this issue) develop a new method to study the resistance to antibiotics of the bacteria communities contained in fresh continental and brackish coastal waters. The method is based on culturing bacteria isolated from those environments, in different conditions of antibiotic concentrations (three antibiotics tested). The analysed bacteria are found to be resistant, even when growing in waters with high concentrations of antibiotics. The resistance is more pronounced in brackish lagoon waters. The occurrence of resistant bacteria is problematic as the resistant communities include some pathogens that may represent severe health problems for humans. Again, while the method was here developed in a Mediterranean context (NW Mediterranean, Montpellier region), the authors argue that it can easily be adapted to tropical and subtropical environments.

Two articles together consider the impacts of both natural and anthropogenic drivers of change. Grenz et al. (this issue) review the existing information of the benthic ecology (i.e. the ecology of the communities living at the seafloor and in the intertidal sediments) in the Terminos lagoon, Mexico. Most of this information is synthesized from grey literature in Spanish. The large Terminos coastal lagoon has been subjected to important anthropogenic forcing over the last decades. Primarily, strong urban and harbour development in Ciudad del Carmen on the coastal barrier is related to the development of offshore oil extraction in the adjacent Gulf of Mexico. This is reflected by the presence of contaminants (polycyclic aliphatic hydrocarbons, chlorinated compounds and heavy metals) in the sediments, the water and the tissues of certain animals in the lagoon. Another important driver is deforestation of the watershed that has led to modifications in hydrology and sediment loadings to the lagoon. The authors argue that these environmental changes will

interact strongly with global changes, particularly seawater rise, and advocate the importance of developing monitoring programs to anticipate the forthcoming ecosystem changes in the Terminos lagoon.

To understand and anticipate the rapid evolution of the coastal zones, it is necessary to monitor it through the acquisition of long time series of high-resolution data. The most appropriate approach is to settle permanent observatories in pilot sites representative of the zones and evolutions under concern. Mahabot et al. (this issue) provide recommendations on what such an observatory should be to monitor the morphological changes of coastal beaches in an intertropical reef environment. The recommendations are illustrated on the Ermitage back-reef beach site in La Réunion Island, where the authors have collected long series of data. The authors present recent technologies such as TLS, Structure from Motion photogrammetry and Lidar bathymetry to repeatedly acquire high-resolution topographic and bathymetric data over large areas at a low to moderate cost. The acquired data can then be used to quantify the ongoing morphological changes of the coastal areas.

Finally, three papers examine the current paradoxes in the management of the littoral areas and question how this management will allow the sustainable development of these zones. Cormier-Salem et al. (this issue) focus on the Can Gio mangrove in the Mekong delta. They present a pilot study that involves biologists and social scientists in defining together the ecosystem services delivered by the mangrove. They compare the seafood and micro-organisms production in several areas of the Can Gio mangrove biosphere reserve, characterized by different management policies. They confront the results with the local fishers' perception of seafood diversity and their knowledge of the protection measures. The inhabitants have a good knowledge of the need to protect the mangrove, and this might favour the fair preservation of the biodiversity that is observed in the study. More work needs to be done however to validate this hypothesis, and the authors advocate the need for further interdisciplinary studies on mangrove ecosystems services. Claeys et al. (this issue) give an insight on a topic in the current front news: the paper aims at characterizing the differential vulnerabilities to environmental hazards of two coastal towns of Guadeloupe. The study explores the historical, legal and

socio-economical context of the two cities to explain the current complexity of the coastal management in Guadeloupe and to understand the drivers of the population vulnerability. The study highlights the adverse effects of well-intended public policies that, instead of reducing the risks for the coastal populations, have weakened the legal situation of the most vulnerable. It also shows that reducing vulnerability is a question of political and socio-economic resources. The analysis of the socio-political framework is also the objective of the paper by Mazé et al. (this issue). In this conceptual paper, the authors advocate the need to combine social science (sociology, political anthropology, history) and natural science to analyse the current coastal management issues. They shed light on the importance of taking the details of the power relationships between stakeholders and their history into account, and not simply applying general globalized management models and concepts.

Most of the papers in this thematic issue demonstrate that the processes at work in the coastal zones are both natural and anthropogenic, both interacting strongly to determine the vulnerability of coastal systems. This statement is true for most earth systems but especially relevant for the coastal zone where natural and social dynamics are deeply intertwined in the causes and responses to risk and vulnerability. An interdisciplinary approach is generally advocated. This special issue is thus a call to strengthen interdisciplinary approaches and develop new transdisciplinary research to monitor and describe the dynamics at work in the coastal socio-ecosystems.

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