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Land–sea interactions at the east coast of Hainan Island, South China Sea: A synthesis

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ABSTRACT

The structure and function of coastal ecosystems is affected by land-based human activities, including changes in water, sediment and pollutant input, as well as land reclamation in coastal areas. Many coastal areas can be considered over-stressed systems as a whole, the ecosystem services of which are strongly impaired. This is particularly important in tropical regions, where the coastal zone is under the influence of a strong climate variability including monsoons and frequent extreme weather events, such as typhoons. During the past decades the continuous development of Hainan's coastal zone and its hinterland, in combination with episodic natural events (e.g., typhoons), caused environmental changes in its coastal ecosystems. However, little is known on the consequences of environmental changes for the biogeochemistry and ecology and, hence, the natural resources of the Hainan coastal ecosystems. The Sino-German inter-disciplinary LANCET (land–sea interactions along coastal ecosystems of tropical China: Hainan) project was designed to address these issues on a local to regional scale and at the same time, to contribute to the global data base in which this type of information from tropical regions is still under-represented. The results obtained from LANCET have been delivered to the local government for an adaptive management at the ecosystem level, and the knowledge is believed to be relevant to other studies of tropical and coastal regions.

1. Introduction

Land-based human activities such as agriculture, deforestation and/or hydraulic engineering (e.g., dam construction) have altered dramatically riverine hydrology, as well as material fluxes to the ocean, entailing consequences such as eutrophication and changes in community structure (i.e., phytoplankton) of coastal and marine ecosystems (Alongi, 2003; LOICZ, 2005; Jennerjahn, 2012). On a regional scale, coastal ecosystems are often under stress due to sewage disposal, destructive fishing practices, aquaculture and tourism (Fabricius, 2005; Huang, 2005). Natural disasters are other hazards to coastal ecosystems which bear the potential of severe damages; tropical storms and flood events are of particular importance, within this context, in the south and southeast Asian region (World Resources Institute, 2011).

The tropical and subtropical coastal ecosystems of the Asia-Pacific Region are affected by substantial changes in both the land and the coastal sectors. They possess an enormous marine biodiversity, but suffer from impacts from a high population density and rapid economic development, a major result of which are the high material inputs from land-based sources (i.e., rivers). Furthermore, tropical and subtropical coastal ecosystems of the Asia-Pacific region are exposed to the above mentioned climatic and oceanic influences, e.g., monsoons. Therefore, these areas are particularly vulnerable to the combined effects of land-based human activities and ocean-/atmosphere-based extreme events. Similar to other tropical environments, fringing coral reefs and related food-webs in the coastal waters of Hainan are of critical importance for the local communities, because of the goods and services they provide, such as fishery resources, coast protection, tourism etc. However, in Hainan, overfishing and destructive fishing practices (e.g., dynamite and cyanide fishing), coastal engineering and brackish water aquaculture have considerably changed the structure and function of fringing coral reefs which, in extreme cases, have caused the extinction of important marine species (Huang et al., 2006). Therefore, knowledge of the status and functions of coral reefs, as well as of the connectivity between individual coastal habitats, is required to manage ecosystem in a sustainable and adaptive way.

Hydrodynamics and climate-related events in meso- and basin-wide scales can modify the function of coral reefs.

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These need to be understood, in order to discriminate between perturbations caused by changes in climate and oceanography and those caused by regional human activities. Off the east coast of Hainan Island, the monsoon drives the seasonal pattern of coastal circulation in surface waters of the South China Sea, for instance, upwelling in summer and down-welling in winter (Su, 1998; Zhang and Su, 2006). In addition, changes in river discharge and material transport to the ocean, as well as the operation of aquaculture can dramatically alter the hydrographic properties and water chemistry in coral reefs and other coastal habitats.

Coastal and marine ecosystems feature a complex mosaic of food web connections. In particular, coastal waters off Hainan embody diverse habitats, including lagoons and estuaries, sandy beaches, mangroves, sea-grass beds and fringing coral reefs. These habitats are key territories for the socio-economic progress of Hainan Island. Over the last 50–60 years, Hainan's coastal zone and its hinterland underwent considerable changes, due to continuously increasing human activities in combination with episodic natural events (e.g., typhoons); this is especially characteristic following the 1980s when China launched the economic innovation and later the establishment of Hainan Province, in 1988. However, little is known on the extent of environmental changes and the consequences for the biogeochemistry and the ecology of coastal ecosystems. Therefore, the interdisciplinary project LANCET was designed to address these issues on a local to regional scale and, at the same time, to contribute to the global data base in which this type of information from tropical regions is still under-represented.

2. Hainan Island: Environmental and socio-economic settings

Hainan Island is located in the northern part of the South China Sea at 18.10–20.10°N and 108.37–111.03°E and it has a surface area of 35.4×10^3 km^2 (Fig. 1). Its climate is dominated by monsoons, with northeast winds in winter (i.e., November to March) and southwest winds in summer (i.e., May to September), with April and October being the transitions between the two monsoon periods. The annual average temperature of Hainan Island is within the range of 22.8–25.8 °C; rainfall ranges between 961 and 2439 mm yr^{-1}, with ca. 80% of it occurring between May and October, when the southwest winds dominate (Statistical Bureau of Hainan Province, 1994–2011). The landscape of Hainan Island is characterized by mountains in the central part, with the Wuzhishan (Note: "shan" means mountain in Chinese) reaching an elevation of 1867 m above sea level, and hills and alluvial plains in the coastal areas. The vegetation is typical tropical broadleaf forests and grass-forbs communities in the high elevation areas (elevation: >500–1000 m), scrub-dominated (e.g., evergreen and deciduous dwarf forest) and cultural crops (e.g., rice, corn and sugarcane) landscapes in the lowlands There are coconut trees along the sandy beaches and mangroves, with muddy sediments in the intertidal coastal areas (Committee of Vegetation Map of China, 2007).

Altogether, there are about 100 rivers with a drainage area of over 100 km^2 each, on Hainan, about 40 of these discharges into the South China Sea; they have a total discharge of ca. 31.0×10^9 m^3 yr^{-1}. In this region, 80–85% of the runoff occurs in the rainy season (Committee of Encyclopedia of Hainan, 1999). Rivers on Hainan have a relative short course (i.e., <300–350 km) and hence, a high elevation to length ratio (i.e., H/L). For example, Wanquanhe (Wanquan River) (Note: "he" means river in Chinese), on the east coast of Hainan Island, has a river length of 156.6 km and an elevation difference of 523 m (i.e., $H/L = 3.34 \times 10^{-3}$). Concentrations of 55–197 mg l^{-1} for total suspended matter (TSM) are typical for Hainan rivers, which is relatively low compared to the river systems of mainland of

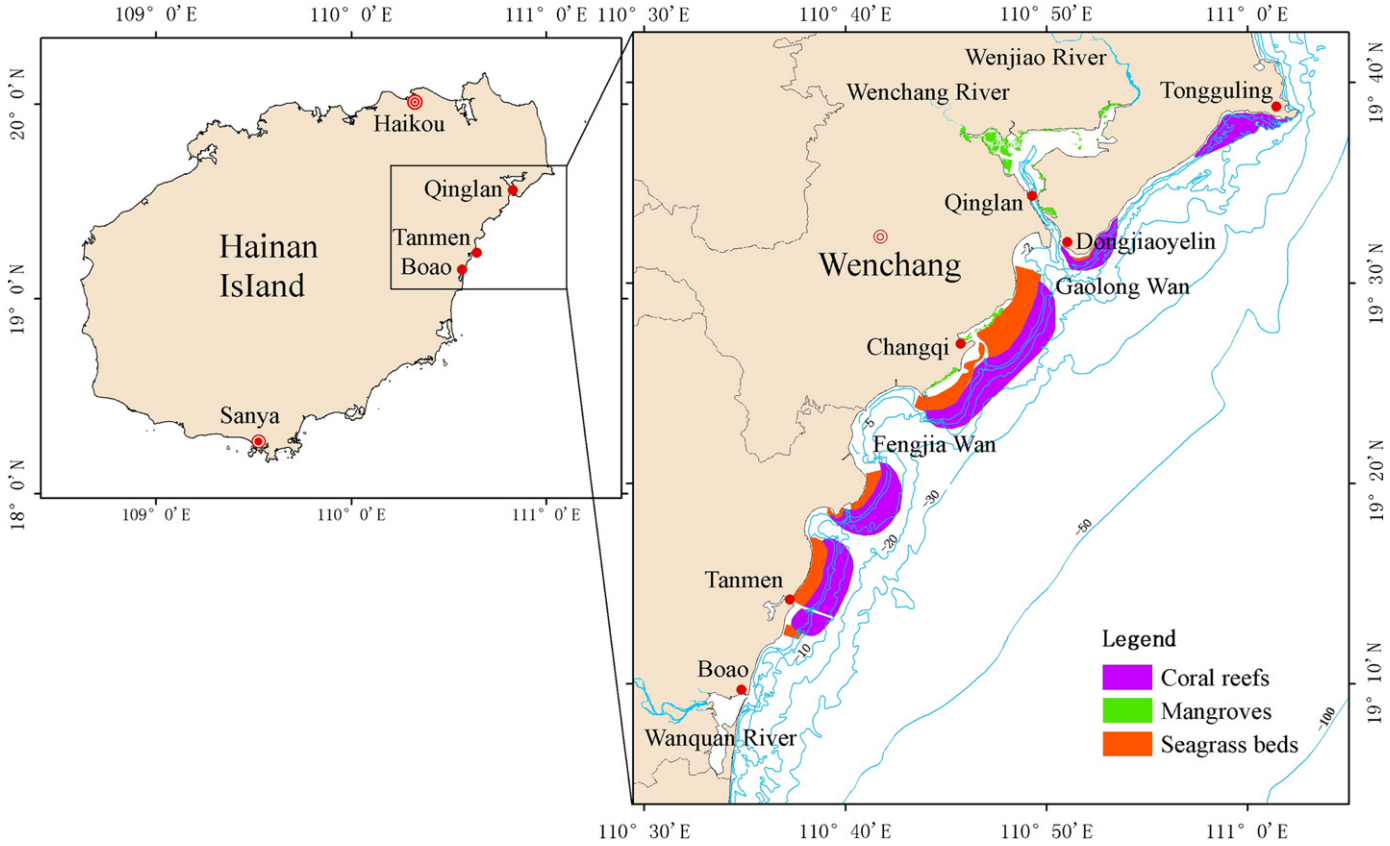

Fig. 1. Study area of the LANCET project, showing the major coastal environments, including mangroves, sea-grass beds and fringing corals.