Continental Shelf Research 57 (2013) 1–2

Contents lists available at SciVerse ScienceDirect

Continental Shelf Research

journal homepage: www.elsevier.com/locate/csr

Editorial

Land–Sea interactions in tropical ecosystems of Hainan, China

ARTICLE INFO

Keywords:
Environmental change
Estuaries
Seagrass
Coral reefs
Mangroves
China

Tropical coasts are particularly vulnerable to global environmental change. While climate change is effective around the globe, human modifications of the coastal zone are much more intensive in the densely-populated tropical and subtropical zones than in the less populated higher latitudes. Along the South and Southeast Asian coasts, naturally high fluxes of land-derived substances into the ocean meet with high marine biodiversity, fast growing population and economies, and a high frequency and intensity of natural hazards, i.e., tectonic activity and weather extremes (e.g., Berz et al., 2011; Groombridge and Jenkins, 2002; Martinez et al., 2007; Seitzinger et al., 2010; Milliman and Farnsworth, 2011). A global analysis found severe threats to human water security and river biodiversity, particularly in tropical and northern hemisphere temperate regions which is, to some extent, offset by a massive investment in water technology in rich nations (Vörösmarty et al., 2010). In that respect, human water security and river biodiversity are highly threatened along China's coasts.

While its contribution to China's gross domestic product is decreasing, the portion of land used for agriculture is still growing and, hence, the potential impacts on rivers and downstream aquatic systems. However, aquaculture is the fastest growing food sector worldwide over the past four decades and China is by far the largest producer of aquaculture goods in the world (FAO, 2010). While the anthropogenic nutrient load of coastal aquatic systems is traditionally ascribed mainly to agriculture, the contributions from and potential threats of aquaculture now become an emerging issue (Glibert and Bouwman, 2012). In addition to that, China's coasts are frequently hit by tropical storms. The tropical/subtropical Western Pacific is the globally most active ocean basin in this respect (Fink and Speth, 1998). This, in turn, means that China's coasts are under pressure from both the landward and the seaward side. The tropical island of Hainan is the largest island in the South China Sea, and it appears to be ideally suited to study the effects of the abovementioned threats on coastal ecosystems. In the past decades, Hainan's population and economy grew rapidly and the contribution to the gross domestic product from agriculture dropped from 80% to 40%. At the same time industry, tourism and aquaculture expanded. The island is also continuously impacted by tropical storms, with several of them directly hitting Hainan every year.

In this Special Issue we present results of the interdisciplinary LANCET (Land–Sea Interactions along Coastal Ecosystems of Tropical China: Hainan) project. In the frame of the Chinese–German Cooperation in Marine Science and Technology, it was initiated to improve scientific knowledge on land–sea interactions in tropical China with regard to the impact of natural and anthropogenic environmental change, as delineated above. The project was funded by the German Federal Ministry of Education and Research (BMBF), the Chinese Ministry of Science and Technology and the Natural Science Foundation of China. The investigations covered the full spectrum of aquatic systems in the land–ocean continuum, including rivers/estuaries, mangroves, seagrass meadows, coral reefs and the coastal ocean, with an upwelling system.

The Special Issue summarizes the findings of the project in 12 individual articles and one synthesis paper. The first two papers characterize the larger scale physical setting and material transport along the Hainan coast and continental margin. Su et al. investigated coastal upwelling, the major oceanographic feature of the region. They found it to be a strongly intermittent phenomenon, in time as well as in space, which is of surprisingly little influence on nearshore coastal waters despite the narrow shelf. Using radionuclides, Huang et al. found shelf sediments to be mainly of terrestrial origin. The Hainan coastal current and upwelling are the major driving forces, resulting in a northward alongshore transport.

The following five papers are dealing with the sources and transformation of land-derived substances in two estuarine systems. Li et al. investigated nutrient dynamics in the Wanquan River estuary. They found moderate to high concentrations of dissolved inorganic

0278-4343/$ - see front matter
http://dx.doi.org/10.1016/j.csr.2012.11.013

nitrogen probably resulting from agriculture in the hinterland and low phosphate levels. The dissolved organic forms made up a considerable part of the total nitrogen and phosphorus loads. Heavy rainfall associated with typhoons can lead to an additional pulsed export of nutrients into coastal waters. Similar observations for organic carbon were made by Wu et al. in that system. Major part of the organic carbon transport occurred in the dissolved form. On a global scale, the yields for dissolved and particulate organic carbon are in the lower range for the Wanquan River. Approx. 10% of the annual carbon load was discharged during a flash flood caused by a 10-day extreme rain event. Further north, Unger et al. found high amounts of freshly produced particulate organic matter in the Wenchang/Wenjiao rivers estuary, fuelled mainly by anthropogenic nutrients derived from municipal and aquaculture effluents. As observed further south in the Wanquan River estuary, torrential rainfall events can lead to a pulsed export of this organic matter into coastal waters, where it can affect seagrass meadows and coral reefs. Fu et al. studied the modification of dissolved and particulate trace metals in both estuaries. Seasonal variations were observed only for a few dissolved trace metals. Elevated levels in the Wenchang/Wenjiao estuary during a wet season probably originated from surrounding aquaculture ponds. Being a toxic element and responsible for widespread pollution of drinking and groundwater in South and Southeast Asia, also arsenic was investigated in detail in the Hainan estuaries by Balzer et al. However, concentrations of all investigated trace metals were low, as compared to other estuarine systems, indicating a low level of contamination.

The impacts of natural forces and human activities on the ecology of coastal ecosystems are addressed by the following five papers. By analyzing a sediment core, Bao et al. reconstructed how the conversion of mangroves into aquaculture ponds affected organic matter composition of tidal flat sediments in the Wenchang/Wenjiao estuary. They found the organic matter contribution from mangroves decreasing from $>30\%$ in the 1970s to 5% nowadays, while contributions from aquaculture increased from $<5\%$ to about 30%. In the same area and adjacent coastal waters, Herbeck et al. found high concentrations of dissolved inorganic and organic matter released from aquaculture ponds, causing eutrophication in coastal waters. Restricted estuarine mixing in the back-reef areas there may aggravate the adverse consequences for seagrass meadows which are already manifested, for example, by overgrowth with epiphytic algae. Krumme et al. investigated the artisanal nearshore fisheries with lift nets. Despite already depleted resources, fishing pressure is high, particularly because of the demand of expanding aquaculture for low value/trash fish, at present making up $>50\%$ of lift net landings. Wang et al. studied the effect of natural forces on coral reefs along the north-east coast of Hainan. They found hydrodynamics and wave energy to be important controls of the structure and spatial distribution of hermatypic corals. Extreme weather conditions, e.g., tropical storms, resulting in high wave energy, can severely damage corals. And finally, Roder et al. observed a reduced fitness and metabolic activity of corals and relate it to eutrophication, siltation and destructive fishing practices.

The overall project results are summarized and recommendations for management measures are presented in a synthesis paper at the end of this Special Issue. With an interdisciplinary approach, LANCET has successfully acquired new knowledge on the response of tropical coastal ecosystems to environmental change. While finding cultural eutrophication to be a serious issue in Hainan's coastal waters was expected, it was rather surprising that aquaculture rather than hinterland agriculture was the major source of nutrients and organic matter. It was also intriguing to find out how intimately linked ecosystems in the land–ocean transition are. The unplanned opportunity of sampling the area before and after the passage of a typhoon demonstrated how such an extreme weather event and attendant phenomena, i.e., heavy rainfall, in combination with the human perturbations, can contribute to ecosystem degradation and loss of ecosystem services.

The LANCET project provided the opportunity to study a coastal area in transition from a natural to an anthropogenically modified state, so in a way being a "global change laboratory". The results obtained have larger-scale implications. In the light of disproportionately expanding aquaculture and the maximum frequency and intensity of tropical storms, our results highlight the particular vulnerability of the South and Southeast Asian coastal zones. In this context, LANCET serves as a model highlighting the need for further studies on the interaction of human perturbations with extreme events. An improved knowledge on that is required for developing appropriate management strategies for a sustainable use of tropical coastal zones.

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Received 8 November 2012

Available online 30 November 2012

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