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Resilience and restoration of soft-bottom near-shore ecosystems

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Throughout the world, intertidal near-shore ecosystems are largely threatened by human impacts (Naylor et al., 1998; Jackson et al., 2001). Mangrove forests and seagrass meadows are major vegetation types of these ecosystems (Hogart, 1999; Hemming & Duarte, 2000). These mangrove forests and seagrass meadows constitute dominant plant communities in these ecosystems and play a crucial role in the coastal environment. Generally, both mangrove forests and seagrass meadows are characterised by high biomass production (Riley & Kent, 1999; Green & Short, 2003), and they are widely recognized as key ecosystems in temperate and tropical near-shore ecosystems (Valiela, 1987; Hogart, 1999; Hemminga & Duarte, 2000). Intertidal near-shore ecosystems with mangrove and seagrass cover are important for biodiversity (De Iongh et al., 2007), they help to stabilize sediments (De Boer, 2007), provide nursery habitats for fish (Pollard, 1984; Nuraini et al., 2007), contribute to the primary production, and play an important role in the nutrient cycling of the coastal marine ecosystems (Oshima et al., 1999; Gras et al., 2003).

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Resilience and Restoration of Soft-Bottom Near-Shore Ecosystems

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Storms and monsoon rains are frequent disturbances that affect mangrove and seagrass cover (Preen et al., 1995; Ferwerda et al., 2007a). In resilient intertidal near-shore ecosystems, the pioneer seagrass species for example can recover quickly after such disturbances (De Iongh, 1996). Many seagrass species are, however, highly sensitive to environmental changes, and losses of seagrass-vegetated areas are now a worldwide problem (Walker & McComb, 1992; Short & Willye-Echeverria, 1996; Gordon, 2007). The decline in most areas can be related to human activities such as industrial and urban sewage discharges, fish farming, trawl fishing, coastal works (as shown for mangroves by Vaiphasa et al., 2007). The main problems in intertidal near-shore ecosystems have an abiotic nature such as increased turbidity, erosion and increased nutrient load (Fourqurean & Zieman, 2002; Ruiz & Romero, 2003; De Boer, 2007). However, also biotic disturbances affect mangrove and seagrass cover, such as overgrowth with epiphytes and macroalgae. The causal relationships between individual factors and observed changes in mangrove and seagrass cover and biomass are difficult to establish due to the complex array of interactions between physical and biological factors that can be simultaneously induced in a same coastal area under influence of human impacts (Terrados et al., 1999; Ruiz & Romero, 2001). Understanding the effect of disturbances and mechanisms of recovery in practice are vital for successful conservation management and restoration. De Boer (2007) reviews current knowledge about the limiting factors for seagrass occurrence, and the effect positive feedbacks in seagrass systems have on these threshold levels.

These positive feedbacks are important to consider in the restoration of soft-bottom near-shore ecosystems as they set thresholds for survival. For example, seagrasses can take nutrients both through below- and above-ground biomass, and can grow under low nutrient concentrations (Iizumi & Hattori, 1982; Gras et al., 2003). The presence of large amounts of seagrass can influence nutrient cycling (Elkalay et al., 2003). Through the above-ground biomass (especially leaves), seagrass meadows absorb nutrients from the water column. One can hypothesize that the more above-ground biomass, the more nutrients can be captured until other factors such as light become limiting. Moreover, above-ground biomass of seagrass promotes sedimentation of dissolved organic matter that increases the nutrient status of the substrate. These processes on so-called soft-bottom substrates are different from hard-bottom substrates such as rocky habitat (Menge et al., 1994). Once again, one can hypothesize that the more above-ground seagrass biomass present in the system, the more sediment can be caught by these seagrasses. Seagrass beds are indeed known to be important in both capturing and stabilizing soft-bottom sediments (Philips, 1978; Fonseca, 1989). The capture of resources by above-ground biomass indicates the existence of a positive feedback mechanism when these resources are limiting. This capturing thus promotes growth, leading to a higher potential to capture the limiting resources (Scheffer et al., 2001). However, when seagrass biomass under these conditions is not sufficient to capture nutrients or cannot stabilize sediment, the seagrass cover might decline (De Boer, 2007).

An important property of ecosystems with such positive feedback mechanisms is that they can exhibit alternate stable states (Scheffer et al., 2001; Van Langevelde et al., 2003). The two alternate states in which these near-shore ecosystems can occur have strongly different properties. For example, seasgrasses harbour a high biodiversity (ranging from crustaceans and fish to mammals and reptiles such as dugong and turtles), while the state with degraded vegetation potentially can offer an environment for shellfish in a soft-bottom substrate only. The seagrass state offers a seabed which is wave and erosion resistant, while the degraded state shows a high risk of erosion (Short & Willye-Echeverria, 1996). Under conditions where such alternate stable states exist, the resilience of these systems might be low. Then, perturbations could lead to sudden shifts resulting in the degradation of the system (Scheffer et al., 2001). Monitoring using remote sensing could provide an early warning system to prevent further degradation of these soft-bottom ecosystems (Ferwerda et al., 2007b).

This special issue covers several topics that deal with the resilience and restoration of near-shore soft-bottom ecosystems. The review of De Boer focuses on the positive feedbacks that operate in seagrass meadows. He discusses a range of factors that determine seagrass occurrence and highlight gaps in current knowledge. Gordon discusses a number of natural and anthropogenic factors that are threatening the health of the reef ecosystems in Australia. He argues that one of the major anthropogenic factors is the impact of sediments and nutrients that run off the land, via the rivers, into the lagoon of the reef. Ferwerda et al. (2007a) show the result of a study on differences in vegetation composition and structure of mangrove vegetation in 2 areas 25 years after either human disturbance or natural disturbance. They hypothesize that the effect of human disturbance on mangrove forest is different than the effect of natural disturbances. Their results show that the vegetation in clear-felled forest showed more adult *Avicennia marina* than in the hurricane-affected forest, and a virtual absence of *A. marina* juveniles and saplings. Vaiphasa et al. study the effect of poor management of pond waste materials of shrimp farms as one of the most serious threats to tropical mangrove ecosystems. They hypothesize that mangroves can tolerate chemical residues discharged from shrimp farms and can be used as biofilters, but the capability of mangroves to cope with solid sediments dredged from shrimp ponds is limited. Using field work and satellite images, they found that the excess sediments discharged from nearby shrimp ponds reduced mangrove growth rates and increased mortality rates.

Ferwerda et al. (2007b) review of current literature on coastal remote sensing and examine the ability of remote sensing to serve as an information provider for seagrass monitoring. They argue that remote sensing offers the potential to map the extent of seagrass cover and monitor changes in these with high accuracy for shallow waters. Moreover, they discuss recent advances in sensor technology and radiometric transfer modelling that have resulted in the ability to map suspended sediment, sea surface temperature and below-surface irradiance. Ferwerda et al. (2007b) stress the potentials of this technology to monitor the factors that cause the decline in seagrasses.

This special issue ends with two papers on the relevance of soft-bottom near-shore ecosystems for biodiversity and nursery of fish. First, De Iongh et al. review the results of a long-term study on dugong-seagrass interactions in Indonesia, which was done during the period 1990 until 2005. They show results on intensive rotational grazing by dugongs in intertidal inshore *Halodule univervis* seegrass meadows and dugong movements in relation to these grazing swards, and explain the temporal and spatial patters of grazing in these meadows. They argue that intertidal *H. univervis* seagrass meadows form a crucial resource for dugong survival. Second, Nuraini et al. show the importance of seagrass as habitat for juvenile groupers (Serranidae) and snappers (Lutjanidae). They found that both species were almost exclusively found in seagrasses, with a preference for microhabitats of high complexity (dense and mixed microhabitats). They argue that the presence of seagrass meadows is critical for juvenile groupers and snappers.

These contributions give insight in the determinants of the resilience and restoration of soft-bottom near-shore ecosystems:

- Describing the patterning of the vegetation of soft-bottom near-shore ecosystems through (hyper)spectral remote sensing
- Explaining the occurrence of mangrove forests and seagrass meadows and their limiting resources
- Investigating the factors that determine mangrove and seagrass growth and mortality
- Predicting the response of soft-bottom near-shore ecosystems to large-scale disturbances
- Predicting and preventing catastrophic responses of soft-bottom near-shore ecosystems to a changing environment

These studies of mangrove and seagrass patterns, the factors determining their occurrence and the effects of environmental change contribute to theory on functioning and restoration of soft-bottom near-shore ecosystems.

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