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Coastal geomorphology and restoration

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ABSTRACT

Increases in human development of the coastal zone, sea level rise and intensity of coastal storms will test the resilience of coastal systems. An integrated approach is needed to describe geomorphic–biologic dependencies, feedbacks between processes and responses, and determine how coastal systems can be maintained or restored. The 2013 Binghamton geomorphology symposium focused on three themes in these research areas (1) the geomorphic response of coastal landforms to changes in sea level and episodic storms; (2) the way these stressors alter geomorphic–biotic interactions and reduce the resilience of coastal environments; and (3) the way natural and human processes are being integrated to restore or maintain dynamic geomorphic and biologic linkages. This issue contains eighteen papers presented at the symposium; six papers are devoted to each of these themes. The papers point to the importance of ecological systems in modulating the responses to natural physical processes and, in turn, responding to geomorphic change and the role of humans in assisting natural processes.

1. Introduction

The need to understand the complex interactions of geomorphic, ecological and human processes in the coastal zone is growing in importance because of predictions of increases in sea level rise, storm activity and population density (Murray et al., 2009; NRC, 2010). These stressors will likely have dramatic effect on the resilience of coastal systems and the subsequent ability of adaptive management strategies to maintain ecosystem goods and services, while simultaneously coping with hazards (Orford and Pethick, 2006; Chapin et al., 2009; Defeo et al., 2009).

Advances have been made by geographers, geologists, biologists and ecologists, working within their disciplines, to understand the couplings between processes in surf, swash, backshore and dune environments (e.g. Stallins and Parker, 2003; Defeo and McLachlan, 2011). Still, a need exists for an integrated approach that will more fully describe the development of geomorphic–biologic dependencies, feedbacks between processes and responses, and maintenance of coastal systems over space and time (Forbes et al., 2004). Understanding the relevant scales of response (absolute and relative) to sea level rise and episodic storms will ultimately increase our predictive capabilities. The strategies and techniques that are currently used to conserve or restore habitats may become less tenable with future climate changes (Orford and Pethick, 2006), making attempts to overcome knowledge gaps more critical.

The emergence of sustainability as a central policy guideline in environmental management should generate greater interest in geomorphic perspectives, especially as they pertain to human activities (James and Marcus, 2006). Knowledge of geomorphic–biotic interactions on coasts that have been artificially restored or urbanized is still rudimentary, despite the efforts of many investigators from the physical and biological sciences (Nordstrom, 2008; Bulleri and Chapman, 2010; Dugan et al., 2011). The degradation of coastal landforms and habitats and the necessity of restoring functions and services will require geomorphologists and ecologists to work together.

The 44th Annual Binghamton Geomorphology Symposium convened on 18–20 October 2013 in Newark, New Jersey, USA to address these issues under the overall theme *Coastal Geomorphology and Restoration*. Three research questions guided the discussion:

1. What will be the geomorphic response of coastal landforms to changes in sea level and the magnitude and frequency of episodic storms?
2. Will changes in the spatial and temporal scale of stressors alter geomorphic–biotic interactions and thereby reduce the resilience of coastal environments?
3. How successful are humans in integrating natural and human processes to restore or maintain dynamic geomorphic and biologic linkages?

Two of the previous forty-three Binghamton symposia were held on the topic of coastal geomorphology (Table 1). The first, in 1972 (Table 1), focused on sandy coastal environments and produced an

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Table 1
Listing of Binghamton symposia 1970–2013.

1970 Environmental geomorphology
1971 Quantitative geomorphology
1972 Coastal geomorphology
1973 Fluvial geomorphology
1974 Glacial geomorphology
1975 Theories of landform development
1976 Geomorphology and engineering
1977 Geomorphology in arid regions
1978 Thresholds in geomorphology
1979 Adjustments of the fluvial system
1980 Applied geomorphology
1981 Space and time in geomorphology
1982 Groundwater as a geomorphic agent
1983 Models in geomorphology
1984 Tectonic geomorphology
1985 Hillslope processes
1986 Aeolian geomorphology
1987 Catastrophic flooding
1988 History of geomorphology
1989 Appalachian geomorphology
1990 Soils and landscape evolution
1991 Periglacial geomorphology
1992 Geomorphic systems
1993 Geomorphology: the research frontier and beyond
1994 Geomorphology and natural hazards
1995 Biogeomorphology, terrestrial and freshwater systems
1996 The scientific nature of geomorphology
1997 Changing the face of the earth: engineering geomorphology
1998 Coastal geomorphology
1999 Geomorphology in the public eye
2000 Modeling and geomorphology
2001 Mountain geomorphology — integrating earth systems
2002 Dams and geomorphology
2003 Ice sheet geomorphology
2004 Weathering and landscape evolution
2005 Geomorphology and ecosystems
2006 The human role in changing fluvial systems
2007 Complexity in geomorphology
2008 Fluvial deposits and environmental history
2009 Geomorphology & vegetation: interactions, dependencies, & loops
2010 Geospatial technologies and geomorphological mapping
2011 Zoogeomorphology and ecosystem engineering
2012 The field tradition in geomorphology
2013 Coastal geomorphology and restoration

overview of the existing state of the art in beach research divided into three sections: coastal processes; barrier islands; and applications of geomorphology (Coates, 1973). The focus was largely on geomorphology. Interdisciplinary studies were confined to a study linking geomorphology to archeology and a study linking dune form and type of vegetation. Barrier islands were a focus because of the world-wide extent, the interest at that time in debates about the origin, and the increasing human use and development. Human altered barrier islands were compared to natural systems in two of the papers, but some topics of great interest today, such as restoration of landforms and habitats, were not directly addressed. The second coastal symposium, in 1998 (Table 1), identified the need to extend understanding of coastal geomorphology beyond sandy beaches to include landforms on rocky coasts (including gravel beaches), carbonate coasts, marshes, and sand dunes (Sherman and Gares, 2002). Four articles were devoted to aeolian transport and coastal dunes, reflecting the growing interest in that long-neglected but currently strong research area. Both previous coastal symposia acknowledged the role that humans play in transforming the coast.

The present symposium places greater emphasis on the role of humans as intrinsic agents of landform change. We return to a focus on sandy systems, but strive for a broader interdisciplinary approach that includes increased representation of themes in ecology and addresses more applications to management, in addition to basic research in the traditional disciplines of geography and geology that have been at the core of geomorphology.

2. Rationale for symposium

Interest in global environmental change has helped shift attention from isolating process–response couplings from instrumented field investigations to broader scale questions. The threats of climate change and the conceptual and technical challenges of predicting morphodynamic change at the all-important 'engineering' scales have become an increasing concern of geomorphologists (French and Burningham, 2009). The worldwide coverage of aerial and satellite imagery provided by government agencies in the immediate aftermath of storms (Fig. 1) and portals that provide easily-accessible time sequences of imagery that extend through multiple decades, such as Google Earth®, have introduced a new age of geomorphic discovery (French and Burningham, 2011). Many of the papers in this issue (Armaroli et al., 2013; Hapke et al., 2013; Houser, 2013; Sherman et al., 2013; Walker et al., 2013) integrate remotely sensed data, spatial statistics, and morphodynamic models in their analyses.

Future climate change will include changes in mean eustatic sea level, magnitude of episodic events, magnitude, timing and extent of morphologic responses and the interactions that occur between linked morphologic and biologic processes (Brown and McLachlan, 2002; Titus et al., 2009; Corenblit et al., 2011). These changes will require development of a better understanding of the spatial and temporal scale of processes and responses, particularly for low-lying areas that are especially vulnerable to hazardous storms (Stone et al., 1997; Fitzgerald et al., 2008). Post-storm adjustments often involve creation of temporary landforms using earth moving equipment (Fig. 2). True restoration of degraded landform assemblages must be based on knowledge of these process–response dynamics and the relationship between geomorphology and ecology to achieve greater dynamic resilience of coastal systems (Nordstrom, 2008). The National Research Council identified some of these issues as critical areas in Earth surface systems research and stressed the importance of developing new interdisciplinary approaches (NRC, 2010). We structured this paper in three sections, representing the three questions posed earlier. The themes are not mutually exclusive, and several of the papers in this issue cross thematic boundaries.

3. Geomorphic response to sea level rise and episodic events

The magnitudes of physical drivers of coastal change are projected to increase, along with the likelihood of coastal inundation and erosion (Webster et al., 2005; Nicholls and Cazenave, 2010). These effects may now be unfolding in coastal locations where beach and dune volumes have been reduced or eliminated, and the lag time between events has not been sufficient for beach–dune recovery because of sediment deficits or human development (Houser and Hamilton, 2009; Morton, 2010).

Predicting responses to episodic events remains a challenge because of the complexity of storm processes, shoreface modulation of wave energy, and cross-shore and longshore gradients in morphology and sediment supply. Recognition of the significance of the nearshore and beach face in supplying sediment to the backshore and eventually the dune is increasing (Sherman and Bauer, 1993; Aagaard et al., 2004; Anthony, 2013), allowing for a more complete view of the constraints to dune building. In some cases, however, the interactions between these subenvironments are still unclear, making it difficult to predict foredune stability (Arens et al., 2013). Armaroli et al. (2013) demonstrate the importance of foredune stabilization by plant growth as key to the performance of existing models to predict foredune erosion from storms.

The great regional differences in wave energy regimes, shoreface and beach/dune morphology and sediment availability are conspicuous when comparing the results of Anthony (2013) on the storm-dominated macrotidal coast of France with the results of Pranzini et al. (2013) on