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Rob Brander
UNSW Sydney

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Coastal geomorphology into the twenty-first century

Wayne J. Stephenson[a,*] and Robert W. Brander[b]

[a]Department of Geography, University of Melbourne, Victoria 3010, Australia
[b]School of Biological, Earth and Environmental Sciences, University of New South Wales, New South Wales 2052, Australia

I Introduction

Viles (1991) suggested that the beginning of the 1990s presented a new decade containing many new and exciting challenges for coastal geomorphologists and, not surprisingly, the same can be said for the beginning of the new millennium. There have been many exciting advances in the last decade and many of these are reported in a number of review articles covering a range of coastal processes and landforms (Sherman and Bauer, 1993; Taylor and Stone, 1996; Hinton, 1997, 1998; Horn, 1997, 1999, 2002; Kench, 1999; Shand and Bailey, 1999; Hesp *et al.*, 1999; Allen, 2000; Díez, 2000; Stephenson, 2000; Butt and Russell, 2000; Van Wellen *et al.*, 2000; Mason and Coates, 2001; Hesp, 2002; Trenhaile, 2002a; Uncles, 2002; Elfrink and Baldock, 2002; Kennedy and Woodroffe, 2002; Spencer and Viles, 2002; Jackson *et al.*, 2002; Murray *et al.*, 2002). Many of these reviews can be found in the special issue of the journal *Geomorphology* (Volume 48) devoted to the 29th Binghampton Symposium. There has also been a recent plethora of textbooks dealing with coastal geomorphology, albeit from somewhat different perspectives (Trenhaile, 1997; Komar, 1998; Short, 1999; Bird, 2000; Haslett, 2000; Nordstrom, 2000; Bryant, 2001; Pye and Allen, 2001; Packham *et al.*, 2001; Woodroffe, 2003; Masselink and Hughes, 2003).

Coastal geomorphology has, over the last decade, experienced a particularly unique stage of evolution, where established theory has been both confirmed and challenged, if not overtaken, by rapid advances in field logistics and instrumentation, computing capabilities and applications, and by an increased globalization of the science itself. Understandably therefore, before we can determine 'where do we go from here?' it has been necessary to take stock and evaluate where we actually are. Despite all our recent advances, significant and often persistent questions remain in our knowledge of coastal

*Author for correspondence. E-mail, wjs@unimelb.edu.au

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systems, while other pathways are being opened for the first time. This report attempts to provide a synthesis of our present state of knowledge across a selected range of coastal topics, primarily focusing on the last six years. Our aim is to provide a reference guide to existing studies and, given that it is not possible to cover all subfields and research articles in a report this size, we apologize in advance to those left out.

II Shoreline evolution

Large-scale coastal evolution undoubtedly represents one of the most complex areas of research in coastal geomorphology. As Schwarzer *et al*. (2003) concluded, this is because the effects of coastal processes over different timescales are interactive and an understanding of large-scale coastal behaviour requires investigations from both short events to long-term processes. This comment encapsulates the age-old problem of linking process studies with historical approaches to landform development. Malvarez and Cooper (2000) presented a surf zone model which they claim enables understanding of morphodynamic evolution of coasts. Cooper *et al*. (2001) illustrated how a sediment budget approach can aid in understanding coastal evolution. Such an approach does appear to overcome some scale linkage problems that result from reliance on process-based models. Battiau-Queney *et al*. (2003) also illustrated the significance of the sediment budget for establishing the longer-term behaviour of shorelines and how proper investigation can overcome misconceptions concerning the severity of coastal erosion.

Cipriani and Stone (2001) modelled longshore sediment transport on the southwest Alabama and Mississippi barrier island coasts. The value of this paper is not only that it successfully links scale, but it also illustrates how longshore sediment transport models can be used to understand coastal morphology and evolution rather than simply be used for engineering applications. This paper differs from most publications on longshore sediment transport, which tend to focus on improved derivations of transport formulae (Wang *et al*., 1998, 2002; Wang and Kraus, 1999; Schoonees, 2000; Van Wellen *et al*., 2000; Jena *et al*., 2001; Kumar *et al*., 2003) although Pilkey and Cooper (2002) offer an alternative view on this subject.

Anthony (2002) discussed the relationship between marine sediment supply and coastal sediment accumulation and how differences along the northern French coast can be explained using these relationships. Whether or not the coastline is gravel and/or sand depends on position relative to the large-scale hydrodynamic and aeolian processes that transported and sorted marine sand during the Holocene. Sanderson and Eliot (1999), Sanderson (2000) and Sanderson *et al*. (2000) considered regional patterns in shoreline configuration and the implications for long-term morphodynamic evolution. Nichol (2002) investigated the stratigraphy of a last interglacial beach ridge system. The resulting model showed how beach ridges could be emplaced by a falling sea level coupled with a supply of marine sediment being transported on-shore.

Light Detection and Ranging (LiDAR) represents a significant advance in large-scale mapping of coastal change at longer timescales. Given time, improved accuracy should see it used for more detailed small-scale studies. Revell *et al*. (2002) demonstrated the application of LiDAR to large-scale beach behaviour, in this case erosion associated with El Niño on the Oregon coast. Stockdon *et al.* (2002) and Sallenger *et al.* (2003) provide a review and examples of the technique when applied to beach change.

III Beach and nearshore morphodynamics

1 Rip currents

Rip currents have received increased attention recently primarily because of their role in nearshore circulation and sediment transport. Process studies have clearly shown the importance of topographic control and tidal modulation of rip flow with maximum velocities at low tide and minimums at high tide (Aagaard *et al.*, 1997; Brander, 1999; Brander and Short, 2000), and the existence of pulsating flow at infragravity frequencies (Brander and Short, 2001). Brander and Short (2000) noted that while processes occurring within large-scale rip systems are extreme, large rips behave in a similar manner to smaller, lower energy rips and Short and Brander (1999) suggested that distinct morphodynamic scaling exists between various wave energy environments. Theoretical advances in our understanding of rip flow and spacing have been made through numerical (Chen *et al.*, 1999; Haller and Dalrymple, 2001; Damgaard *et al.*, 2002; Haller *et al.*, 2002) and laboratory (Haas and Svendsen, 2002; Dronen *et al.*, 2002) modelling. Murray and Reydellet (2001) and Murray *et al.* (2003) have applied concepts of self-organization to model rip geometry, spacing and dynamics.

2 Shear waves

Shear waves represent one of the newest and most significant phenomena discovered in the nearshore in recent years and have attracted increasing interest. Significant advances have been made in understanding these waves and mathematical descriptions are available (Bowen and Holman, 1989; Oltman-Shay *et al.*, 1989; Dodd *et al.*, 1992; Dodd, 1994; Dodd and Falques, 1996; Reniers *et al.*, 1997; Ozkan-Haller and Kirby, 1999; Lippmann *et al.*, 1999; Baquerizo *et al.*, 2001). From a geomorphic perspective, shear waves have a direct role in sediment suspension and transport. Based on field measurements, Miles *et al.* (2002) determined the effect of shear waves on sediment suspension and transport on the seaward side of an intertidal bar. Although suspension occurred at the incident wave frequency, there was modulation at the shear wave frequency. Shear waves accounted for up to 16% of the total cross-shore transport, and up to 37% of the oscillatory cross-shore transport. Interestingly, the longshore sediment transport attributed to shear waves was in the opposite direction to the current, but was only 12% of the total transport.

3 Cross-shore sediment transport

The complexity of cross-shore sediment transport continues to present problems and fruitful research. Aagaard (2002) investigated the role of changing water levels, resulting from tides and storm surge, on surfzone morphodynamics. Nearshore hydrodynamics were modulated by changing water levels as was sediment transport. As a consequence, bar smoothing was identified as the process leading to more subdued topography on beaches subject to larger tidal ranges. Aagaard *et al*. (2002) attempted to predict cross-shore sediment transport on a barred beach and developed a model based on dimensionless parameters that indexed undertow, incident wave skewness and the cross-correlation between orbital velocity and sediment concentration. Their model predicts onshore sediment transport resulting from incident waves on gently sloping beaches and/or with large bed shear stresses. On steeper beaches and/or in the inner surf zone, offshore sediment transport occurs because of undertow. Ogston and Sternberg (2002) used both wave tank and field data to assess suspended sediment flux under breaking and broken waves to provide better estimates of sediment eddy diffusion coefficients and the vertical profile of the eddy.

Hicks *et al*. (2002) monitored cross-shore sediment transport associated with storm-driven bar migration (both onshore and offshore). Hequette *et al*. (2001) examined the influence coastal morphology has on nearshore sediment transport. Beaches backed by a bluff had greater offshore transport during storms than a barrier beach where overtopping occurred. Masselink and Pattiaratchi (2001a) reported that the dimensionless fall parameter failed to predict seasonal profile change from barred to nonbarred beaches on sheltered beaches along the coastline of Perth, Western Australia. Seasonal changes in the direction of littoral drift, which narrowed and widened beaches, provided a better explanation. Larson *et al*. (2000) used an 11-year record of waves and profiles from Duck, North Carolina, to explore the usefulness of canonical correlation analysis. They reported that there is potential for predicting the profile response with an acceptable degree of accuracy once a regression matrix relating the profiles to the waves has been established that represent typical variability of the site. Ruessink *et al*. (1998) found that simple energetics models adequately predict cross-shore sediment transport in 3–9 m water depth. Ruessink (2000) developed an energetics-based model for cross-shore suspended sediment transport resulting from bounded infragravity waves.

4 Nearshore bars

Nearshore bar formation continues to perplex workers and numerous attempts have been made to reconcile the various hypotheses for bar formation. Wijnberg and Kroon (2002) reviewed bar formation and noted that the most significant advances would probably come from long time series of morphology and forcing conditions, rather than from intensive field experiments. This view reflects the increasing number of publications using data sets with long time frames.

Van Enckevort and Ruessink (2003) used a 3.4-year data set of almost daily time-exposure images of the double-barred coast at Noordwijk (the Netherlands). Seasonal bar migration only dominated the bar crest variability at the outer bar on time spans between 7 and 13 months. There was a strong interannual signal, with limited seasonal variability, and with fluctuations at weekly scales that are long compared with the characteristic timescale of individual events, suggesting a response to sequences of events rather than to individual events. Moore *et al*. (2003) used orthorectified vertical aerial photography covering 16 years to characterize the behaviour of multiple bars. Bar formation was consistent with formation by breaking waves, standing infragravity waves and edge waves.

Shand *et al.* (2001) provided detailed information on bar switching, a process where longshore bars detach and the landward bars on one side of the newly developed discontinuity realign and join with the seaward bars on the other side. Shand *et al.* (2001) identified two types of switching based on 6.3 years of photography. The first, shoreward propagating bar switching originates in the outer surf zone and the location of switching then moves landward. The second is stationary switching which begins and remain within the mid-surf zone. High energy conditions are necessary for bar switching to occur, but antecedent morphology and other hydrodynamic factors may also be important (Shand *et al.*, 2001). Shand (2003) found an association between bar switching mode and bar migration.

Despite the view of Wijnberg and Kroon (2002) that long-term data sets are needed to advance our understanding of bar behaviour, useful contributions have also been made by shorter-term studies. Ruessink *et al.* (2000) analysed six weeks of bathymetric surveys and video images to quantify short-term variability in the bar-crest position of the double barred beach at Egmond aan Zee (the Netherlands). This beach exhibited considerable quasi-regular alongshore variations, such as crescentic plan shapes. Cross-shore variation in morphology related to on/offshore bar migration and three-dimensional change resulted from horizontal amplitude growth, migration or length scale change of the quasi-regular topography. Dulou *et al.* (2002) utilized a small wave tank to investigate bar formation. Results support the break point hypothesis for bar formation. Kroon and Masselink (2002) investigated intertidal bars on a macrotidal beach over a spring tide to spring tide cycle. Bar migration was closely linked to the time that surf, not swash, processes acted on bars, which was in turn a function of tidal cycles. Neap tides were conducive to onshore bar migration under low energy conditions. Ruessink and Terwindt (2000) utilized three, five week studies over two years to examine cyclic bar migration at interannual timescales. Lee *et al.* (1999) showed that bar formation is influenced by the pattern of the storm surge hydrograph.

5 Beaches

In the area of beach research more attention is now being paid to embayed beaches, low energy beaches (although a widely accepted definition of low energy is lacking), mixed sediment beaches and beaches in macrotidal settings. This move represents the need to consider a wider range of beach types than those usually considered when investigating nearshore processes and morphology. This is particularly important if the morphodynamic model is to have a truly global application.

Embayed beaches have received more focused research since they have been recognized as possibly being morphologically distinct from open coasts. Da Fontoura and De Menezes (2001) examined embayed beaches with various degrees of wave and identified three distinct types: exposed, semi-exposed and sheltered. Da Fontoura *et al.* (2002) and Anthony *et al.* (2002a) considered the longshore variation and behaviour of embayed beaches suggesting that longshore transport often means erosion at one end but not a long-term loss of sediment. Storlazzi and Field (2000) investigated the distribution and transport of sediment along an embayed shoreline, noting that structural setting controlled transport by presenting barriers to sediment flux.

Beach morphodynamics in macrotidal settings has also been a focus of recent research (Levoy *et al*., 1998). Levoy *et al*. (2000) argued that they have extended the megatidal dimension of the meso-macrotidal beach classes from various combinations of morphology, wave, sediment and tidal characteristics. Levoy *et al*. (2001) show that outside the surf zone, these megatidal beaches are characterized by wave-dominated mid-tidal zones and tide-dominated low-tidal zones during spring tides and suggested the term 'mixed wave-tide-dominated' for beaches with very large tidal ranges. Bernabeu *et al*. (2003) modelled the profile behaviour of meso- and macrotidal beaches under different wave and tide conditions, noting that such beaches are not well represented in beach modelling. Their model is based on a two-section equilibrium beach profile, which they validated with field and laboratory data. They claimed that this beach morphological model provides a framework for understanding first-order behaviour of beaches under the action of waves and tides.

Masselink and Pattiaratchi (2001b) analysed 49 years of wind data to characterize sea-breeze activity and the subsequent wave environment on the coastline of Perth, Western Australia. Sea breezes were found to have a major impact on wave energy along sheltered coastal environments and on tropical and subtropical coasts. Given the wide global distribution of sea breezes, Masselink and Pattiaratchi (2001b) argued that further research was needed to assess the impact of sea breezes on shorelines. Doucette (2002) subsequently showed the impact sea breeze has on nearshore ripples by causing offshore sediment migration.

While there is increasing interest in mixed sediment beaches, the number of publications on them still lag behind those devoted to sandy beaches. Most attention has focused on longshore transport rates. Van Wellen *et al*. (2000) and Mason and Coates (2001) provided a review of sediment transport. Voulgaris *et al*. (1999) reported sediment transport calculations based on passive acoustic signatures of shingle and an active emitting electronic pebble released into the nearshore. Jennings and Shulmeister (2002) presented a tripartite classification of gravel beaches, based on morphodynamic properties. The three types identified are a pure gravel beach, mixed sand and gravel beach and composite gravel beach. However, the significance of this scheme with respect to the process regime remains to be demonstrated. Masselink and Li (2001) modelled the role of infiltration on beach gradient and found that on coarse beaches the resulting higher hydraulic conductivity caused steeper gradients than on sand beaches, where it was argued that swash asymmetry, resulting from infiltration, controlled gradient.

Abrasion of clasts in mixed sediment beaches is thought to be an important process causing loss of beach volume so that determination of rates is important for sediment budgeting. Hemmingsen (2001) reported tumbler experiments to determine the abrasion rates in mixed beaches. Dornbusch *et al*. (2002) also reported attempts to study abrasion in gravel beaches using *in situ* tracers. Both investigations showed that rates of abrasion differ significantly depending on location, lithology, residence time in the beach and degree of weathering. However, there is clearly some way to go before abrasion rates determined experimentally, can be used in sediment budgeting.

IV Dunes

The impact of land use changes and vegetation on coastal dunes continues to be topical (Seeliger *et al.*, 2000; Reinoso, 2001; Musila *et al.*, 2001; Baas, 2002; Tsoar and Blumberg, 2002). The application of GIS to analysing changes in dune morphology and volume was reported by Andrews *et al.* (2002) and Woolard and Colby (2002) illustrated the application of LiDAR to the same issue while Shanmugam *et al.* (2003) reported the use of different remote sensing techniques in mapping dune ecosystems and vegetation patterns on dunes. The internal structure of dunes was investigated using ground penetrating radar by Bailey and Bristow (2000) and Bristow *et al.* (2000). Holocene dune development remains a popular theme with a number of investigations in a variety of settings (Murillo de Nava and Gorsline, 2000; Goudie *et al.*, 2000; Orford *et al.*, 2000; Sanderson *et al.*, 2000; Hesp, 2001; Borówka and Rotnicki, 2001; Clemmensen *et al.*, 2001; Wilson *et al.*, 2001; Wilson, 2002; Mastronuzzi and Sanso, 2002; Regnauld and Louboutin, 2002; Arbogast *et al.*, 2002; Murray-Wallace *et al.*, 2002 and Orford *et al.*, 2003).

Ruessink and Jeuken (2002), using 100–150 years of profile data collected at 1-km intervals along 160 km of the Dutch coast, examined the behaviour of the dunefoot position at different spatial and temporal scales. They identified sand wave patterns with wave lengths up to 10 km and migration rates up to 200 m yr^{-1} and linked these to beach sand waves. The implication is that variability in dunefoot behaviour is controlled by variability in beach width.

Process research on coastal dunes has focused on foredunes, blowouts and parabolic dunes with recent studies indicating that flow structure over foredunes and resulting sediment transport and deposition is very dependent on dune morphology and vegetation cover (Hesp, 2002; Hesp and Pringle, 2001). Theoretical advances were made by Bauer and Davidson-Arnott (2003) who presented a numerical modelling approach to sediment transport across the beach to dune. In particular the model incorporates beach geometry, effective fetch and angle of wind approach. They argued that their framework provides a ‘robust theoretical foundation’ for future studies of beach–dune interaction, and permits alternative hypotheses regarding the uneven spatial and temporal distribution of dune height and growth rate to be tested. Results from both these studies continue to highlight the importance of understanding dune/beach interaction.

V Estuaries

Elliott and McLusky (2002) revisit the long-standing issue of estuary definition and present a generic framework for the definition, classification, monitoring, assessment, reporting and management of estuaries noting that the system was devised for European estuaries. Categorization was also undertaken by Cooper (2001) who visited 280 estuaries on the microtidal, wave-dominated South African coast. Variations in geomorphology were attributed to antecedent topography and relative sediment supply from either marine or fluvial sources. Five types of estuary were recognized within two categories. The first category included three types that maintain a semi-permanent connection with the open sea and the second category contains two types of closed estuary. Cooper (2001) argued that the different types of estuary indicate the possibility of a number of different development regimes and that the traditional infilling model is oversimplified. FitzGerald *et al.* (2002) grouped estuaries on the New England coast into three broad categories based on morphology, hydrographic regime and sediment transport characteristics: wave-dominated, mixed-energy tidal inlets and riverine-associated tidal inlets. Roy *et al.* (2001) recognized three estuary types: tide-dominated, wave-dominated and intermittently closed based on geology and entrance conditions that control tidal exchange. Evans and Prego (2003) made the case for the revival of the term 'ria' amongst geologists at least and argue that such features do not sit well in the broad definition of estuary. It should be clear then that the classification and definition of estuaries remains problematic. Given that coastal geomorphology has moved away from classification of coastal landforms perhaps it is time to move on from this issue with respect to estuaries.

Estuarine dynamics and sedimentation continue to be actively researched. Huang *et al.* (2002) and FitzGerald *et al.* (2000) investigated inlet dynamics. Anthony *et al.* (2002b) investigated the sedimentological development of a fluvially dominated estuary, while Cooper (2002) examined the role of extreme floods in both tidal and fluvially dominated estuaries. Van der Wal and Pye (2003) reported the use of hydrographic charts and GIS to measure channel migration. Lario *et al.* (2001) applied high resolution particle size and environmental magnetic analyses to estuarine sedimentation and were able to identify and distinguish between two high-energy events, a storm and tsunami, each responsible for the input of coarse sediment.

VI Rocky and coral coasts

There has been a recent resurgence in interest in rocky coasts over the last five years. Most notable was the European Shore Platform Erosion Dynamics project completed in 2001. Stephenson (2000) and Trenhaile (2002b) both present substantive reviews on the topic of shore platforms and rocky coasts.

1 Shore platforms

Allan *et al.* (2002) presented an interesting example of shore platform development in a lacustrine setting over a very short timescale of 52 years. In the absence of significant wave energy, they proposed a model for development that supports the role of subaerial processes as the primary formative process. Stephenson and Kirk (2001) investigated coastal rock weathering and documented the phenomenon of rock swelling where surfaces are observed to rise up over months rather than wear down as might be expected. They argued that this behaviour results from salt growth and wetting and drying, and speculated that it may be an important part of the weathering of coastal rocks. Stephenson (2001) considered the issue of shore platform width, and attempted to measure the rate at which the seaward edge of platforms retreat. No erosion was found in air photographs and the conclusion was drawn that platforms tend towards stable equilibrium.

A number of variations of a mathematical model of shore platform development have been used to investigate wave erosion with a constant sea level (Trenhaile, 2000), late Quaternary sea levels (Trenhaile, 2001a), weathering (Trenhaile, 2001b), Quaternary evolution of platforms and continental shelves (Trenhaile, 2001c) and tectonically active coasts (Trenhaile, 2002b). Modelling of this nature offers the possibility to elucidate relationships between processes and morphology at longer timescales than can be gained from contemporary processes studies of shore platforms.

2 Cliffs

The episodic nature of cliff erosion is now well recognized. Although problematic, temporal episodicity has been incorporated into modelling. However spatial episodicity remains a problem. Sallenger *et al.* (2002) identified the linkages between El Niño-driven storm events, beach width and episodic cliff erosion. Beach width varied with the presence of giant cusps and increased cliff erosion occurred at embayments when wave runup exceeded a threshold representing beach width. Moore and Griggs (2002) reported an improved method of determining cliff retreat rates using GIS and predicting future cliff position. Hapke and Richmond (2002) investigated the impact of seismic and storm events on episodic cliff retreat by using three-dimensional mapping to analyse cliff failure styles and retreat magnitudes. They found storms had a greater impact on both the linear extent of cliff failure and the amount of retreat than seismic events. Lee *et al.* (2001) suggested ways to select the appropriate probabilistic model for determining cliff recession for different modes of recession and Hall *et al.* (2002) presented a stochastic simulation of cliff retreat that incorporated the episodic behaviour of cliff retreat. Duperret *et al.* (2002) reported a detailed examination of a cliff fall event in chalk on the French coast on the English Channel. They emphasized the role of subaerial processes and noted that particularly heavy rainfall prior to the collapse was probably the triggering mechanism.

3 Coral reefs

A number of studies have examined the geomorphology of coral reefs with attention being focused on Holocene reef growth and island development. Woodroffe *et al.* (1999) considered the development of atoll reef-islands in the Cocos (Keeling) Islands and Woodroffe *et al.* (2000) described platform and fringing reef growth in Torres Strait. Kennedy and Woodroffe (2002) provide a review of fringing reef growth and morphology. Woodroffe and Morrison (2001) report on the late Holocene accretionary history of reef islands on Makin, in western Kiribati.

Reef sediments and reef sedimentation have been described by Kench (1997) in the Cocos Islands and at the latitudinal limits of reef growth at Lord Howe Island by Kennedy and Woodroffe (2000) and Kennedy (2003). Harriott and Banks (2002) presented a biophysical model for the latitudinal variation of reef growth. Rasser and Riegl (2002) investigated reef rubble production and binding. In terms of process studies, Kench (1998a, b, c) described the physical processes and controls on sediment transport in atoll environments in the Indian Ocean (Cocos Islands), but an understanding of the morphodynamics of reef platform and reef islands remains poor. The significance of this knowledge gap is highlighted by recent modelling of the morphological response of atoll islands to sea-level rise (Cowell and Kench, 2001; Kench and Cowell, 2001)

4 Tsunami and rock coasts

The role of tsunami in shaping rocky coasts has become a topical issue. Aalto *et al.* (1999) argued that sinuous grooves on a shore platform at Peeble Beach result from sculpting by high current velocities generated under tsunami. Bryant's (2001) unconventional book has fuelled the current debate as to whether or not tsunami, storm waves or less energetic process have shaped rocky coasts. However work by Felton (2002) and Noormets *et al.* (2002) indicates even very large blocks at high elevations can be emplaced and moved by storm waves, blocks that Bryant cites as evidence for tsunami. Work by Hearty (1997), Nott (1997) and Felton and Crook (2003) discussed the difficulty in separating causative factors, such as cyclones and tsunami, while Rubin *et al.* (2000) and Keating and Helsley (2002) cast doubt on the giant Hawaii tsunami hypothesis identified by Bryant (2001) as a significant event shaping the New South Wales shoreline. These debates do highlight the need to establish the frequency and magnitude of tsunami events in order to understand the role (if any) of such large-scale events in coastal development.

VII Conclusions

The last six years have been a particularly productive period in the field of coastal geomorphology and this paper serves as a starting reference guide for some of the work conducted in selected areas. It should be noted that we have focused on articles published in accessible international journals. Excellent research on all of the presented topics can be found in various conference proceedings (both international and regional), but these references have not been included here. Furthermore, there are obvious topic omissions, such as nearshore waves, beach morphology, sea level and theoretical applications of the science of coastal geomorphology itself. Perhaps most importantly, we have only barely touched upon some of the exciting methodological advances which have spurred our discipline on in recent times. Where do we go from here? In our view, the challenge for coastal geomorphology in the new millennium lies in our ability to harness and apply new technology in collaborative research partnerships. Synergistic studies incorporating specialized knowledge of field measurement, laboratory and numerical modelling skills are unfortunately few, but in order to improve upon our interpretation and prediction of coastal process and evolution, they are very necessary and must be encouraged.

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