Estuarine, Coastal and Shelf Science 150 (2014) 1–10

Contents lists available at ScienceDirect

Estuarine, Coastal and Shelf Science

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

The status of sandy beach science: Past trends, progress, and possible futures

Ronel Nel [a], Eileen E. Campbell [b, *], Linda Harris [a], Lorenz Hauser [c], David S. Schoeman [d], Anton McLachlan [a], Derek R. du Preez [b], Karien Bezuidenhout [a], Thomas A. Schlacher [d]

[a] Coastal and Marine Research Institute & Department of Zoology, P O Box 77000, Nelson Mandela Metropolitan University, Port Elizabeth 6031, South Africa
[b] Coastal and Marine Research Institute & Department of Botany, P O Box 77000, Nelson Mandela Metropolitan University, Port Elizabeth 6031, South Africa
[c] School of Aquatic and Fishery Sciences, University of Washington, 1122 NE Boat St, Box 355020, Seattle, WA 98195-5020, USA
[d] School of Science and Engineering, The University of the Sunshine Coast, Q-4558 Maroochydore, Australia

ARTICLE INFO

Article history:
Received 16 July 2014
Accepted 24 July 2014
Available online 7 August 2014

Keywords:
sandy beaches
ecology
biology
conservation
management

ABSTRACT

Open-ocean sandy beaches are coastal ecosystems with growing relevance in the face of global change. They provide key ecosystem services, such as storm buffering, nutrient cycling, water purification, nursery habitats for resource species, and feeding-breeding habitats for focal species (e.g. endangered sea turtles and shorebirds), and have also become nodes for economic development and cultural use. As a result, beaches face a range of threats, primarily from extractive use, habitat modification and development, sea-level rise and coastal squeeze. Consequently, balancing conservation of the ecosystem and sustainable use of the goods and services is particularly important for sandy shores. Thus, the only way to ensure their protection and continued provision of their valuable services, especially in a period of rapid global change, will be to apply knowledge generated from sound science in beach conservation and management. Here we aim to (1) identify and outline the broad ecological paradigms in sandy beach science; (2) report on a citation analysis of the published literature of the past 63 years (1950–2013) to provide context regarding the topics and location of research, the size and institutional composition of the research teams; and (3) investigate whether beach ecology can and has been incorporated into integrated coastal zone management practices. Past research was framed by specific paradigms (chiefly the Swash Exclusion Hypothesis and derivatives), which can be identified with distinct principles and concepts unique to beaches. Most of the sandy beach literature comes from only a few countries (dominated by USA, South Africa, Brazil and Italy), published by small research teams (<4 authors), mostly from single institutes. The field has yet to establish large multi-disciplinary teams to undertake rigorous experimental science in order to contribute to general ecological theory. Despite the constraints, beach science is responding to new challenges, with increasing use of the latest techniques. However, research in conservation and management specifically remains limited, with stronger focus on anthropogenic impacts, in turn leading to management of people on beaches rather than conservation of the ecosystem itself. We conclude with a look to the future for sandy beach science, and a summary of the contributions to this Special Issue.

1. Context

Human history and culture are tightly linked to sandy beach ecosystems. The oldest records of food collection from beaches date back to 110 000 years ago (Jerardino et al., 2014), when shellfish collection in South Africa may have facilitated the survival of humans through a period of unstable and adverse climate (Jerardino et al., 2014). From these early beginnings of food collection (Marean, 2010; Jerardino et al., 2014), our interests have diversified to: the extraction of a range of commodities, including living resources (McLachlan et al., 1996; Schoeman, 1996; Defeo, 2003), sand and other minerals (Lubke et al., 1996; Ramirez et al., 2005; Simmons, 2005; Young and Griffith, 2009); expansion of beach-centred commercial and recreational activities (Brazeiro and Defeo, 1999; Clark et al., 2002; Defeo, 2003; Martínez et al., 2007;

* Corresponding author.
E-mail address: Eileen.Campbell@nmmu.ac.za (E.E. Campbell).

http://dx.doi.org/10.1016/j.ecss.2014.07.016
0272-7714/

Barbier et al., 2008; Lozoya et al., 2011); as well as the recognition of key ecosystem services (i.e. buffer zones and nutrient cycling) performed by sandy beaches (Schlacher et al., 2007; Schoeman et al., 2011). However, the activities associated with our new interests are also threats to the ecosystem (Defeo et al., 2009). Therefore, a balance must be sought to ensure continued provision (and use) of the goods and services, and conservation of the unique biota (Harris et al. 2014a). For this to be effective in the face of an increasing human population inhabiting the coast (Small and Nicholls, 2003), as well as global environmental change (Schoeman et al., 2014), beach conservation and management should be based on sound science. This requires a solid and comprehensive understanding of ecological functions, attributes and resilience of beach systems. Further, such evaluations should be predicated on the ability to predict responses to stressors and changes.

This synthesis follows the VIth International Sandy Beach Symposium (ISBS), with its theme: "A new paradigm in the face of global change". We present a historical account of the development of the scientific focus for sandy beach science to assess whether the discipline has responded to new issues (such as climate change and invasive species), and so developed new directions of research. To this end, the paper aims to 1) identify and outline the broad ecological paradigms in sandy beach science; 2) report on a citation analysis that assesses whether research topics have diversified and integrated over time, the location of field-based studies, and the size and institutional composition of research teams; and 3) investigate whether beach ecology can and has been incorporated into integrated coastal zone management practices.

2. A historical perspective of sandy beach research

A basic comparison of the number of papers indexed by the Thomson Reuters Web of Science (WoS) published at any time on 'sandy beaches' ($n = 2\,936$) relative to other coastal systems indicated that beach science was underrepresented in the literature. Rocky shore systems (search term 'rocky shores') were studied with similar intensity (3 157 publications), while 'mangroves' (11 149 publications), 'coral reefs' (20 065 publications) and 'estuaries' (36 358 publications) had up to an order of magnitude more publications listed. This underrepresentation of beach science in the literature, coupled with the exponential increase in the number of publications on beaches over the last 63 years (Fig. 1), suggests that it is a relatively new and emerging discipline. This is likely because

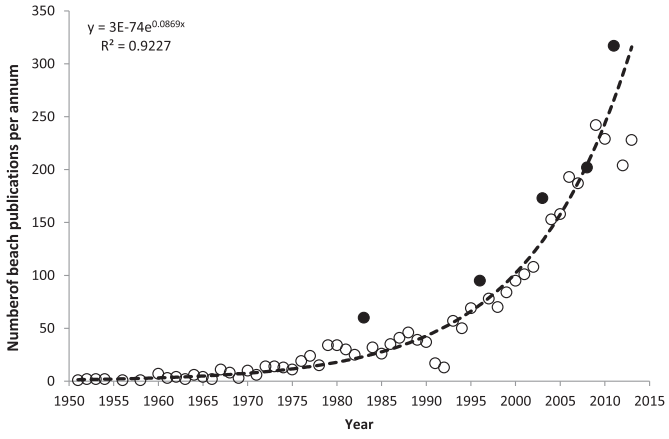

Fig. 1. The number papers published on sandy beaches per year between 1950 and 2013. (Solid dots indicate the years in which International Sandy Beach Symposium Proceedings were published).

beaches were formally recognised as ecosystems only three decades ago (McLachlan, 1981).

A database of all sandy beach publications was compiled to enumerate research trends in the discipline over the period 1950–2013. A targeted search of English literature (i.e. papers with an English title and/or abstract), using the search term 'sandy beaches' was conducted. (The use of wildcards yielded >7000 papers which included non-environmental literature and so was explicitly avoided). The search was followed by a search using 'surf zone' to include sandy beach phytoplankton studies. WoS was reasonably complete on recent beach literature (post 1980), but the earlier research was underrepresented, so the literature database was augmented with references from Google Scholar. Here, the search terms were modified to be more specific to ecology ('sandy beaches' + ecology and 'surf zone' + ecology). Unpublished reports, theses or dissertations were included prior to 1980, but only if the citation was available online and thus in the public domain. Literature on coastal ecology or coastal zone management with direct reference or relevance to beach ecology was included, but manuscripts on more general topics were excluded. Literature specific to other habitats like dunes, estuaries, lagoons, rivers or fjord beaches were excluded. Our approach therefore evaluated the bulk of the literature on open-ocean sandy beaches for the given time period ($n = 3\,876$ papers).

3. Main concepts in sandy beach research

We first attempted to identify distinct theoretical principles in beach ecology and so outline the broad ecological paradigms. This question underpins the philosophy of the discipline - is sandy beach ecology a discrete discipline with a unique worldview/paradigm, or is it just a subset of general soft-sediment ecology?

Possibly the most significant theoretical advance of sandy beach ecology has been the integration of biological and physical sciences. Prior to the Ist ISBS (in 1983), beach studies were primarily descriptive (e.g. Dahl, 1952; Barrass, 1963; Bowers, 1964; McLachlan, 1977). Coastal biologists and ecologists studying beach fauna worked with limited reference to the physical environment and completely without a conceptual framework of beach types. At the 1983 meeting, presentations by coastal engineers, physical oceanographers and coastal geomorphologists introduced biologists to key physical processes and morphodynamic models of beach types (Short and Wright, 1983; Swart, 1983). These physical models have proved essential to the understanding of beach ecology, providing the basic framework around which ecological concepts have been structured. Four key physical concepts are now recognised: (1) the underlying geology provides the first-order control of beach types (Jackson et al., 2005); (2) interactions among sand, waves and tides provide second-order control, giving rise to; (3) a series of beach morphodynamic types, ranging from microtidal reflective (narrow steep) to macrotidal ultradissipative (wide and flat with extensive surf zones); and (4) the main physical process defining the beach ecosystem is sand transport and storage, which links intertidal beaches to adjacent marine (surf) and terrestrial (dune) compartments (Short, 1996). These four fundamental physical principles define the littoral active zone and the physical drivers of open-ocean beach ecosystems (McLachlan, 1990).

Another clear theoretical insight was the identification of general adaptations required in the harsh sandy beach environment. Early ecological studies focused on intertidal benthic macrofauna. Zonation patterns were recognised even though the fauna is cryptic and zones not nearly as well defined as on rocky shores (Dahl, 1952; Salvat, 1964). Early work concentrated on the biology, physiology and behaviour of sandy beach macrofauna (Brown, 1983). The essence of these studies was the realisation that beach macrofauna