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Sandy beaches can survive sea-level rise

J. A. G. Cooper[1,2] ✉, G. Masselink[3], G. Coco[4], A. D. Short[5], B. Castelle[6], K. Rogers[7], E. Anthony[8,9], A. N. Green[2], J. T. Kelley[10], O. H. Pilkey[11] and D. W. T. Jackson[1,2]

ARISING FROM M. I. Vousdoukas et al. *Nature Climate Change* https://doi.org/10.1038/s41558-020-0697-0 (2020)

Vousdoukas et al.[1] assert that global sea-level rise (SLR) poses a threat to the existence of sandy beaches. They use global databases of sandy beaches, bathymetry and wave conditions to drive a simple model based on the Bruun rule to quantify shoreline retreat, to which they add a background ambient trend based on satellite data. When retreat is more than 100 m by 2100, they declare those beaches near extinct by the end of the century. We feel that this is an incorrect and potentially damaging finding. Critical to the paper's conclusions is the fact that, provided that accommodation space is available, beaches migrate landwards as sea level rises and shorelines retreat. Many contemporary beaches formed thousands of years ago and migrated landwards during postglacial SLR[2]. Globally, hundreds of beaches have been retreating at rapid rates for more than a century, but have not been extinguished[3]. In southwest France, for example, the shoreline has receded >100 m but still has wide and healthy beaches[4]. The underlying premise of Vousdoukas et al.[1] originates in an inappropriate model—the Bruun rule, in which SLR promotes offshore sediment transport. As stated in their methods[1]: SLR-induced shoreline retreat "…depends on the amplitude of SLR and the transfer of sediment from the subaerial to the submerged part of the active beach profile". While we agree that offshore sediment transport might happen in cases of very steep topography, in most cases sediment transport is onshore during SLR[2,5].

Sandy beaches are highly variable in form and setting, and it is widely accepted that there is no single response to SLR[2,5]. They may (1) migrate landwards due to onshore sediment transport via overwash without loss of beach width (for example, barrier beaches on relatively gentle substrates), (2) experience recession due to offshore sediment transport (such as beaches backed by non-erodible cliffs or sea-walls) or (3) be stranded on the seabed (overstepped) as intact sand bodies (this requires very rapid SLR and/or particular combinations of morphology and sediment supply)[6]. Beaches may even prograde under SLR when the sediment budget is overwhelmingly positive[7]. Where well-developed dune systems are present, sediment supply from the eroding dunes may significantly temper SLR-induced coastal retreat. Sandy shoreline responses to SLR depend on many local environmental factors, including coastal morphology, sediment supply and transport (onshore, offshore, longshore), the rate (not just amount) of SLR and the ambient nearshore dynamics. Their paper's methodology[1] is based on a single model (the Bruun rule) with the addition of a background shoreline trend. For settings characterized by very substantial background shoreline changes (such as deltaic shorelines), this inclusion of the ambient trend might encompass the local/regional factors but elsewhere, local factors (for example, the presence of dunes, sub-beach bedrock outcrop, shore protection structures) are likely to dominate the shoreline response.

The Bruun rule's shortcomings have been well documented[8–12], and alternatives are being sought by some researchers[9–12]. As applied in Vousdoukas et al.[1], it requires a space- and time-invariant cross-shore profile, ignores sediment supply, is strictly two-dimensional and considers only the amount (not rate) of SLR. Crucially, it does not account for the topography, or the material nature of the basement over which the beach is migrating (Fig. 1). Its central mechanism (offshore transport of sand during SLR) is not a valid process on the majority of the world's beaches. Even in locations where this mode of shoreline retreat may operate, a beach is still predicted to remain, which seems to be overlooked by Vousdoukas et al. Where it is not a valid description of shoreline behaviour, it should not be applied. Past and erroneous applications of the Bruun rule at regional and global scales do not provide justification for the continuation of the practice.

Additional methodological shortcomings include the use of an arbitrary 1:300 beach gradient cut-off to avoid excessive recession rates and an arbitrary constant (E factor) to moderate the predicted shoreline retreat. E is randomly generated to range between 0.1 and 1.0, centred on a median of 0.75. The constructed distribution of E is not based on any evidence of its distribution.

The headline result of this paper—"the near extinction of almost half of the world's sandy beaches"—requires an arbitrary and unjustified amount of shoreline retreat of 100 m. Where a beach is backed by a sea defence structure, it will be eroded, but if accommodation space exists (as in most of the world's beaches), it will migrate. Coastal erosion is a complex process that requires rigorous consideration of local, regional and global factors and reliable models. Collectively, the assumptions and shortcomings that characterize the approach in this paper[1] inhibit the formulation of reliable and robust predictions of shoreline change due to SLR.

Some coasts for which the application of the Bruun model is especially inappropriate are highlighted by Vousdoukas et al.[1]. The Suriname coast, for example, is subject to the overarching influence of large mud banks migrating along the inner shoreface[13]. Moreover, there is no major beach-related tourism and only a few artificial impediments to shoreline migration. Australia is singled out as the

[1]School of Geography and Environmental Science, Ulster University, Coleraine, UK. [2]Geological Sciences, University of KwaZulu-Natal, Durban, South Africa. [3]Coastal Processes Research Group, Plymouth University, Plymouth, UK. [4]School of Environment, Faculty of Science, University of Auckland, Auckland, New Zealand. [5]School of Geosciences, University of Sydney, Sydney, New South Wales, Australia. [6]CNRS, UMR EPOC 5805, Université de Bordeaux 1, Pessac, France. [7]School of Earth, Atmospheric and Life Sciences, University of Wollongong, Wollongong, New South Wales, Australia. [8]Aix Marseille University, CNRS, IRD, INRA, Coll France, CEREGE, Aix-en-Provence, France. [9]USR LEEISA, CNRS, Cayenne, French Guiana. [10]School of Earth and Climate Sciences, University of Maine, Orono, ME, USA. [11]Nicholas School of the Environment, Duke University, Durham, NC, USA. ✉e-mail: jag.cooper@ulster.ac.uk

Fig. 1 | The geomorphology and material landward of a sandy beach are important determinants of its behaviour under SLR. During SLR, waves can access onshore sand supplies, thus ensuring continued healthy beaches. **a**,**b**, The arid Namibian coast with its bare sand (**a**) and the subtropical KwaZulu-Natal coast (**b**) with vegetated sand dunes are dramatic examples. **c**, The paraglacial coast of Northern Ireland also contains beaches backed by erodible, sediment-supplying glacigenic sediments that will sustain beaches as sea levels rise. **d**, Beaches that are backed by cliffs or sea-walls, such as at Oostend, Belgium, are cut off from adjacent sand-supplying dunes. As sea level rises, such beaches will suffer coastal squeeze and disappear or need to be artificially replenished. Photograph in **a** courtesy of Andrew Green; photographs in **b**–**d** courtesy of Andrew Cooper.

country potentially most affected by sandy beach erosion, primarily because it has a very long coastline; however, in reality, Australia has a low risk of beach loss because the overwhelming majority of the coastline is undeveloped, allowing for unimpeded beach migration.

Planning for SLR is necessary, but the paper's mention of Dutch engineering as a solution is inappropriate. The necessary expertise, economy and nearshore sand supplies exist in few locations outside the Netherlands. Locking other nations into large-scale efforts to hold the shoreline would be economically and environmentally disastrous.

Sandy beach responses to SLR are highly site-specific and temporally variable[14]. The generalization of complex processes and extrapolations of datasets to large spatial (that is, global) and long temporal (to 2100) scales by Vousdoukas et al.[1] are inappropriate. They do not present a global analysis; rather, it is a local analysis undertaken for the whole planet. The same model is applied everywhere using datasets (waves, beach slope) that provide local measurements but without detail of important local constraints[14] on shoreline behaviour. Failure at the local level, where computations are performed, cascades into their integrated results. Incorrect model outputs may unnecessarily cause alarm, as has been the case with this paper, and could prompt inappropriate policy responses.

Instead of global applications of flawed concepts, new methods are needed to predict the impacts of SLR on the coast. This will require better datasets of coastal morphology (in the satellite-derived datasets used by Vousdoukas et al., for example, many 'sandy beaches' are misidentified) and improved understanding of the mechanisms of shoreline response in given settings. As sea level rises, shoreline retreat must, and will, happen. Beaches, however, will survive. The biggest threat to the continued existence of beaches is coastal defence structures that limit their ability to migrate[15].

Online content

Any methods, additional references, Nature Research reporting summaries, source data, extended data, supplementary information, acknowledgements, peer review information; details of author contributions and competing interests; and statements of data and code availability are available at https://doi.org/10.1038/s41558-020-00934-2.

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Additional information
Correspondence and requests for materials should be addressed to J.A.G.C.

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