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1 **Sandy beaches can survive sea-level rise**

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26 Vousdoukas et al.¹ assert that global sea-level rise (SLR), poses a threat to the
27 existence of sandy beaches. They use global data bases of sandy beaches,

28 bathymetry and wave conditions to drive a simple model based on the 'Bruun Rule'
29 to quantify shoreline retreat, to which they add a background ambient trend based on
30 satellite data. When retreat is more than 100 m by 2100, they declare those beaches
31 near-extinct by the end of the century. We feel this is an incorrect and potentially
32 damaging finding. Critical to the paper's conclusions is the fact that, provided
33 accommodation space is available, beaches migrate landwards as sea level rises
34 and shorelines retreat. Many contemporary beaches formed thousands of years ago
35 and migrated landwards during postglacial SLR². Globally, hundreds of beaches
36 have been retreating at rapid rates for more than a century, but have not been
37 extinguished³. In SW France, for example, the shoreline has receded >100 m but still
38 has wide and healthy beaches⁴. The underlying premise of Vousdoukas et al.¹
39 originates in an inappropriate model, the 'Bruun Rule', in which SLR promotes
40 offshore sediment transport. As stated in their Methods section: SLR-induced
41 shoreline retreat "...depends on the amplitude of SLR and the transfer of sediment
42 from the subaerial to the submerged part of the active beach profile". Offshore
43 sediment transport might happen in cases of very steep topography, but in most
44 cases sediment transport is onshore during SLR^{2,5}.

45 Sandy beaches are highly variable in form and setting, and it is widely accepted that
46 there is no single response to SLR^{2,5}. They may (i) migrate landwards due to
47 onshore sediment transport via overwash without loss of beach width (e.g., barrier
48 beaches on relatively gentle substrates), (ii) experience recession due to offshore
49 sediment transport (e.g., beaches backed by non-erodible cliffs or sea walls), or (iii)
50 be stranded on the seabed (overstepped) as intact sand bodies (this requires very
51 rapid SLR, and/or particular combinations of morphology and sediment supply)⁶.
52 Beaches may even (iv) prograde under SLR when the sediment budget is
53 overwhelmingly positive⁷. Where well-developed dune systems are present,
54 sediment supply from the eroding dunes may significantly temper SLR-induced
55 coastal retreat. Sandy shoreline response to SLR depends on many local
56 environmental factors, including coastal morphology, sediment supply and transport
57 (onshore, offshore, longshore), rate (not just amount) of SLR, and the ambient
58 nearshore dynamics. The paper's methodology¹ is based on a single model (the
59 Bruun Rule) with the addition of a background shoreline trend. For settings
60 characterised by very significant background shoreline changes (e.g., deltaic

61 shorelines), inclusion of the ambient trend might encompass the local/regional
62 factors, but elsewhere local factors (e.g., presence of dunes, sub-beach bedrock
63 outcrop, shore protection structures) are likely to dominate the shoreline response.

64 The Bruun Rule's shortcomings have been well-documented⁸⁻¹², and alternatives are
65 being sought by some researchers⁹⁻¹². As applied in this paper, it requires a space-
66 and time-invariant cross-shore profile, ignores sediment supply, is strictly 2-
67 dimensional and considers only *amount* (not rate) of SLR. Crucially, it does not
68 account for the topography, or the material nature of the basement over which the
69 beach is migrating (Fig. 1). Its central mechanism (offshore transport of sand during
70 SLR) is not a valid process on the majority of the world's beaches. Even in locations
71 where this mode of shoreline retreat *may* operate, a beach is still predicted to
72 remain, which appears to be overlooked in the paper by Vousdoukas et al..
73 Where it is not a valid description of shoreline behaviour it should not be applied.
74 Past and erroneous applications of the Bruun Rule at regional and global scale do
75 not provide justification for continuation of the practice.

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

81 The headline result of this paper – “*the near extinction of almost half of the world's*
82 *sandy beaches*” – requires an arbitrary and unjustified amount of shoreline retreat of
83 100 m. Where a beach is backed by a sea defence structure, it will be eroded, but if
84 accommodation space exists (as in most of the world's beaches), it will migrate.
85 Coastal erosion is a complex process that requires rigorous consideration of local,
86 regional and global factors, and reliable models. Collectively, the assumptions and
87 shortcomings that characterise the approach in this paper¹ inhibit the formulation of
88 reliable and robust predictions of shoreline change due to SLR.

89 Some coasts for which application of the Bruun model is especially inappropriate are
90 highlighted by Vousdoukas et al.¹. The Suriname coast, for example, is subject to the
91 overarching influence of large mud banks migrating along the inner shoreface¹³.
92 Moreover, there is no major beach-related tourism and only few artificial

93 impediments to shoreline migration. Australia is singled out as the country potentially
94 most affected by sandy beach erosion, primarily because it has a very long coastline;
95 however, in reality, Australia has a low risk of beach loss because the overwhelming
96 majority of the coastline is undeveloped, allowing for unimpeded beach migration.

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

102 Sandy beach response to SLR is highly site-specific and temporally variable¹⁴.
103 Vousdoukas et al.'s¹ generalization of complex processes and extrapolations of data
104 sets to large spatial (i.e., global) and long temporal (i.e., to 2100) scales are
105 inappropriate. They do not present a global analysis; rather, it is a local analysis
106 undertaken for the whole planet. The same model is applied everywhere using
107 datasets (waves, beach slope) that provide local measurements but without detail on
108 important local constraints¹⁴ on shoreline behaviour. Failure at the local level, where
109 computations are performed, cascades into their integrated results. Incorrect model
110 outputs may unnecessarily cause alarm, as has been the case with this paper, and
111 could prompt inappropriate policy responses.

112 Instead of global applications of flawed concepts, new methods are needed for
113 predicting impacts of SLR on the coast. This will require better datasets of coastal
114 morphology (in the satellite-derived datasets used in this paper, for example, many
115 "sandy beaches" are misidentified) and improved understanding of the mechanisms
116 of shoreline response in given settings. As sea level rises, shoreline retreat must,
117 and will, happen. Beaches, however, will survive. The biggest threat to the continued
118 existence of beaches is coastal defence structures that limit their ability to migrate¹⁵.

119

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155

Figure Caption

156 Figure 1. The geomorphology and material landward of a sand beach is an important
157 determinant of its behavior under sea level rise. Sea level rise can tap into onshore
158 sand supplies, thus ensuring continued healthy beaches. The arid Namibian coast
159 (A) with its bare sand and the subtropical KwaZulu-Natal coast (B) with vegetated
160 sand dunes are dramatic examples. The paraglacial coast of Northern Ireland (C)
161 also contains beaches backed by erodible, sediment-supplying glacial sediments
162 that will sustain beaches as sea levels rise. A cliff or seawall-backed beach such as
163 at Oostend, Belgium (D), however, is cut off from adjacent sand-supplying dunes. As
164 sea-level rises it will suffer coastal squeeze and disappear or be artificially
165 replenished.

166 (Credits: Photograph A. Andrew Green; Photographs B,C,D. Andrew Cooper.)

A**B****C****D**