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2.16. Adapting beaches for the future

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The Spanish Mediterranean coastline has a total length of approximately 3000 km (including islands) and is characterized by a great geomorphological diversity, including more than 750 km of sandy beaches. The current configuration and problems of the coastal system can be explained mainly by human intervention in the natural environment, which has intensified since the middle of the 20th century with the regulation of hydrographic basins, the demographic explosion and massive tourism in the coastal zone. The consequences of this transformation on the physical coastal environment have been the decrease in sediment input from rivers to the marine environment, changes in the redistribution of sediment and the urban occupation of a large part of the emerged beach. These human-induced changes have led to a considerable increase in risks (erosion and flooding) on the coast over the last few decades and a continuous loss of the emerged beach surface, which in turn has resulted in a large increase in the need for coastal protection works. Superimposed on these processes, variations linked to climate change (including water temperature, sea level, storms and flash floods) are becoming more important for the coastal ecosystem and will increase the risks in the coastal zone and produce generalized beach erosion in the near future (in fact, they are already doing so). On a global scale, it has been estimated that more than 50% of current beaches will disappear by the year 2100 as a consequence of sea level rise (Vousdoukas *et al.* 2020).

Shoreline change and monitoring

There is therefore evidence that in a relatively short period of time (a few decades) the coastline as we know it today will change, so there is necessary to design a new coastline that can adapt to the expected changes following guidelines that society can accept. Without discarding any of the possible options in the adaptation strategies, it seems reasonable to promote those that include nature-based solutions, as they prioritize the sustainability of the marine ecosystem and will presumably have a lower cost for future generations. This long-term strategy must be multidisciplinary and cross-cutting, considering all environmental aspects that can be incorporated together with social and urban planning aspects. To achieve this, it is necessary to obtain continuous, high-quality data on parameters of interest (for example, the morphological evolution of the beaches and the frequency and intensity of storms.) and, more importantly, to process these data to provide an updated view of the state of the coast at all times.

The Oceanic and Coastal Sedimentary Processes Group of the Institut de Ciències del Mar-CSIC in Barcelona began its studies on the sedimentary dynamics of the Catalan coast and the distribution of sediment inputs to the marine environment in the 1980s. New observational methodologies have been progressively incorporated in these studies, such as video monitoring of the coastal zone (Figure 1), the use of tripods on the seabed, instrumented anchorages for data collection (current velocity and suspended sediment concentration) and the incorporation of citizen science (the CoastSnap project). The Group's experience in data collection and, above all, in data interpretation and definition and in cataloguing parameters of interest (Durán *et al.* 2016), allows us to offer to the society a consolidated scientific knowledge for the evaluation of impacts and the prediction of the future behaviour of coastal ecosystems.

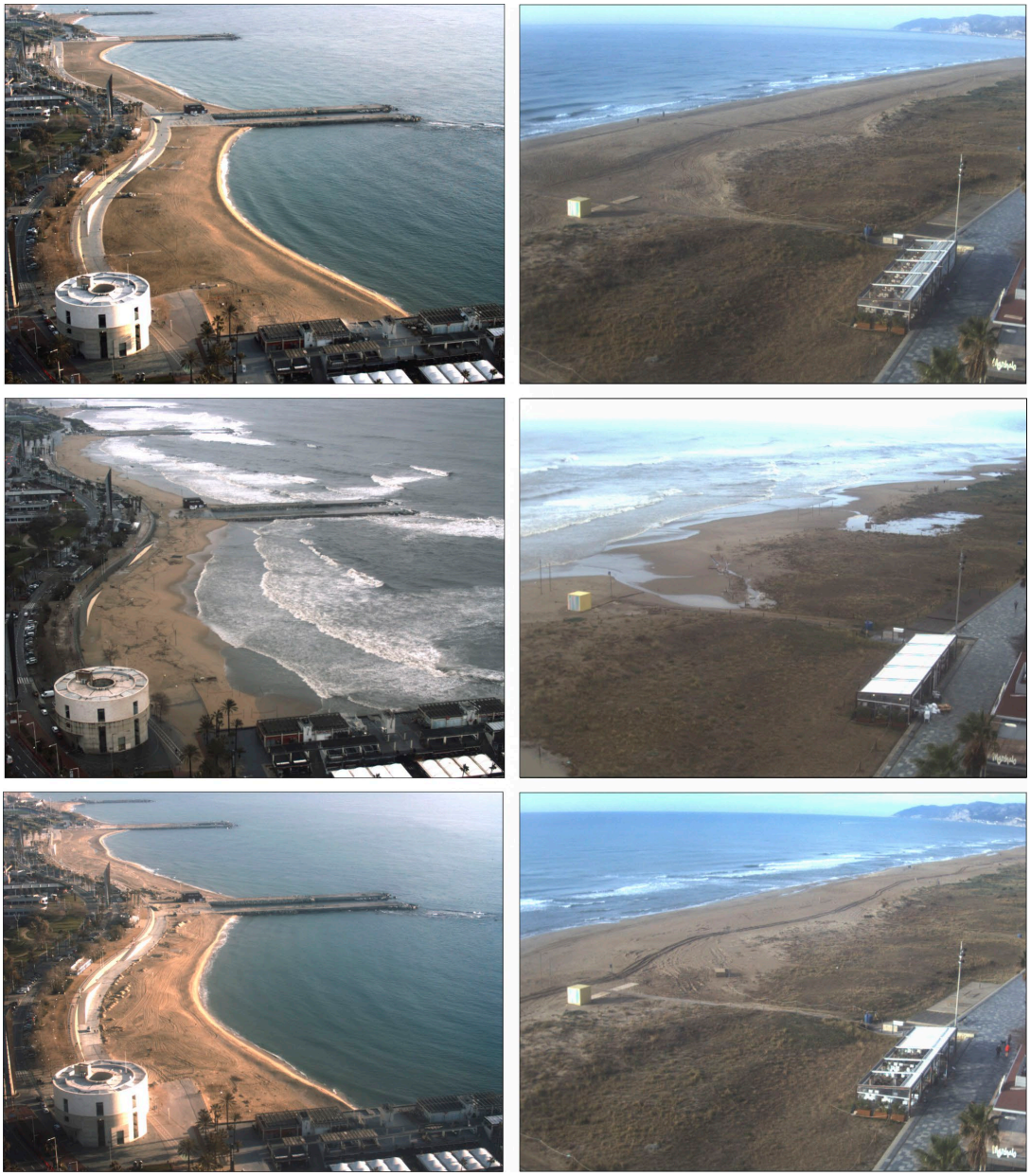

Figure 1. Beaches of Barcelona (left) and Castelldefels (right) one week before (top), during (centre) and one week after (bottom) the Gloria storm of January 2020. This storm was the most extreme ever recorded on the Catalan coast. Images taken from the ICM-CSIC video monitoring stations (coo.icm.csic.es).

The general objective of the coastal adaptation strategy is to assess whether it is feasible to maintain (or even improve) the functionality of beaches as a protection from storms, an habitat and a place for social uses in the long term, and to propose the main lines of action to achieve this. These lines of action should consider a more sustainable future in relation to the use of beaches, which includes, for example, reducing the need for sand for artificial regeneration and minimising the negative impacts of storms; improving the quality of water and sediment; and minimizing maintenance costs. And this must be done in a scenario where the needs of almost

all the beaches will be in mutual competition, so that a general coordination (including a comprehensive sediment management plan) will be necessary to optimize the available resources. In short, this adaptation of the beaches, which will have to be faced over the coming decades, requires a considerable economic investment and may entail the need to give up certain beaches. It must be attempted to avoid further compromising future generations so that recreational access to the beach will not become a luxury.

Identifying adaptation strategies

In order to build a more sustainable alternative, two complementary lines of action are suggested in the short term: a) improving and adding versatile and scalable protection structures that can be easily expanded according to the needs of the beaches where they are essential (dune fields, artificial regeneration, protection dikes, etc.); and b) promoting "smart beach" actions that consist of optimizing management based on detailed knowledge of available resources, proposing measures to reduce damage from storms, optimize the use of sand and anticipate future problems. The use of observation tools such as video monitoring has proved to be very useful in beach management (Simarro *et al.* 2020) and has been successfully applied over the last two decades in the city of Barcelona (Ojeda and Guillén 2008).

In the longer term, what will happen if extreme storms such as the one that occurred in January 2020 (the Gloria storm) come to occur every two to three years, as forecasts for the mid-21st century indicate? It will be difficult to maintain the same configuration of beaches as at present: the flood level will rise and the destructive impacts of waves will affect hitherto protected areas. On a time-scale of decades, an urban and land management policy must be initiated to expand the maritime-terrestrial zone and incorporate an interior zone with sufficient extension to allow the beach to accommodate erosion and flooding during high-energy events (artificial dunes that facilitate adaptation and protection, areas capable of absorbing floods, etc.). The more natural a beach is, the more easily it can adapt to new conditions. When gaining space for the beach is not a possible alternative (as in many urban beaches), the development of new protective structures and large-scale artificial sand reclamation can be considered.

In summary, humankind has been able to enjoy contact with the sea in many different ways and has adapted very quickly to the changes that have occurred throughout history. Our adaptation to different uses is much easier than the geomorphological adaptation of the coast itself. Therefore, maintaining the recreational aspects of the beach should not be our essential objective in the design of our beaches of the future; rather, it seems more appropriate to prioritize moving towards a safe, environmentally healthy and sustainable coast.

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References

Durán R., Guillén J., Ruiz A., Jiménez J.A., Sagristà E. 2016. Morphological changes, beach inundation and overwash caused by an extreme storm on a low-lying embayed beach bounded by a dune system (NW Mediterranean). Geomorphology 274: 129–142.

Ojeda E., Guillén J. 2008. Shoreline dynamics and beach rotation of artificial embayed beaches. Mar. Geol. 253, 51–62.

Simarro G., Calvete D., Souto P., Guillén J. 2020. Camera calibration for coastal monitoring using available snapshot images. Remote Sens. 12: 1840.

Vousdoukas M.I., Ranasinghe R., Mentaschi L., Plomaritis T.A., Athanasiou P., Luijendijk A., Feyen L. 2020. Sandy coastlines under threat of erosion. Nature Clim. Chang. 10: 260–263.

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