Chapter 35
Future Perspectives of the Spanish Coast

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35.1 Introduction

The chapters included in this book demonstrate a high degree of knowledge about the coastal dynamics of many segments of the coast. The highlights of the functioning of wind, waves, tides and currents in each one of the sectors composing the Spanish coast have been studied and described. The main geomorphologic and sedimentary features of, so as the depositional or erosional trends or each coastal track are also defined. According with this knowledge, national, regional and local administrations have in their hands the tools to develop a correct Integrated Coastal Zone Management in each one of these coastal tracks agreeing with the criteria suggested by Evans (1992). This is vital in Spain, especially, take into account that a big part of the Spanish economy is based in the tourism of sun and beaches. Nowadays, the present coastline suffers the errors committed by the coastal managers in the past, before all this knowledge had been acquired.

As was commented in Chap. 1, in the 60s and 70s decades many dams were built along the main Spanish rivers cutting the natural sediment bypass to their mouths and coastal adjacent areas. The presence of hundred of dams caused a sedimentary deficit on the coastal systems and the coast responds with a generalized retreat, observed in every track studied in the chapters of this book. In addition, many hard structures like groins, breakwaters and seawalls, were built in lineal coasts, to avoid this coastal erosion. Other rigid structures like jetties were also built to stabilize estuarine mouths where harbors were established in its interior. A consequence of these structures is the disruption of the natural longshore

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transport, compartmenting the coast in small cells and also causing problems of erosion updrift of each rigid structure.

Other problem caused by an incorrect coastal management was the dismantling of entire chains of coastal dunes. Many kilometers of the Spanish coast were urbanized transforming the natural beach dune system in urban beaches attached to promenades or directly to first-line buildings. The presence of these structures caused a rigidization and a leak of flexibility of the coast. The absence of the foredune facilitates the direct attack of storm waves on these buildings and promenades, causing every year tremendous economic damages.

By all of these causes, the present Integrated Coastal Zone Management along the Spanish coasts represent an exciting challenge for the competing administrations, since today the entire Coast is public and protected by laws, but with a big responsibility, because now all the scientific knowledge is available for the coastal managers.

35.2 Future Challenges for the Managers

The framework of the global warming represents a direct menace, not only for the natural coastal systems, but mainly for the human structures installed in them. During next decades a slight but continuous sea level rise and an increment of the frequency and intensity of storms are expectable (Eliot 2016).

In this context, natural environments continue having the flexibility to evolve according these new parameters. In these systems, the tendencies of the future coastal evolution will be conditioned by the quantitative balance between: the velocity of sea-level rise, the rate of sediment supply from the continent and from the shelf and the volumentric capability of coastal agents to rework this sediment supply. As was explained in the Chap. 1 of this book, Global warming acts on the three variables: (1) on a hand, the sea level will rise a mean about 3.0 mm/yr in the Spanish coastal areas, (2) on the other hand, in Spain is expectable a decreasing of the rains, which imply a diminution of sedimentary supply coming to the coast from rivers, (3) finally, an increment of wave energy (and sediment rework capability) will be caused by significant increases of wave dimensions, so as a spike of the number of storms.

Just writing these words, the fourth of a series of extreme storms affected severely the Spanish Coastline. From the 1st of March 2018 these four successive storms affected directly the Gulf of Cadiz in three weeks. Two of these storms, named Emma and Gisele coincided with spring tides. The coincidence of high astronomic tides and a storm surge of 0.60 m elevated the sea altitude to unusual levels unreached since 1981. The duration of various days of these storms provoked also the coincidence on the coast of sea waves and strong winds. In the case of

Emma, the 1st of March, wind reached velocities upper than 30 knots, that incremented the wave dimensions to reach Hs of 6.40 m. The arrival of Gisele, two weeks later, again during spring tide conditions increased the damages in the urban beaches previously dismantled by Emma (Fig. 35.1a, b).

It can be expected that natural systems will be tailored to these new dynamic conditions. So, the coast will evolve to a transgressive situation with beaches and dunes even more eroded and overwashed (Fig. 35.1 c, d) and displaced to upper areas and fluvial mouths invaded by marine waters. On the contrary, the anthropized systems lost the natural flexibility and cannot evolve in an adequate way to this new scenary. The consequences for the Spanish Coast are severe. These, have been described in a study by the EU (Policy Research Corporation 2016), and already exposed in the Chap. 1 of this book.

The measures for the coastal protection in Spain have traditionally used rigid defenses, without taking into account the effects that these installations normally trigger. The evolution of knowledge in the last decades should make managers reflect that relocation and the named soft measures (replenishments) should be best solutions for protection of our coast. In this sense, the managers must use dynamic criteria, generated by geomorphologists and sedimentologists, to define the management policies and maintenance of the coast in the context of Global change.

This is a challenging framework for the coastal managers and the economic development of the entire country will be in their hands in the next decades, since

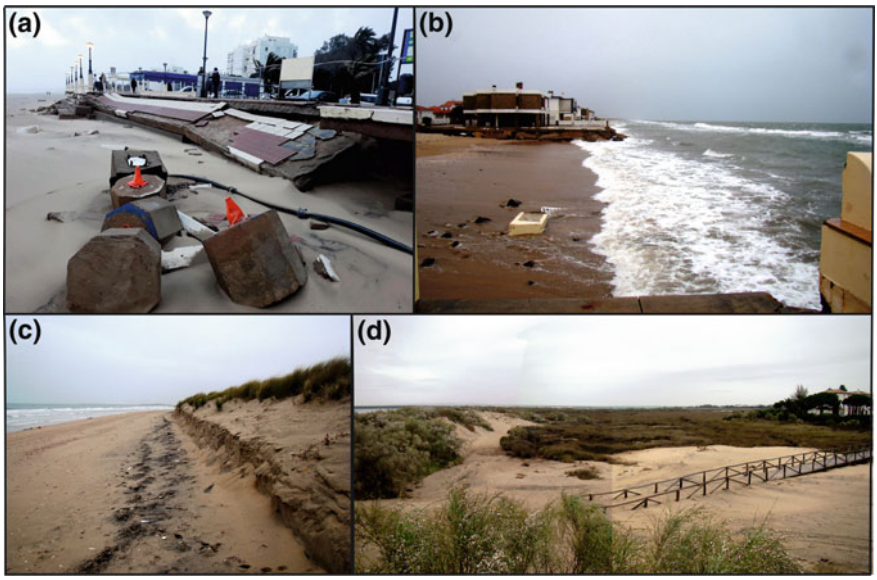

Fig. 35.1 Damages caused by the storms Emma and Gisele in the Southwestern Spanish Coast. **a** Damages in the promenade of Playa Central (Isla Cristina, Huelva). **b** Damages in the buildings of La Antilla (Lepe, Huelva). **c** Scarp berm in a foredune. **d** Washover fan over a salt marsh by breaching of a foredune

not only the touristic business, but the biggest cities, the richest industries and the main harbors are located just in the coast. For this reason will be necessary a cross-jurisdictional cooperation, taking into account that in Spain there are three levels of administration: national, regional and local.

35.3 Perspectives in the Coastal Science

In recent decades the research efforts that encourage a deeper knowledge of the coastal system are increasing.

The main contributions of the coastal investigators in the last years have been making around three main research lines: (1) contribution to the general knowledge on the coasts from a dynamic, geomorphological, sedimentological and environmental points of view, (2) contributions about pure methodological development and use of new techniques to the coastal knowledge and (3) contributions of environmental diagnosis, showing the effects of some human actions on the coast, mainly focused to planning of coastal management (Andrés and Gracia 2000; Blanco-Chao et al. 2003; Hernández-Calvento et al. 2005; Gómez-Pujol and Fornós 2007; Morales et al. 2009; Montoya et al. 2011; Flor et al. 2013; Malvárez et al. 2015; Pons-Buades et al. 2017). These same three lines mark the tendencies for the next years, especially in the context of the Global change.

35.3.1 Studies on Coastal Dynamics, Geomorphology and Sedimentology

The general guidelines of the knowledge on the dynamics and geomorphologic functioning of the Spanish Coast are already established. However, much remains to be done in different ways. Here are the main trends that must be the future research lines to respond to the immediate challenges.

- *Underground record and architectural studies*: The main part of the studies already developed was centered in the surficial distribution of sediment. Future research must focus the stratigraphic record, especially regarding the 3D architectural disposal of the sedimentary facies. These studies, can contribute to determine geometries of sedimentary bodies and, superimposing a sediment chronology, can help to understand possible slight sea level movements in the last 5000 years.
- *Study of coastal events*: Coastal events are important energetic and destructive punctual processes. It is important as a future guideline to characterize the effects of each one of the storms and tsunamis arrived to the coasts in the future, but also recognize the record of these events in the past in order to establish return periods and make correct previsions of future damages.

- *Extension of the studies to the submarine areas of the coast*: At the moment, the biggest part of studies was focused in the emerged part of the coast, but the shore is an integrated system and to get an adequate knowledge of the dynamic processes it is necessary to extend the studies to the sub-littoral areas. In this sense will be necessary to apply new techniques described as follows.
- *Upscale and downscale the studies*: Once the mesoscale dynamics of our coasts have been characterized it is necessary a two-sense change of scale. In a hand, more detailed and specific studies in a minor scale would be useful to understand small nuances in processes and sedimentary distribution. On the other hand, a connection of studies done in adjacent areas has to be done in a macroscale to understand some problems in a wider context.

35.3.2 Studies on Methodological Development and Use of New Techniques

- *Sensors for process measuring*: Developments in technique incorporated during the last years a new generation of sensors to measuring processes. In this sense, wave gauges, tidal stations and Doppler currentmeters, capable to do time-continuous measures and register them in dataloggers could be the best examples. These datasets will contribute to a better understanding of the environmental knowledge of the coastal systems.
- *Geophisical methods*: Last years, is being a trend the use of acoustic techniques like Side Scan Sonar or Seismic profiles to complete the geomorphological and sedimentological underwater and underground information of coastal systems. These methods were widely and successfully used by the marine geologists in deeper areas. The technical development of cheaper, more reduced and versatile equipments will contribute to extend the studied areas to the subtidal coast.

In the same way, the use of Ground Penetration Radar is being used to characterize the internal structure of sandy barriers and littoral dunes y the land portion of the coast.

- *Topographic and bathymetric methods*: New acoustic and laser techniques like multibeam echo sounds and aerial LIDAR have allowed in the last years to get high resolution bathymetric and topographic records. These records contributed to elaborate digital terrain model (DTM) that integrate terrestrial and underwater very useful in coastal areas to understand some unaboarded geomorphological aspects.
- *Mathematical models*: Modelling of hydrodynamic and sedimentary processes is a new tool which is being used by geoscientists to understand the functioning of the coastal systems. Uncalibrated models were at the moment an excellent method to know the cause of past effects, but also for a good prevision of future actions on the coast. In the future, the use of these models in coordination with

the data obtained by the previously described sensors will allow a correct calibration of the models in order to develop previsions totally reliable which can help the coastal managers to take adequate decisions.

35.3.3 *Environmental Studies and Integrated Coastal Zone Management*

The beginnings of the studies about the coast were aboarded by the coastal engineers. The first aim of these studies was to adapt the coast to human requirements. When geo-scientists enter to study the coast, a pure scientism was focused to the correct understanding of the natural coastal system and the consequences on coastal dynamics of the structures built by the civil engineers. Now, under the present state of the art, a new focus is necessary: knowledge to be applied to the ICZM. In order to get the best criteria to take decisions will be necessary studies about the followings items.

- *Mapping vulnerability*: Detailed charts of the coastal zone, including maps of degree of vulnerability to coastal events, not only in natural environments, but especially in the human occupied coast.
- *Conceptual modeling*: Conceptual models are conceived as a method of visualizing integrated and interpreted data. There are different conceptual models that would be applied in Coastal Geosciences, but the most interesting for the coastal managers are those that synthesize processes and sedimentary transport as a response of modifications in the parameters that make evolve the coast (natural or human). In this way, conceptual models are a useful way to convey resource information to politics, since must be a system of representation understandable to experts and non-experts.
- *Transversal interdisciplinary studies and debates*: After directives of the European Union like Horizon 2020, scientist would tend to a transversal and interdisciplinary vision of their studies. Take into account these new rules, coastal scientists are obligated to incorporate the vision of geographers, geologists, oceanographers, biologists, archaeologists, coastal engineers, mathematicians, physicians, geochemicals and lawyers to build multi-visionary teams capable to analyze any aspect of the future coastal planification that hardly would be approached by individual specialists.

35.4 Science for the Society

The last challenge that needs to be addressed is to carry the knowledge to the general society. Since the entire population is and will be affected by the coastal processes, in the future, the coastal scientists are strongly forced to communicate

our discoveries to people. Therefore, it is not enough to write scientific publications, but write communications comprehensive for a non-technical audience and report it in media, webpages and social networks.

Ultimately, coastal scientists have to focus on the future by addressing challenges that become increasingly difficult, especially in a context of economic crisis that considerably limits investments in research. However, we will address this task with our best weapons: effort and illusion.

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