**MORPHODYNAMIC INTERACTIONS OF CONTINENTAL SHELF, BEACH AND DUNES: THE CABOPINO DUNE SYSTEM IN SOUTHERN MEDITERRANEAN SPAIN**.

Short Title: Morphodynamics of Cabopino Dune System. Spain

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**Abstract**

The complex morphodynamic interactions between nearshore, shoreface and dune systems are usually simplified by studying these zones and their associated processes in isolation. However, the established relationships between each of them suggests that an *integrated* approach is required to examine the genesis, evolution and adaptation of the entire morphodynamic system. The Cabopino dune system in southern Spanish Mediterranean Sea provides a clear example of a *linked* morphodynamic system in which a relatively large dune system has been generated and grown through the supply of sediments from an adjacent littoral supply environment. Here, we present a conceptual model of how the nearshore has provided suitable conditions for beach and dune development. We purport that synchronisation of sediment activation in the marine and aeolian sections of the system have played a major role in this microtidal setting in which temporal aspects are not only tied to storm action, but to large sedimentary features moving alongshore.

*Keywords****:*** *Mediterranean Dunes, Marbella, Nearshore-beach-dune, synchronisation, Costa del Sol.*

**Introduction**

Beach morphodynamics is a common concept through which we understand the functioning of beach sedimentary systems. Viewed as a continuous feedback process where interacting forcing factors and morphology help form complete systems, is now well-established in the field (Masselink and Gehrels, 2015; Gómez-Pujol et al., 2007; Loureiro et al., 2013, Short and Jackson, 2013). Compared to previous approaches, it represents a more detailed analysis on ‘how’ rather than ‘what’ processes are at play and their significance in giving beach form. However, morphodynamics still involves segregation of the various sub-environments of the nearshore/beach/dune continuum. Thus, many have attempted to link at least parts of the system (Short and Hesp, 1982; Saye et al., 2005). Even though this view is plausible, there are significant shortcomings such as actual sediment supply (Phillips et al., 2017) which can vary during dune consolidation phases (e.g. Psuty, 1992) and often this is also only viewed from a cross-shore dimension. However, in post-glacial sediment-supplied coasts where littoral drift is present, nearshore sand bodies may appear and move *along* the nearshore system, helping provide decadal to century scale temporary dissipative morphodynamic settings, causing beaches to accrete and boosting subsequent dune development. Sand dunes are landforms resulting from sedimentary accumulation along *and* across a coastal system. The interconnected beaches to the inland areas help generate sufficient sediment input for the back beach zone and, with sufficient winds, can initiate foredune accumulations. Optimal settings are usually those associated with dissipative beaches and high wave energy supplying abundant sediments from marine sources from a gently sloping accommodation space (Hesp, 2012). Those beaches then must be subject to modally high wind speeds and appropriate directions for the aeolian entrainment of sand. Dunes evolve from foredunes to a spectrum of morphologies conditioned by aeolian interactions between morphology and vegetation (Houser, 2009).

In the longer term, a falling sea level regime during coastal dune formation is normally required for dunes to become distinctive features (Pye, 1983). Dunes form during slow sea level fall with significant phases identifiable in the stratigraphic record of the dune bedding (Lario et al., 1995). In terms of sediment availability to initiate nearshore/beach/dune interaction, most Atlantic-facing European coastal dune systems are associated with the period between 18K BP and the present, known as the Last Glacial/Interglacial Hemicycle (LGIH) (Hernández-Molina et al., 1994) when both glacial and riverine sediments placed sediments in the active zone of present sea level. However, Mediterranean coastal dunes fronted by steep continental shelves are not associated with glacial deposits but rather with those of river mouths and/or coastal lagoons (Pye, 1983). Their development and growth is limited to very recent sediment supply, which, when combined with limited forcing factors (waves and winds) are normally several orders of magnitude in size below those of north Atlantic beach and dune systems. However, Mediterranean dune fields exist that do not seem to correspond to this general pattern, possessing an Atlantic type physical scale and, more importantly, a distinctive link to nearshore derived sediments rather than riverine or lagoon sources (Guisado-Pintado et al., 2013).

In terms of their geomorphology, western Mediterranean dunes are typically narrow, often closely linked with deltas and/or fronting lagoons or *albuferas* (Sanjaume and Gracia, 2011). Although most of the Spanish, French and Italian coasts are characterised by highly developed (socio-economic) coasts with heavily modified coastal dune systems, genetically, it can be postulated that nearly all dune systems originated during the Flandrian maximum (6k to 5k years B.P.). These systems have been altered by river dissection or other geomorphological processes related to small variations in morphodynamic behaviour (Goy et al., 1996). Recently, human-induced change has pushed most of these systems into unrecognisable dune fields. This artificial modification of dunes is not solely constrained to the direct destruction from urbanisation, but more importantly to the distortion of the system by changes in the original conditions of their formation. For example, interruption of sediment supply from marine sources to the coastal system as well alteration in the structure of cellular nearshore circulation patterns can disconnect, if not eliminate completely, the nearshore-beach-dune feeding pathway. In terms of morphodynamics, the role of vegetation in dune development has also been highlighted (Xu et al., 2015). Mediterranean dune vegetation forms above the beach with a successional sequence that is more complex and diffuse than that of Atlantic or other open ocean-type dunes (Sanjaume and Gracia, 2011). Shrubs of the typical Mediterranean bioclimatic stages are found in average conditions in these dunes. However, at the confluence of Atlantic and Mediterranean ecosystems, transitional environments in the western Mediterranean provides the basis for vegetation patterns that colonise the system and ultimately affects morphodynamic processes. Unusual bioclimatic conditions are present in the Cabopino dune complex (described later in this article) that help affect the development of both mobile and fix dune types.

Here we use the Cabopino dune system (Fig.1) to demonstrate how Mediterranean dunes can grow to extents and volumes comparable to European Atlantic dunes, even under low energy settings from both wave and wind forcing as well as intermittent and limited sediment supply. The vital link of nearshore, beach and dune dynamics when viewed as integrated system provides an insight into the dune system’s dynamics.

*Study Area.*

The Cabopino dune system is located in the southern Mediterranean coast of Malaga Province, Spain. It is a central feature of western Costa del Sol and the well-developed dune system of the Alborán Sea in Spain (Fig. 1). The dunes are located in the eastern section of the Ensenada de Marbella and extend from Marbella to Calahonda about 12 kilometres to the east. Beach profiles are usually steep and far from dissipative, modally adjusted to high frequency waves generated by the local sea waves that are common in fetch limited environments of the Alboran Sea, generating a steep and narrow surf zone (Malvárez, 1999).

*Wave regime*

Given that the effective fetch is limited to an average distance of 500 km, sea waves are common and only rarely do swell waves filter in from the Atlantic Ocean to the site. This results in a concentration of wave action on a narrow fringe of a steep coastal shelf. The contemporary wave climate in the region, is characterised by long periods of calms (over 77% per year) in which the wave heights are less than 1 m (around 0.8 m are found in summer and almost 1.3 m in winter) and periods are short (T: 4-5 seconds) corresponding to short-crested waves forced by local winds and limited fetch. Wave and wind approach is characterised by the alternation, almost 50%, of westerly and easterly winds, both in summer and winter seasons. Tidal range is microtidal (<0.2 m average astronomical tidal range) and semidiurnal and thus the main (contemporary) hydrodynamic influence on the coast is wave action. In terms of high-energy events, decadal records showed that storms are characterised by a low variability of wave approach; the majority are easterly events (range from 80-135 degrees) with deep water wave heights greater than 5 m (Guisado-Pintado et al., 2013).

Figure 1 here

The Alborán Sea can be classified as low energy given the modal wave energy regime. However, the coast of Andalusia, although not being highly influenced by large storms, can experience intense storm activity, particularly during the winter (Guisado-Pintado, 2012). High-energy events are dominated by high frequency storm waves with periods of less than 7 seconds and significant heights of over 5 meters causing water level surges (Backstrom et al., 2008) and thus have an important influence in the morphodynamic environments and coastal processes of this part of the coast. Given that the Alborán Sea is adapted to low wave energy conditions, wave parameters and morphodynamic processes induced by these extreme wave conditions are notably different to those observed under modal conditions. The dispersal of energy during shoaling and breaking generates distinctive morphodynamic settings under modal and storm conditions. Modal wave conditions are characterised by very low wave energy dissipation values (peaks of 0.003 W/m2) that occur rapidly along a short shallow-water section on the steep foreshore, close to the shoreline (around 2 m seaward which corresponds to 50 cm depth), with a breaking zone that extends no wider than 170 m. Conversely, during storms, the surf zone widens fourfold and increases the peak values of dissipation to almost double that of modal conditions and the significant shoaling seems to occur at around 10 m depths (Guisado-Pintado et al., 2014).

*Wind regime* (Aeolian forcing factors). The overall local wind regime is analysed from the offshore buoy network, Puertos del Estado (Fig. 2). Based on the Alboran buoy data from 1997-2006, during summer months predominant winds are from the west (40%) that reach *higher* speeds of > 8 m/s, whereas for 35% of the record subordinate) easterlies occur with lower associated speeds. Calms make up 5.95% of the record.

Figure 2 here

For winter and spring periods, however, wind velocities and frequency tend to be higher for easterlies. For a global annual record, the wind rose shows a predominance of easterlies (E, 18%; ENE 15%) with higher velocities, whereas westerlies (W 13%, WSW 12%) are present but less dominant (Fig. 2).

**Methodology**

Methodologies applied in previous works characterising Cabopino dunes by the authors are combined to provide an idea of the general dynamics of the area (past and present) and for the proposed conceptual model. In the marine and nearshore zones, the wave propagation and dissipation model SWAN (Simulation WAves Nearshore), developed by Delft University of Technology (Booij et al., 1996) was used to calculate wave orbital velocity, induced stress, energy dissipation and to provide data to establish beach state classification through Surf Scaling Parameter (Wright and Short, 1984) calculations. Dune geomorphology was examined by interpretation of historical aerial photographs and Ground Penetrating Radar and Global Positioning System which were used as a preliminary insight on stratigraphy and topographic control of radar data respectively.

*Nearshore and beach morphodynamics.*

Information on nearshore forcing factors were gathered by combining offshore wave information from the national network of wave buoys (Puertos del Estado, 2012) and results from simulated conditions after propagation to the nearshore using the SWAN model to simulate the development of wave spectra propagating from deep to shallow water. For the study area, a set of nested grids were used to obtain boundary conditions of wave spectrum as an input for the nested grid extending from intermediate to shallow waters. The modelling results were then analysed in a GIS using relevant morphological (sea bed gradient and distance of peak energy to shore) and hydrodynamic (wave amplitude and wave period) variables to calculate morphodynamic state using the Surf Scaling Parameter (Wright and Short, 1984). A full description of SWAN and morphodynamic calculations methodology is discussed in Guisado-Pintado et al. (2013).

*Dune geomorphology.* Identification of the full natural layout of the dune system was made via historical and contemporary aerial photographs. This provided the basis for dune classification in conditions prior to urbanisation that took place during the 1960s and 1970s for the whole area. Aerial photographs from 1956 were used to provide a map of dune types and GPS surveys were also designed to describe topographic features across dune-type morphologies. GPS profiles across the dune field were measured (see location in Figure 7), based on evidence from 1956 aerial photography using a Leica Zeno 20 RTK GPS. Finally, in order to see basic internal dune structure and to identify representative dune bedding, 2 GPR transect surveys using a Pulse EKKO PRO Ground Penetrating Radar with 100 MHz antennae and simultaneous GPS were conducted along optimal areas (non-urban development) identified by aerial photography.

Other available resources showing the overall setting of the platform and nearshore bathymetry were also used (Fernández Salas and Malvárez, 2015) to establish the overall environmental setting and linkages between the three morphodynamic zones (dunes, beach and nearshore) (Fig 3).

Figure 3 here

At the start of the Cabopino dune system (from the central portion of the bay towards the East in Figure 1), significant infralittoral prism formations can be seen (Fig. 3). These sand bodies show the classic geometry of a spit, but in this case it is submerged. These formations can be linked to a drift-aligned coastline accumulation tendency and a ‘feeding’ system that may have generated large deposits in recent times. Further, it is likely to be a mobile sediment source, topologically associated with the Cabopino dune system. However, the dominant figures on the platform are the submarine canyons and the Placer de las Bovedas complex (Fig. 3) made up of a concentration of heavy minerals generated by the mobilisation of materials on the beach and the wave-induced offshore currents generated by shoaling.

**Results**

The nearshore morphodynamics of the entire bay fronting the Cabopino dune system appears to work as a unique cell transporting sediments from west to east. In terms of platform and nearshore characteristics, a main sediment deposit is located north of Placer de las Bovedas where rivers seem to have created a significant sink to the lee of this prominent feature. The analysis of the nearshore hydrodynamics shows that this deposit intercepts wave fields, in particular under storm conditions when the wave orbital velocities indicate agitation well offshore to depths of up to 25 metres (Fig. 4).

Figure 4 here

The morphology of the platform therefore seems to generate significant directional forcing to incoming waves and related energy dissipation and stress patterns. Results from the nearshore wave propagations (Fig. 4A) demonstrate that under easterly modal conditions, the wave action is concentrated on a narrow surf zone no wider than 1500 m with near bottom wave orbital velocities (Ubot) reaching maximums of less than 1 ms-1 and almost over the shoreline. Under easterly storm conditions (Fig. 4B) in areas such as Punta de Baños (mouth of Guadalmina river) and Punta Calaburras, orbital velocities increase from 0.5 ms-1 to 0.8 ms-1 (Figure 4). Of particular significance is the increase in velocities identified around the Placer de las Bovedas sand bank, indicative of the potential for wave-induced sediment transport in the area.

Wave-induced stress (Figure 5), was examined from visualisation of vector results and a directional component of force to the East was observed. This suggests a potential West to East circulation in the nearshore for littoral drift even under storm conditions from East. The intense refraction of the eastern cape in the Ensenada may generate this phenomenon under high energy conditions.

Figure 5 here

Beach states (Fig. 6) are ‘intermediate’ at river mouths as well as at the existing deltas and ‘reflective-intermediate’ beach states are concentrated mostly along the western reaches of the bay, with breakers energetically plunging on the shoreface due to the significant steepness of the beach, indicative of potentially erosive behaviour (Fig. 6B). Under easterly conditions, most of the deltas maintain their intermediate state, meanwhile some of the beaches in a dissipative state switch to intermediate (Fig 6A). The bay tends toward dissipative modes to the East with a small number of beaches in intermediate-reflective state. Most beaches in the Bay are dissipative with a minor number of beaches in intermediate-reflective state that is influenced by the incident waves. Dissipative beaches at Cabopino show spilling breakers whereas intermediate and reflective beaches are characterised by plunging breakers very energetic at the shoreface. Overall, surf zones and beaches become dissipative environments with broadened active zones under storm high-energy events (Figure 6).

Figure 6 here

Dune topographic analyses with GPS followed dune crests and trough elevations and their distribution across the profile from the in-land sections (average 750 metres inland) to the current shoreline. Topographic profiles show a decreasing pattern typical of aeolian features rather than beach ridges that followed sea level in the descending trend of the last 6k years. Aerial photographs showed dune types along and across the system (Figure 7).

Figure 7 here

The western section shows significant imbricated parabolic dunes related to a process of reworking of previous structures of parabolic dunes, given the potential diminishing sediment supply scenario, as described by Hesp and Walker (2013). The foredunes at this stage (1950s) were well developed and a clear indication of substantial sediment supply that is no longer available. Slip-face structures observed in GPR profile on dune crests are interpreted as indications of the landward advance inland of the transgressive dunes at times when the large volumes of sediments created mobile dune trains (see circled detail on Fig. 8).

Figure 8 here

Sediments collected and analysed by Del Rio (2017) showed a dominance of fine sands and positive skewness (Fig. 9) which is to be expected from dissipative beach and dune systems, which appears to be the state the beach was in when sediment analyses were conducted. Potentially, the synchronisation phase is positive at this time for dune building.

Figure 9 here

**Discussion and conceptual model proposal**

The dynamics of the coastal system, stretching from the lower shoreface up to inland terrestrial hinterland, is represented on many different spatial and temporal scales. Spatially in the cross-shore, it can vary from just a few hundred metres up to several 10's of kilometres, while alongshore it can stretch for 101-103kilometres. Interactions also occur at extremely variable temporal scales. In the longer term, the Cabopino dunes exhibit, as interpreted from the preliminary GPR work and historical aerial photo-interpretation, a continued forcing and sediment supply dynamic over a significant time period, helping to generate distinct spatial zones and complexities that in turn drive multiple forcing factors. This affects the ability of the system to actually house or store the vast quantities of sediment involved. Elevations of some 20 metres and marked slip-faces could be indications of sustained interactions between nearshore, beach and a well-developed dune field (Figures 7 and 8), although we do not provide dating and thus we cannot affirm if the beach has been providing a source of sediment and dune building phases continuously over the last six thousand years. Large parabolic dunes existed in the inner sections of the system (now inactive due to vegetation) revealing dynamics related to reactivation of sediment sinks, perhaps associated with foredunes in the absence of beach-related sediment feeding and utilisation of blow-out material.

The three dimensional space into which sediment is moved through and delivered to storage zones within the coastal system, known as 'accommodation space', and the physical configuration of this is crucial in dictating the capacity of the system to hold and retain sediment (Muto and Steel, 2000; Jackson and Cooper, 2009). The low-lying, geologically-framed coastal basins are ideal accommodation for sediment storage. The landward-most regions of the accommodation space represents the most resilient zone where sediment can be stored. During fluctuations in sediment supply, vast quantities of sand can be transported by both marine and subsequently aeolian processes to locations far beyond the reach of future drops in sea levels and effectively sand deposits are stranded or perched as dune systems inland. In our model. sediment input fluctuations could be associated with a passing (marine) longitudinal sand body under the correct synchronous conditions of sediment supply from nearshore to the beach. These pulses of sediment delivery to the coastal accommodation space help contribute to the evolution of the coastal dune and beach systems.  Although the longer temporal scale in the system and the *net* result of the contemporary sediment body remaining in the accommodation space, is likely more pertinent than microscale events (annual to decadal), we propose in our conceptual model that fluctuations in development of the dune system may be linked to pulses in the morphodynamic regimes of the various parts of the system (i.e. nearshore, beach and dune). Given the constraints in wave and wind energy at the Cabopino site, coupled with the episodic sediment supply shortages, the sedimentary coastal system that we see today should be operating within a relatively narrow 3-D space inside the overall accommodation space itself. Outside of these areas we see relatively little sediment dynamics occurring and inland dunes remain essentially locked-in and inactive (currently) while subaqueous sand bodies lie beyond wave base.

These are characteristics that link the Cabopino system to nearshore processes and dissociate it from direct riverine supply typically found in Mediterranean environments. Thus, the feeding of the system shows evidence of build up even under limited new feeding from the river network in recent times to build up the foredune (see figure 9) which would allocate the dynamics of continental shelf and nearshore features, such as the indicated longshore depositional bodies as the main modulating agent in dune development/degradation sequences (Fig. 10).

Figure 10 here

The beach supplying the initial sediments, would have had to perform like a fully dissipative environment which is not common in Mediterranean settings and can only be explained by an active and continuous link between an abundant nearshore sand supply that transferred sediments of the necessary type for the transfer from beach to dune material to be so effective in a short timespan (e.g. Aagaard et al., 2004; Houser, 2009; Phillips et al., 2017).

*Dune dynamics*

Transgressive dunes (Hesp and Walker, 2013) are usually associated with high energy dissipative and intermediate coasts and are normally only present on intermediate beaches where high energy storm waves help puncture the foredune zone and funnel sediment through large parabolic dunes (Hesp, 2012; Delgado-Fernandez et al., 2018). They are rarely found next to reflective beaches or low energy systems. The occurrence of transgressive dune fields is also associated with unidirectional winds and the resulting landforms extend tens of kilometres inland (Hesp and Walker, 2013). Thus, the Cabopino dunes exhibit a morphological response that seems detached from the usual forcing factor configuration in lower energy Mediterranean settings. Variables such as beach slope, orientation, fetch, wave energy, vegetation and sediment supply all determine dune formation and evolution, operating with the conceptual synchronisation proposed by Houser (2009). However, instead of responding to storm events affecting meso-tidal dissipative environments, the Cabopino site may be responding to a synchronisation of beach states to sand bodies positioned in front of the active nearshore when wind is active enough to promote large scale dune building phases. Highly oblique wind direction and/or abundant littoral drift may impede the generation of a foredune prior to transverse dunes dominating the landscape. Wind roses for the site (Figure 2) seem to show that cross-shore winds do exist over sufficient periods to enable foredune genesis. Under those conditions, ephemeral nebkha dune types may appear, inducing high supply and mobility of the beach/dune interaction in Cabopino, as identified in the literature (e.g. Hesp, 2012). Although this region of the Mediterranean has been subject to significant fluctuations over long time periods (Lario et al., 1995), examination of (contemporary) distributions of grain sizes on the beach and foredunes shows that surficial sediment sorting appears to correspond with the standard model for foredunes development (Fig. 9). Considering that beach spits consist commonly of greater sediment sizes, the possibility of an emerged spit developing alongshore to constitute a drift aligned beach/dune system can be discarded. This also supports the concept of submerged sand bodies leading beach and dune evolution when synchronised with sediment input and wave and wind energy.

The sediment supply to the beach and dune complex, thus, is a determining factor because it appears to be (i) providing sufficient sediments and (ii) moving the sand bodies to promote beach states that are closer to dissipative. Previous research (Malvárez et al., 1998; Guisado-Pintado et al., 2013) also shows that the continental shelf, down to depths of 50 metres, is dominated by complex sediment transport related bedforms. The proposed sediment circulation cell (Fig. 10) assumes that large deposits store sands and presumably promote sorting in average to shallow water conditions behind the Placer de las Bovedas, 10 to 15 km to the west of the dune field. There are two possible explanations for the general fluctuation in sediment supply. The first may be due to a link to a short-term burst of sediment input from specific events linked to storms or sediment supplied by abnormal (flood) river input or deforestation, and the relocation of migrating sand bodies that modulate the nearshore morphodynamics to generate more or less dissipative states on the beach and thus prompting dune development/starvation phases.

The sediment circulation cell for the entire bay proposed in this paper corresponds to apparent pulsing dynamics and the timing of synchronised events. Sediment input from rivers is not sourced locally at the dune field (like in many other Mediterranean dunes) but from far-field locations. Nearshore wave action develops significant upper platform activity that in turn generates long term sand bodies that cause the intermittent position of more dissipative environments that eventually feeds the beaches and ultimately the dunes (Fig. 10)

Figure 10 indicates the link between the apparent path and timing of sediment migration and its relationship with dune building. The most significant element appears to be the temporal scale of the sediment input pulses because from the initiation of sediment input to the system (provided by rivers to the West of the dune system onshore of Las Bovedas) a period of time on the order of hundreds of years, may be required for longshore drift to entrain the sufficient sediments for nearshore circulation. The sediments that are stored in the shallower realms of Las Bovedas are, however, at depths that require very high energy for nearshore circulation and is thus dependent on longer term climatic forcing such as storminess. Once the sediment is circulating eastwards (see figure 10) the central part of the Bay and the change in exposure of the shoreline promotes a more accentuated, closer to the shore, littoral drift. In those conditions, longshore bars form and eventually weld to the beaches to the East of the system, and becomes more dissipative. It is then that conditions are met to generate dissipative beaches and foredunes that initiate dune genesis helping form the sequence in the dune system (transgressive dunes, blowouts and parabolics). As littoral drift continues submerged bars continue drifting eastwards and eventually get detached from the active (and narrow) surf zone that tends toward intermediate to reflective types. It is apparent when analysing figure 10 (and fig. 4) that sand bodies continue a south-easterly journey that finishes in a deep water sink, such as the pronounced canyon of Calahonda beyond 50 metres depth at the end of the system (see circled bottom right feature in Fig. 10).

Given the importance that eastward sediment transport implies in this system we should also consider the possibility of a counterclockwise circulation pattern inside the Ensenada. This, coupled with the refraction induced by SE storms at high energy events, would better explain the easternward sediment transport on the continental shelf border, from the input zone (Guadalmina-Guadalmansa river systems and Placer de Bóvedas sand bank) to the dune zone (Cabopino cape). It would also move sediments to the sink zone (Calahonda submarine canyon). Although the circulation pattern could be tested through the application of mathematic models, the use of sediment tracers would be probably be much more definitive. These lines of research, though outside the scope of the current paper, would improve testing of the conceptual model.

Figure 11 here

The conceptual model proposed in this paper (Fig. 11) explains why there are pulses of morphodynamic conditions that favours dissipative beaches to create foredunes and periods when dune dynamics respond to starvation from marine sources and are driven solely by aeolian processes, totally detached from other sediment supplying mechanisms. This model also explains why the Cabopino system has developed over geological timescales as an ‘Atlantic’ system where dunes are linked to continental shelf and nearshore processes fed by large deposits rather that the more limited and localised ‘Mediterranean’ dunes closely linked to more recent riverine or lagoonal sources with less dependence from marine sediment sources.

**Conclusion**

As dune systems are a significant factor in protecting low-lying coastal systems, our knowledge of the connectivity between nearshore, beach and the actual dune field is still surprisingly poorly understood as a linked system. Through the morphodynamic analysis of these three zones in an unusual coastal environmental setting for dune development, this paper investigates the origin and evolution of a Mediterranean dune system that, despite the low energy settings (waves and wind) and the relatively low sediment input rates, has developed into a 12 km dune system over the last interglacial. The maturity and variety of the dune morphologies were analysed through aerial photographs, GPS ground truthing and basic GPR profiles, exhibits a fully developed catalogue of dune scenarios that are linked to episodes of nearshore and beach construction followed by significant aeolian activity. Here we propose in a conceptual model, that under certain synchronised scenarios, optimal conditions for dune building phases are met by all three zones merging as one large functioning system for a period. The latter is believed to move vast quantities of sediments along the nearshore, giving a series of sand bodies that modulate morphodynamic states and generates dissipative conditions even in this microtidal low wave energy setting that, in turn, promotes beach growth and sediment entrainment. The last of the marked sand bodies appear to be travelling beyond the 50 metre isobaths and heading, as is likely on previous occasions, into large canyons off the shelf platform and thus the future development and maintenance of the Cabopino dune system may be uncertain.

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