NATURA 2000

Action plan for the habitat type

2110 Embryonic shifting dunes

in the mediterranean biogeographical region

Irene Delgado-Fernández, Juan Bautista Gallego-Fernández,
Francisco Javier Gracia Prieto, Concha Olmeda y Juan Carlos Simón

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MINISTERIO PARA LA TRANSICIÓN ECOLÓGICA Y EL RETO DEMOGRÁFICO

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Madrid, 2025

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Larus audouini. Authorship: Freepik image bank

Sterna albifrons. Authorship: Adobe stock image bank

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Background and introduction

A Habitat Action Plan serves to guide the measures required to maintain and restore habitat types to a favourable conservation status throughout their range at the biogeographical level.

Within the framework of the Natura 2000 Biogeographical Process and following the conclusions of the 2nd Mediterranean Biogeographical Seminar, held in November 2017 in Limassol (Cyprus), five workshops were organised between 2019 and 2021. These workshops were designed to standardise procedures for monitoring, assessing and preserving habitat types of community interest in the Mediterranean region (hereafter referred to as MED Workshops).

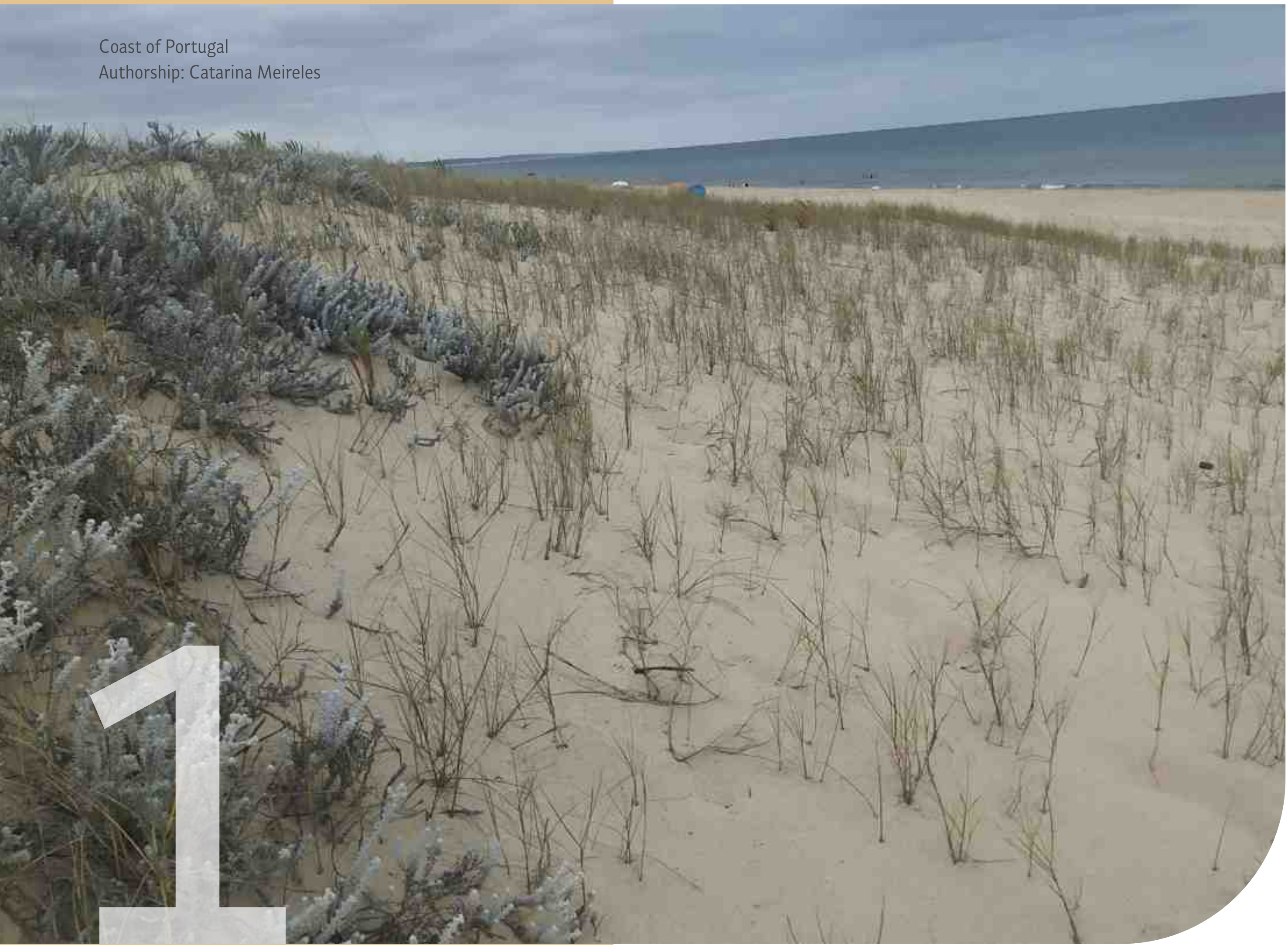
MED Workshop #5 was conceived as a tool for the practical convergence and compilation of the concepts and methodologies set out in the other four workshops, concluding with the preparation of a table of minimum contents for an action plan for a type of habitat, which was agreed with those attending the workshop.

As a result of the efforts carried out in the MED Workshops, it was recognized the need to move forward jointly on preparing a pilot action plan for a habitat type of Community interest. As a commitment to follow up on this issue, a proposal was made during the meeting held on November 23, 2021, to set up a Working Group comprising representatives from all the Member States within the Mediterranean region.

The elaboration of this action plan was done by a Group which included scientific and technical coordinators, scientific experts and representatives of national authorities from all the EU Mediterranean countries, as well as participants from the European Commission. The Spanish Ministry for Ecological Transition and the Demographic Challenge provided support to the preparation of this action plan.

Furthermore, this exercise also served to identify information gaps and additional needs for completing adequately an action plan and start its implementation. Being a pilot initiative, it was also useful to gain experience for the preparation of other habitat action plans in the framework of the Natura 2000 biogeographical process.

Cakile maritima. Gulf of Cadiz. Spain. Authorship: Juan Bautista Gallego Fernández


Coast of Portugal
Authorship: Catarina Meireles

1

Objective and scope of the action plan

Mediterranean coastal dunes harbour some of the most threatened habitats in Europe. Recent studies indicate the disappearance of c. 25% of their historical distribution, with substantial losses in associates species. This suggests that intense degradation processes are occurring in coastal dune habitats, particularly on the upper beach and on shifting dunes (Sperandii, 2020). Like other coastal environments, coastal dunes and beaches are at the receiving end of most touristic and recreational-related human activities along the coast (Cooper and McKenna, 2009). Urbanization and increasing coastal population densities are limiting their mobility and leading to issues such as ecosystem degradation, coastal erosion and coastal squeeze, among other impacts (Esteves, 2014; Harris et al., 2015; Lithgow et al., 2019). Inappropriate management of human activities has led to coastal ecosystems degradation, loss and fragmentation (Defeo et al., 2009; Cooper et al., 2009). However, science-based management that incorporates understanding of the system's dynamics can lead to the preservation of both the function and biodiversity of dynamic coastal environments such as coastal dunes (Davidson-Arnott and Bauer, 2021).

Overall aim of the action plan: to promote the necessary actions to achieve favourable conservation status of the habitat type in the biogeographical region.

Scope: biogeographical region and the MS where the habitat is present.

Ammophila arenaria. Gulf of Cadiz. Spain
Authorship: Juan Bautista Gallego Fernández


Tenebrionidae dunes
Authorship: Freepik image bank

2

Habitat type definition and ecological characterization

2.1. Habitat type definition

There are various definitions of "embryo dunes" in the scientific and policy literature. The EU Habitats Directive adopts the following description, available at the European Nature Information System (EUNIS; https://eunis.eea.europa.eu): "*Formations of the coasts of the Atlantic, the North Sea, the Baltic Sea and the Mediterranean, representing the first stages of dune construction, constituted by ripples or raised sand surfaces of the upper beach or by a seaward fringe at the foot of the tall dunes (Interpretation Manual of European Union Habitats, 2013)*".

Member states can specify the EU Habitats Directive's definitions in their own national contexts. Several descriptions exist in the scientific literature too (see Table 1 for examples in France and Italy). We propose the following simplified definition, which encompasses elements from those by Hesp (2002), Montreuil et al., (2013), Hesp and Walker (2013), and Puijenbroek et al., (2017) (Table 1):

Source	Policy examples
France: Cahier d'habitats (Bensetiti et al., 2004)	This habitat develops immediately at the upper contact of the high tide lines, on areas with slight to no slope. Sandy substrate, fine to coarse-grained, sometimes mixed with organic debris, occasionally washed by waves during storms. Vegetation adapted and favored by regular burial linked to wind dusting from the top of the beach.
Italy: interpretation manual of the Habitats Directive (Biondi et al., 2009)	The habitat is found along the low, sandy coasts and is often sporadic and fragmented, due to anthropization both linked to the management of the dune system for bathing purposes and for the construction of port and urban infrastructures. The habitat is determined by perennial psammophilous plants, of the geophytic and hemicryptophytic type which give rise to the formation of the first sandy mounds: "embryonic dunes". The most "builder" species is Elytrigia juncea (=Agropyron junceum ssp. mediterraneum, = Elymus farctus ssp. farctus; = Thinopyrum junceum (L.) Á.Löve), rhizomatous grass which manages to increase its rhizome both horizontally and vertically thus forming, together with the roots, a dense network which incorporates the sandy particles.

Source	Research articles examples
Puijenbroek et al., 2017	First stage of dune development. Formed when sand is deposited within discrete clumps of vegetation or individual plants. Once vegetation becomes established above the high-water line, it serves as a roughness element that facilitates sand deposition and reduces erosion. An embryo dune is thus the result of an interaction between vegetation and aeolian processes (...). In time, embryo dunes may develop into foredunes.
Hesp y Walker, 2013	Small coastal dunes found at the back beach. Often new or developing. Formed by the deposition of sand by wind and the colonization of pioneer vegetation species.
Montreuil et al., 2013	Formed at the coast when wind-blown sand accumulates around an irregularity or obstacle. Typically, small, and discrete and are colonized by pioneer plants and species tolerant of seawater inundation.
Hesp, 2002	"Incipient foredunes". The main differences between embryo dunes and established foredunes are the degree of geomorphological development (e.g. height, width, continuity) and the characteristics of the vegetation cover.

Table 1. Examples of embryo dune definitions in policy documents and scientific publications.

Agreed definition: *"2110. Embryonic shifting dunes: Small coastal dunes located at the back beach, formed by the deposition of sand by wind and the colonization of pioneer vegetation species."*

2.2. Ecological characterization

2.2.1. Main habitat characteristics and ecological requirements

Embryo dunes context

Embryo dunes constitute a pivotal area within the nearshore-beach-dune continuum (Figure 1) and serve as a critical juncture between marine and aeolian processes, particularly on a seasonal timescale (Davidson-Arnott et al., 2019). Functioning as sand reservoirs in the back-beach region, they represent the initial aeolian landforms susceptible to wave erosion, thereby modulating the energy that arrives to the foredune toe during storm events. Beyond sediment redistribution, these dunes play a vital role in facilitating biological exchanges both across the shore and within the broader region alongshore. They offer a niche for flora and fauna characterized by frequent morphological changes and periodic seawater inundation, serving as transitional ecosystems bridging the marine and terrestrial realms.

Charadrius dubius. Authorship: Adobestock image bank

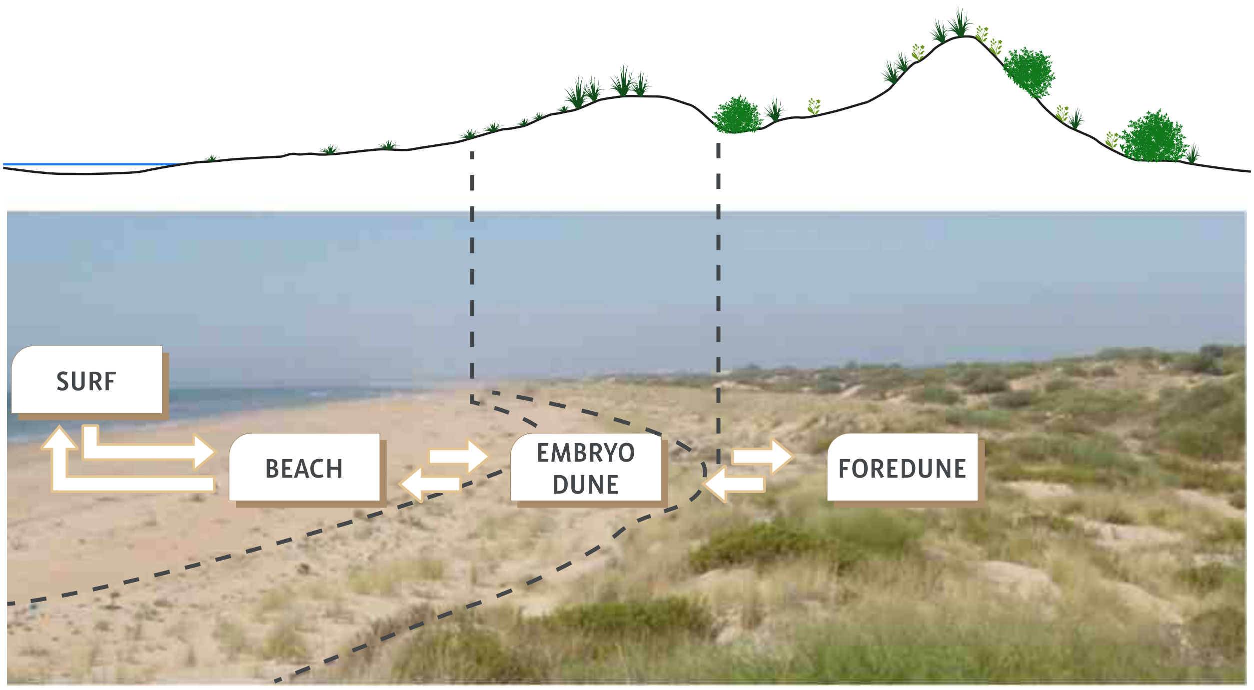


Figure 1. Embryo dunes as part of larger beach-dune systems. They are characterised by regular exchanges of sediment and organic matter. Photo credit: Juan Bautista Gallego Fernández.

Main habitat characteristics and geo-ecological requirements for the habitat to exist

Embryo dunes are formed through the accumulation of aeolian sand around obstructions or uneven landforms (Montreuil et al., 2013), followed by the colonization of pioneer vegetation species (Hesp and Walker, 2013; Pujenbroek et al., 2017). Characterized as the initial phase in foredune evolution, these formations are commonly referred to as "incipient foredunes" (Hesp, 1983). Embryo dunes are "transient" landforms that exhibit an ephemeral nature; they either dissipate due to wave erosion or progressively grow and establish themselves as foredunes (Hesp, 2002; Sabatier et al., 2009; Gao et al., 2020).

Embryo dunes rely on the following key specific elements for their existence:

1. they require sufficient surface area within the back-beach area where sediment can accumulate, forming the foundation for their development;
2. they rely on a source of sediment, typically delivered from the beach in front where wind action entrains and transports sand to the embryo dune area;
3. they depend on the significant role played by the presence of vegetation, and a source of propagules (seeds, fragments of plants) from one or multiple plant species. These plants interact with the wind-blown sand, favoring the gradual formation of the embryo dunes as they trap and stabilize the accumulating sediment (Figure 2). Marine storms and littoral currents help disperse species and play an important role in connecting dune habitats (Joyce et al., 2022).

Coastal dunes: key elements and processes

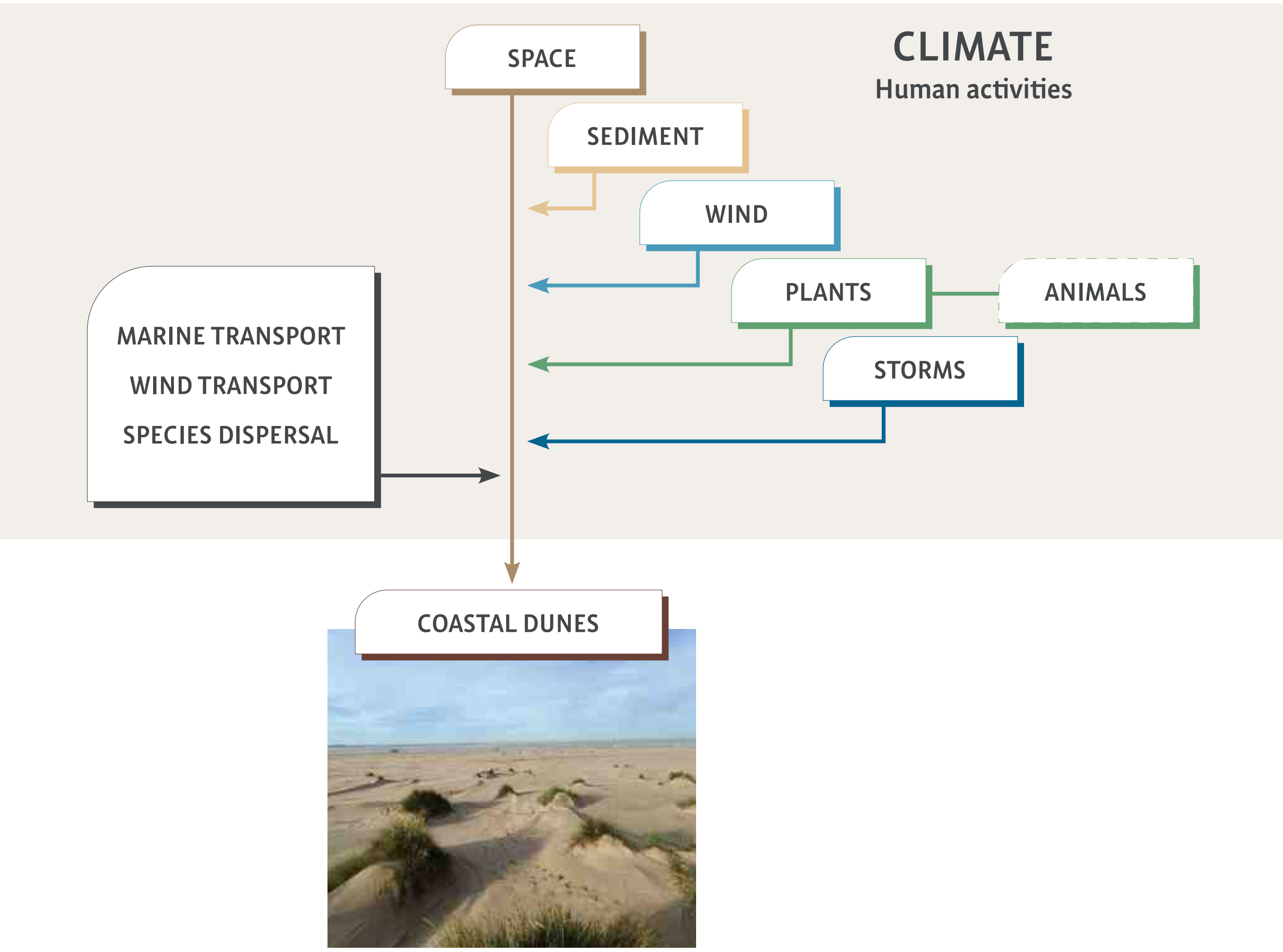


Figure 2. Some key elements & processes involved in coastal dune formation, many of them applicable to embryo dunes. By Juan B. Gallego Fernández.

Main characteristics

Embryo dunes can be observed across global coastal settings, spanning from polar to temperate, subtropical, and tropical regions (Hesp, 2002; Olivier and Garland, 2003; Anthony et al., 2007; Puijenbroek et al., 2017). They serve as the initial phase in dune formation, and they exhibit adaptability to diverse local geological and climatic contexts. Their mature phase, foredunes, have been found across various shoreline typologies encompassing beaches, estuaries, lagoons, lakes, and even hinterland plains (Carter et al., 1992; Nordstrom and Jackson, 1994; Hesp, 2002). Furthermore, embryo dunes demonstrate the capacity to develop in settings such as shorelines backed by cliffs and/or promenades.

Sterna nilotica. Authorship: Freepik image bank

Embryo dunes can be classified into four eco-geomorphological types (Hesp, 2002):

1. Ramps: areas where seedlings germinate on sloping backshores, and/or rhizomatous and/or stoloniferous plants grow seawards from landward sources, and/or plants germinate or grow on scarps or at the base of a foredune scarp.
2. Terraces: locations of rapid plant growth on the backshore, particularly on quickly prograding beaches, and/or where seaward plant growth matches accretion rates, and/or where plants grow across on backshores that experiences little sand accretion (e.g., low energy beaches) because of moderate plant density or short plants.
3. Hummocky patches and mounds: areas with limited sand supply where embryo dunes formed due to plant trapping effects, creating small mounds or nebkhas prone to rapid changes due to energetic winds or storm flooding (Goldstein et al., 2017). Their often-elongated shapes merge to form continuous dune ridges.
4. Ridges: formed where rapid accretion mainly occurs in the seaward portion of plant canopies, and/or with high plant density and height, and/or low seaward growth rates compared to accretion, and/or wave scarping of foredunes relocates aeolian deposition to the scarp base, leading to ridge formation parallel to foredunes and shoreline.

Variability

The evolution of coastal dunes in general is shaped by numerous factors (Table 2) operating across diverse temporal and spatial scales (Walker et al., 2017). These include short-term parameters impacting aeolian sediment transport, such as surface moisture (Namikas & Sherman, 1995); mid-term factors influencing the nature of aeolian inputs to coastal dunes (Delgado-Fernandez and Davidson-Arnott, 2011); and long-term elements governing sediment budgets and shoreline dynamics (Davidson-Arnott and Bauer, 2021).

Abiotic	Examples
Climate, oceanography	Average wind speed
	Prevailing wind direction
	Mean annual precipitation
	Mean annual temperature
	Mean annual moisture
	Prevailing wave type (sea waves/swell waves)
	Average wave height
	Storm regime
	Tidal range
	Sea level trend
Shoreline & beach	Shoreline orientation
	Shoreline trend (erosion/progradation)
	Beach type (reflective, dissipative – intertidal slope)
	Average beach sediment size
	Back beach type (e.g., cliff, lagoon, promenade)
	Sediment transport towards dune
	Width of dry beach
	Growing season
	Crusts / beach cementation
	Other types of surface conditions
Embryo dune geometry	Embryo dune height (m)
	Embryo dune width (m)
	Embryo dune length (m)
	Longitudinal continuity (% transverse corridors with respect to total length)
Chemistry	Soil – organic matter content
	Sediment salinity
	Prevailing beach composition (carbonates, silicates)
Biotic	**Examples**
Plant species composition	Plant cover / bare soil
	Species diversity (richness/indices)
	Dominant species
	Dune builders (Ammophila /Elymus...)
	Pioneer species
	Sources of propagules
	Relation with adjacent communities
	Alien species (presence, density...)

Biotic	Examples
Fauna species	Bird species: feeding / breeding
	Turtle nesting
	Frequentation of wild vertebrates (mice, rabbits, deer, ...)
	Frequentation of domestic animals (cows, goats, sheep, ...)
	Pollinators diversity
	Soil fauna (e.g., invertebrates)
	Relation with adjacent communities
Habitat structure	Relative length of foredune
	Presence of longitudinal parallel features (ridges, crests, etc.)
	Continuity/fragmentation (number of fragments)
	Disturbance by human activity and infrastructures
Habitat functions	Beach sediment reservoir
	Foredune sediment reservoir
	Biodiversity support (split...)

Table 2. Parameters generally used in the characterisation of coastal dunes. Many could be used to characterise the range of conditions/variability of embryo dunes across the MED region.

2.2.2. Dynamics (spatial and temporal) of the habitat type throughout the region

Embryonic dunes are naturally dynamic both along- and cross-shore. Among the variables outlined in Table 2, the influential role of medium to long-term shoreline dynamics and alterations in sediment availability stands out as major factors governing the formation and evolution of embryo dune habitats. Positive sediment budgets and sand availability for dune construction in prograding shorelines lead to the growth of embryo dunes in both height and width, eventually developing into foredunes. On the other hand, in erosional or stable shorelines, embryo dunes tend to erode more frequently (Davidson-Arnott et al., 2019).

Figure 3 shows an example of embryo dune decadal evolution at Magilligan Point (Northern Ireland). Positive sediment budgets and shoreline progradation of the distal end of the sand spit led to embryo dune vertical growth and its transition into a foredune within a decade (see change from 2010 to 2021). This coincided with embryo dune erosion and a transition into back-beach to the sides of the distal end, as a result of changes to the spit shape. In 2021, a new embryo dune zone was visible in front of the former embryo dune (now established foredune). The area covered by this new embryo dune might or might not be similar to the area covered by the previous embryo dune in 2010, but both situations are common, and result from the natural dynamism expected from this habitat.

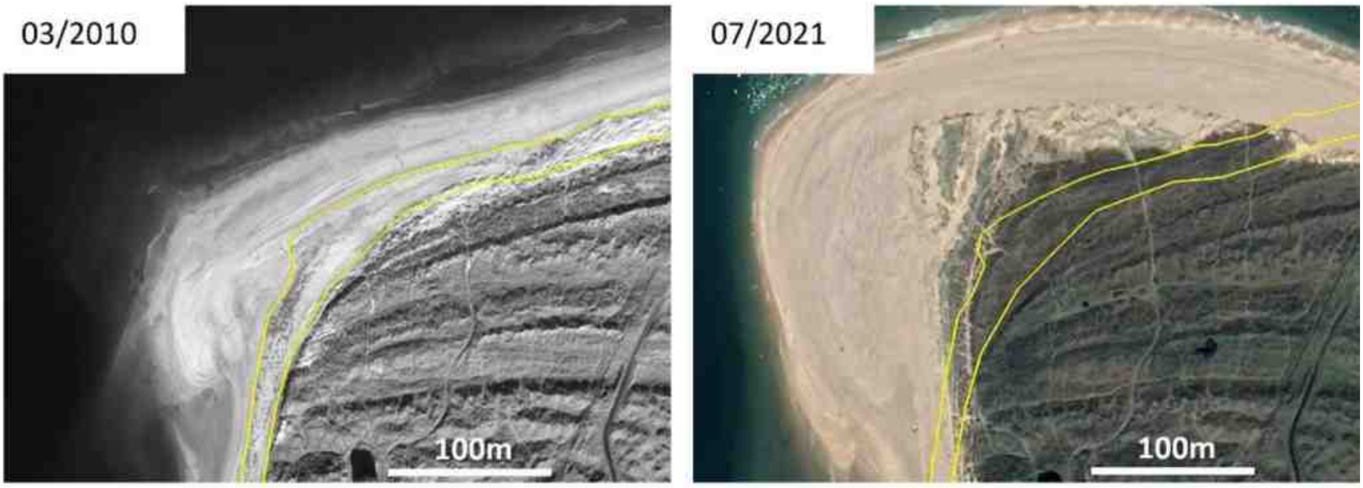


Figure 3. Embryo dune spatial-temporal dynamics at Magilligan Point (Northern Ireland). The highlighted embryo dune area in 2010 (to the left, in yellow) transformed over the course of the next decade, becoming a foredune in the central area of the distal end of the spit, and shifting to a back-beach zone to the sides of the distal end of the spit in 2021 (right-hand side). Background image: Google Earth Pro.

Figure 4 shows an example of embryo dune seasonal changes at a stable and/or receding coastline at Prince Edward Island National Park (Canada). Embryo dunes are commonly found during periods of relative calm weather (Figure 3, left). Low energy, swell waves transport sand from the nearshore into the beach; from there, the sand is transported by competent winds into the dune zone, where it can fill in dune scarps, travel up the foredune stoss slope, and/or form embryo dunes (see section 2.2.1.). Large sea waves and storm surges often flatten the beach and erode embryo dunes (Figure 3, right), with the more powerful storms also capable of eroding the foredune stoss slope and even breaching foredunes. A newly formed embryo dune might appear coming next spring, depending on the frequency of storm and the rate of beach recovery following storms. This calm / storm weather cycle is one of the foundations in our understanding of beach-dune morphodynamics (Dean, 1977; Short and Hesp, 1982; Cowell and Thom, 1994; Masselink et al., 2014).

Figure 4. Beach-dune cyclic dynamic interactions involving embryo dune erosion with storm waves during the fall and winter (right) and embryo dune formation and growth during the late spring and summer (left) at Prince Edward Island National Park, Canada. Credit: Irene Delgado-Fernández, Robin Davidson-Arnott & Jeff Ollerhead.

2.2.3. Relations with other habitat types

Embryo dunes form part of a succession of dune habitats from the most stressed environments of the subaerial beach, exposed to storms, strong winds, saline spray, etc., to the inner continental environment characterized by a sheltered low relief under freshwater conditions (Figure 5). Sand dune communities tend to display an aggregated spatial pattern at the more stressful end of the gradient, and a segregated spatial pattern in the least stressful conditions (Santoro et al., 2012, Conti et al., 2017).

According to the Stress-Gradient Hypothesis, negative interactions between species are generally predominant under non-stressful environmental conditions, while stressful conditions lead to a decrease in the importance of competitive interactions in community assembly, or even to a rise in facilitating interactions (Bertness and Callaway 1994). Coastal dune community succession is possible due to the process of plant facilitation (Connell and Slatyer, 1977). Facilitation is an ecological mechanism consisting in the interaction between the nurse species, which are able to colonize a stressful habitat and modify the microenvironment, modifying the habitat and facilitating the establishment of new species (Maun 2009; Navarro-Cano et al., 2019; Maggi et al., 2011). In detail, the process of facilitation includes several positive interactions that occur between physiologically independent individuals, and is mediated through changes in the abiotic environment or through other organisms (Lasso-Rivas, 2015). Facilitator, colonizing species can mitigate extreme conditions and benefit other species.

Polygonum maritimum. Gulf of Cadiz. Spain
Authorship: Juan Bautista Gallego Fernández

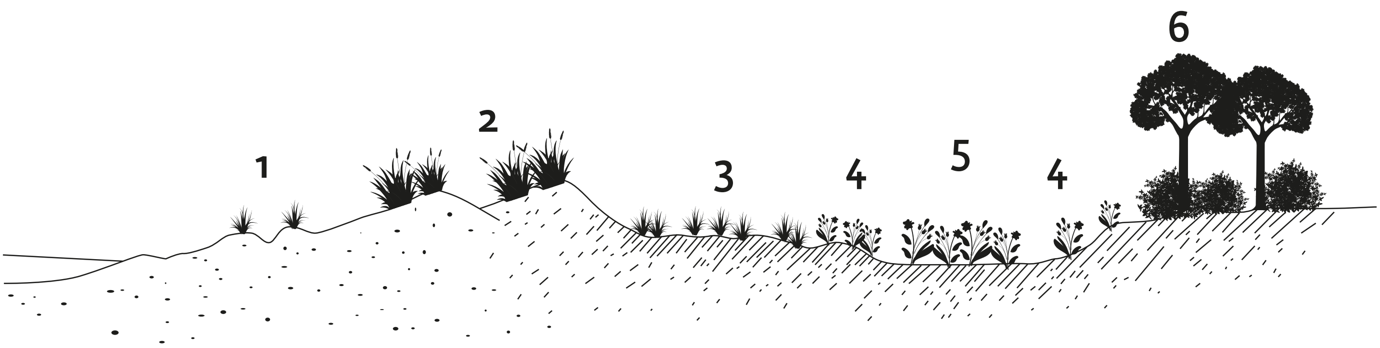


Figure 5. Example of transect of Mediterranean dune systems showing 1: pioneer / embryo dunes; 2) mobile dunes; 3) fixed dunes; 4-5) interdune depressions; 6) stable dunes. Modified from Costa (1987).

2.2.4. Gap analysis and future needs

We have identified crucial gaps in understanding the geomorphological and ecological dynamics of embryo dunes across the Mediterranean region. There is a need to quantify the variability of embryo dunes and the processes controlling them across the MED. This includes a detailed understanding of habitats characteristics and their connection to their surrounding environments, such as the width, slope and morphology of beaches and how this impacts embryo dune formation and ecological dynamics. There is a gap in understanding embryo dune commonalities and differences across countries within the MED region, likely a reflection of a wider gap related to the absence of global surveys of coastal dunes. Additionally, the absence of conceptual models delineating the functioning and dynamics of embryo dunes in the MED region presents a significant gap to effective conservation and management.

Carpobrotus invasion. Portugal. Authorship: Catarina Meireles

Oenothera drummondii. Gulf of Cadiz. Spain
Authorship: Juan Bautista Gallego Fernández

Conservation status and trends

According to Article 17 of the Habitats Directive, conservation status of habitat types is regularly evaluated by Member Sates (every six years). Four main parameters are used in the assessment of conservation status of habitat types:

- Range: overall distribution area.
- Area: surface of the area occupied by the habitat.
- Structure and functions: condition of the habitat.
- Future prospects: based on the analysis of pressures and threats that affect the habitat

Results of the latest assessment of embryo dunes in the Mediterranean countries can be found in the following report: **https://nature-art17.eionet.europa.eu/article17/habitat/summary/?period=5&group=Dunes+habitats&subject=2110&region=MED**

Further details about knowledge and methodologies available for the assessment of these parameters are presented in the following sections.

3.1. Current knowledge about distribution and area estimate

3.1.1. Area inside and outside Natura 2000 sites

Data on current area occupied by embryo dunes have been reported by EU Mediterranean Member States in 2019 as shown in table 3.

EU MS	Total area (Km²)	Short-term trend	Area inside N2000 (Km²)	% in N2000
Croatia	0,16-0,39	Uncertain	0,16-0,39	100%
Cyprus	0,35	Unknown	0,169	48%
France	1-3	Decreasing	3	100%
Greece	32,85	Stable	12	37%
Italy	13,09-74,13	Decreasing	13,47	18%
Malta	0,012	Stable	0,012	100%
Spain	5,52	Decreasing	4,57	83%
Portugal	Absent data	Decreasing	36	

Table 3. Official data available from MS - Art.17 report (2013-2018). N200 = Natura 2000 Network.

3.1.2. Methodologies used to estimate habitat area under Article 17 reporting and to detect changes in the overall area covered by the habitat (in MED MS)

There is considerable variability in the methodologies employed by Member States across the Mediterranean region to assess the extent of the area occupied by embryo dunes. Diverse approaches have been reported, showcasing a wide range of techniques and tools used for measuring and quantifying the presence and dimensions of these coastal features. These include the use of orthophotos/aerial photographs, published maps, drone imagery, and even ArcGIS online "Field Map" (Figure 6). Scales used vary from 1:2000 to 1:25.000 according to the information collected for the elaboration of this action plan (see further details in section 3.1.4).

Arctotheca calendula. Invasive Allien Species. Portugal
Authorship: Catarina Meireles

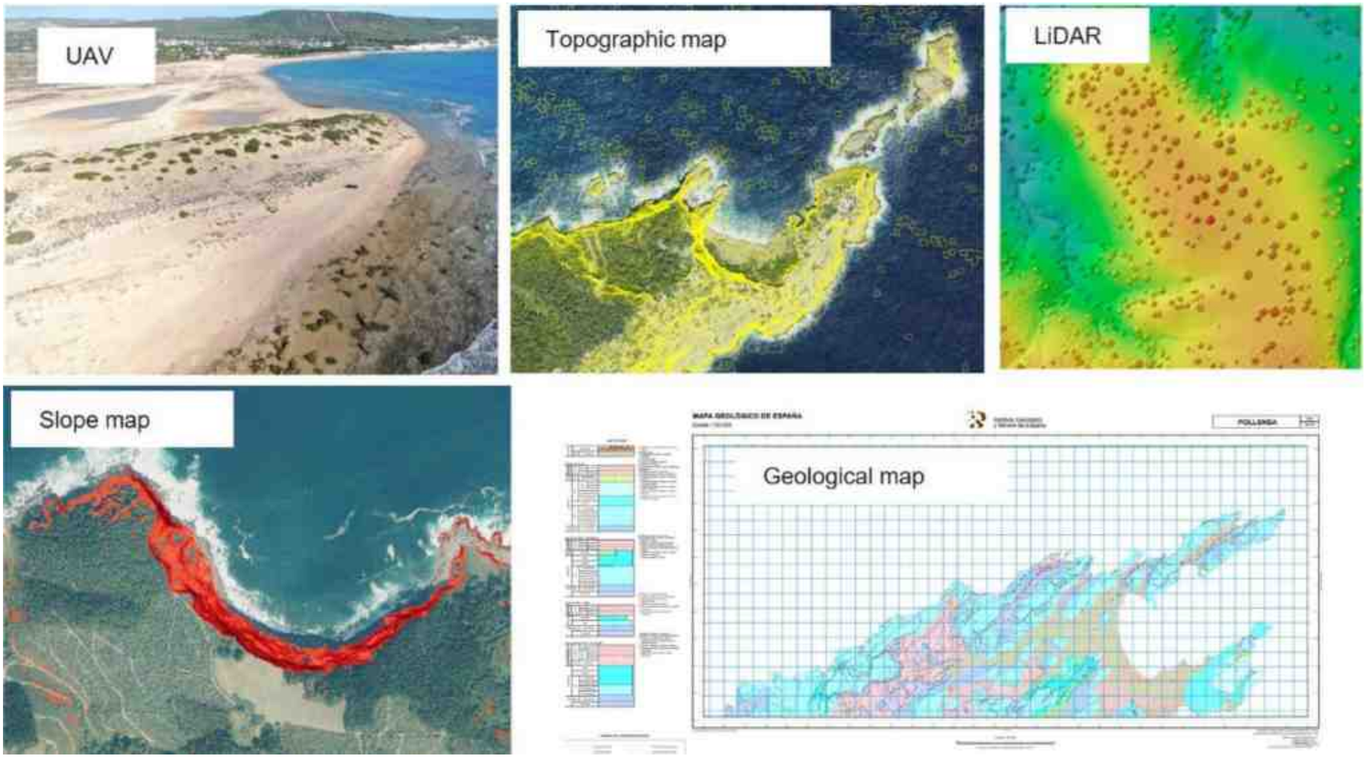


Figure 6. Examples of sources of information.

3.1.3. Methodologies available in the literature to estimate habitat area and main issues

In the academic literature, coastal scientists have used both remotely sensed products (e.g., aerial photography), proximal sensing (e.g., laser scanning), and field mapping (e.g., transects,) to follow the behaviour of embryo dunes over time. Two main reference studies can be cited as examples: the analyses by Puijenbroek et al., (2017), who identified individual dune forms within the embryo dune area using both transects and aerial photography; and the study by Montreuil et al., (2013) who used frequent laser scanning for detailed mapping of embryo dune seasonal changes within a selected coastal plot (Figure 7).

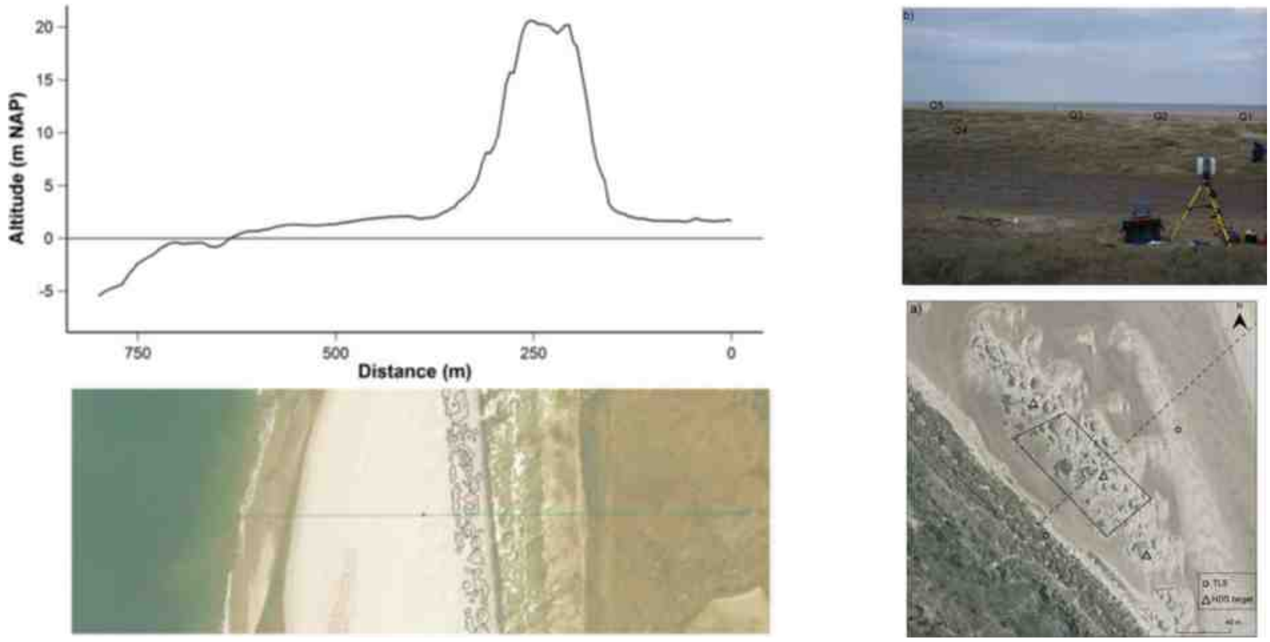


Figure 7. Embryonic dunes mapping examples from the literature [transects, aerial photography – Puijenbroek et al., 2017 (left); Montreuil et al., 2013 (right)].

Known mapping issues

When closely tracked, changes in the morphology and ecology of embryo dunes can be observed over time, employing methods like those outlined previously. However, there are no standard methods to measure embryo dune evolution at regional and transregional scales.

Issues to precisely limit the space occupied by coastal dunes are well-known. For example, in their article "Crowd-sourced identification of the beach-dune interface", Smith et al., (2020) discuss the challenges of identifying the beach-dune interface (i.e., the seaward limit of the dune area, encompassing, if present, the embryo dune zone). Their study used the contributions of 167 geomorphologists, of whom 85 self-identified as experts in coastal dunes. The approach asked respondents to delineate or recognize the boundary or transition zone between the beach and the dune area, using common features such as surface (e.g., vegetation, wrack) and morphometric (e.g., slope, curvature) elements, among other 4 categories. Participants were given 3 sets of data: 1) two-dimensional cross-shore transects; 2) aerial photographs; and 3) oblique imagery. Their analyses revealed a significant difference in both the horizontal and vertical identification of the dune toe, which was strongly influenced by the researchers' backgrounds and the image perspectives.

Surface colour could be used also as an indicator of incipient vegetation cover on the upper beach. Vegetation introduces a mottled texture on the images and adds grey tones that darken the original sand colour. However, in some cases the natural colour of the sand may be originally dark, if the sediment forming the beach comes from the erosion of volcanic or metamorphic rocks rich in dark minerals. In such a case the distinction between beach and dune should be made according to the minor, often subtle, topographic changes, or if a clear change in the surface texture is identified (see Figures 7A and B). Beaches rich of quartz show lighter sediments and embryo dunes can be recognized much more easily (see Figures 7C and D).

Figure 8. Examples of narrow bands of embryo dunes developed in the upper beach. Cases A and B correspond to beaches formed by dark minerals, while cases C and D correspond to beaches composed of lighter sediments. Background images from Google Earth Pro.

To date, there is no consensus or agreement regarding a standardized definition of "beach-dune boundary" and the alignment of these metrics with observations made in the field.

3.1.4. Proposal of standard methodologies to harmonise the calculation of the habitat area in the Mediterranean countries

The variability in methodologies currently used to estimate habitat area partially reflects the complexities inherent in studying embryo dunes, as well as the lack of science-led protocols that can be implemented by MS. This highlights the need for standardized methods to ensure more consistent and comparable assessments across Mediterranean coastal areas. Attending to criteria such as reproducibility and accessibility, the following methodological approach is proposed:

A. Using Google Earth (GE) as the initial step to collect extent information:

   The use of GE offers five significant advantages: 1) it is accessible to anyone with a computer and an internet connection; 2) it is a freely available platform; 3) it operates effectively across diverse spatial scales, allowing both detailed zooming in and broader zooming out, catering to the requirements of the methods outlined below; 4) it enables the mapping of changes over time through the 'historical imagery' tool; and 5) it establishes a common technique that can be uniformly applied across Member States.

B. Working across scales but establishing a Common Reporting Scale (RS) and Minimum Mappable Unit (MMU):

   When inquired about their working scales, MS provided a range spanning from 1:200 to 1:25,000. The scientific literature extensively addresses the challenges and considerations regarding different mapping scales in natural environments (Margules and Pressey, 2000). While finer scales allow for a more detailed view of local habitats and species distribution, they might not be practical for covering larger areas. Conversely, larger scales offer insights into regional patterns and landscape heterogeneity, revealing other important aspects. To strike a balance between these challenges, we proposed a **common reporting scale (RS) of 1:2500** as the standard for producing final maps. **Google Earth provides the flexibility to use finer or broader working scales**, zooming in for detailed habitat observation or zooming out for a broader contextual view (as shown in Figures 9, 10). This approach aligns with the perspective of researchers emphasizing the simultaneous consideration of multiple scales to comprehend ecosystems comprehensively (Levin, 1992).

Silene littorea. Portugal. Authorship: Catarina Meireles

   For the particular case of small but significant dune areas (e.g., some of the embryo dunes found in Malta) a smaller mapping scale could be adopted as an exception to the harmonised method proposed above.

   A proposed **minimum mappable unit (MMU) of 500 m² (0.05 ha)** is suggested. For example, this could encompass an embryo dune measuring 100 m alongshore x 5 m cross-shore. These minimum mapping dimensions should effectively cover most of the beach-dune systems in the MED region, with exceptions limited to exceptionally small areas.

C. Incorporating habitat natural dynamics

   All habitats experience changes over time, and these trends are integral to the assessment of the Habitat Directive's conservation status. However, the dynamic nature of embryo dunes means that their extent is naturally prone to fluctuation. Unlike more stable habitats, embryo dunes are not expected to maintain a consistent area in the same location with each observation. In fact, the absence of an embryo dune is not necessarily indicative of the degradation of this habitat (Section 2; Figures 3 and 4). The significant dynamism of this habitat undermines the validity of point observations every 6 years (the HD's reporting period), as measurements may merely capture an arbitrary snapshot of an extremely variable landscape. In other words, as a healthy embryo dune can exhibit multiple development stages, from minimal sand accumulation to a well-developed ramp or the phase preceding its transitioning into a mature foredune, a singular observation over time may overlook the spectrum of natural stages experienced by this habitat. The apparent absence of embryo dunes does not mean that in the incoming months or years the upper beach can develop a continuous band of such incipient dunes.

The sedimentary dynamics of the beach itself and the morphosedimentary situation and stage that the beach may exhibit in the moment of image catchment can be informative about the theoretical or potential development of embryo dunes in the near future. Figure 9 shows an example taken from Valencia coast through Google Earth: the upper beach does not present any indicator of embryo dunes, probably absent after the winter season (the photo was taken in March 2021); however, the nearshore shows the arrival of crescent sand bars, many of them beginning to weld to the intertidal beach. This incoming sediment will promote sand transport and deposition inland, favouring the generation of embryo dunes in the following months.

Figure 9. Beach and dunes in the protected Saler beach, south of Valencia (Spain). No evidence of embryo dune can be seen in the image, taken after the winter season. However, the presence of crescent sand bars in the nearshore zone (yellow arrows) is indicative of imminent sediment availability in the intertidal zone, which subsequently would be transported by wind to form incipient dunes. Background image from Google Earth Pro.

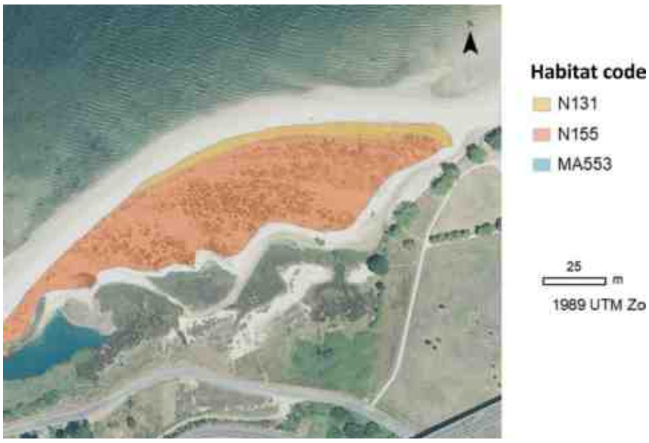


Figure 10. Example of dune habitat mapping (such as N131 Atlantic and Baltic embryonic dunes and N155 Atlantic and Baltic dune fine-grass annual communities) according to different EUNIS habitat codes (Author: María Aranda, TRAGSA).

Ideally, regular, and frequent reporting at required locations would lead to better understanding the diverse stages of embryo dunes, their defining features, and their conservation status. However, for practicality, we propose a mapping approach that aims at finding the **maximum extent of embryo dunes observed within a 6-year period**. This approach demands additional time and effort from surveyors because it involves examination of all available Google Earth photography within the study period for required sites. Nevertheless, this approach enhances the likelihood of finding embryo dunes and mapping them at comparable development stages. This method would work well in areas where embryo dunes have been washed away by storms, for example, as long as there is embryo dune recovery or the area is prone to new embryo dune formation, or embryo dunes existed at some point along that section of the coastline within the 6-year period prior to reporting.

The implementation of the Habitats Directive mandates the assessment of habitat types in all N2000 sites. Consequently, each Member State (MS) should have access to Google Earth images over the reporting period of six years. However, this requirement may pose limitations in certain regions where Google Earth updates its imagery irregularly. This technical gap is noted in section 3.1.8.

3.1.5. Favourable Reference Values for range and area

Favourable Reference Area (FRA) is defined as the surface area in each biogeographical region considered the minimum necessary to ensure the long-term viability of the habitat type (Ref. Art. 17 reporting guidelines).

Based on information reported by Mediterranean Member States, there is not a precise estimation of FRA in any country, but in general it is considered that this surface area was greater some decades ago.

3.1.6. Proposal of standard methodologies to harmonise the definition of Favourable Reference Area in the Mediterranean countries

One of the main requirements of embryo dunes to develop is the presence of sufficient surface area in the upper beach to allow sand to be trapped by vegetation and form patches and sand mounds. If the area has been maintained without any significant perturbation through time (human destruction, storminess, etc.) and conditions are favourable, the mounds will very probably evolve to form an embryo dune area. It is hence important to detect moments and intervals in the recent past in which such incipient dunes were undisturbed long enough to achieve their maximum possible development, according to the available space and sediment, and dynamic conditions. As a consequence, a Favourable Reference Area could be the best situation detected for the dunes in the recent past – if they could reach such optimal extension, the maintenance of favourable conditions would let the system to reproduce that state of development.

So, a way to define the maximum potential extension attainable by embryo dunes in each coastal segment could be to revise the recent historical evolution of the incipient dune, related to the last decades (from the 1980's onwards), and identify the greatest area reached by the habitat. That would be the Favourable Reference Area. The sources of information for historical images of the coastal zone could be multiple. Again, Google Earth could be an interesting resource, although the oldest images lack sufficient resolution for correctly identifying embryo dunes (see Section 3.1.8). It would be preferably to consult other sources like aerial photographs or other high-resolution satellite images.

Larus audouini. Authorship: Freepik image bank

Because the absence of embryo dunes is not necessarily indicative of an unfavourable conservation stage, studies of changes in embryo dune extent and area covered should be linked with the reasons for those changes.

3.1.7. Trends analysis

Comparison of images along the last decades will give information about the recent trends showed by the habitat. A simple measure of variations in the extension showed by the embryo dunes will give ideas about its fluctuant behaviour, periods of intense erosion or growth, etc. The quantitative comparison among different historical images must be used as the main tool for establishing the conservation status of the habitat. Nevertheless, the comparison must only be made if the general boundary conditions persist: drastic changes in the sources of sediment, in the rates of sediment supply, in the plan-geometry of the shoreline, in the longitudinal extent of the coastal physiographic unit, etc., should invalidate this procedure, since such drastic changes will prevent any possible recuperation of preceding situations.

Carpobrotus edulis. Portugal. Authorship: Catarina Meireles

3.1.8. Main difficulties, gaps and future needs

Section 3.1.4. describes the proposed methodology for estimating the habitat area. The technique involves the use of Google Earth imagery at each of the assessed sites over a period of 6 years, something that may not be available at all Natura 2000 sites throughout the MED region. It is currently unknown how many of the sites might fall into this limitation. A future necessity is therefore to establish the percentage of locations where Google Earth lacks sufficient imagery to undertake the assessment, and to analyse how much of this limitation affects the overall evaluation.

Section 3.1.6 suggests a methodology to estimate favourable reference values for area and discusses the limitations in the context of available records. The earliest images from Google Earth go back to the 1980s and have limited spatial resolution, making them not suitable for the area analyses. Potential solutions to this technical gap could be the subject of future studies. In the meantime, other sources such as national inventories or historical photography could be an alternative as long as the MMU and mapping scale remain similar to the ones proposed here.

The need to estimate reference values proves challenging in the case of embryo dunes, as outlined in the previous section. Even among coastal scientists and dune experts, inaccuracies arise in measuring the habitat's boundaries (Section 3.1). Additionally, at any given position on the beach, the habitat can naturally fluctuate between zero area covered (e.g., after a storm) and a fully developed embryo dune (e.g., following a long period of calm weather conditions; Section 2.2). Over decades, embryo dunes may "disappear" as they transition into foredunes or due to natural shoreline dynamics.

A significant gap exists in developing a method to distinguish these natural fluctuations in embryo dune surface area from changes (increase or decrease) caused by anthropic factors such as pressures, threats, and conservation interventions. This is further explored in sections 4 and 5.

Future needs include the development and application of a standard methodology across MS to estimate the Area occupied by the habitat (including scale, frequency, methodological tools, etc.) and the Favourable Reference Area.

3.2. Structure and functions

3.2.1. Current assessment of structure and functions parameter (under art. 17 reporting)

Different methodologies are currently used in the Mediterranean Member States for the assessment of structure and functions of embryonic dunes in the Mediterranean Member States (Angelini et al., 2016; Aranda et al., 2019; Dimopoulos, 2018; Goffé, 2011), which use different variable, measurement methods and sampling protocols, although some common aspects can also be identified (Table 4). These differences point to the need for harmonised procedures.

Artemisia campestris. Gulf of Cadiz. Spain
Authorship: Juan Bautista Gallego Fernández

France	Width of the non-wooded dune
	Presence of seagrass
	Degree of marine erosion
	Presence of habitat indicator species
	Nitrophilous species coverage (list of nitrophilous species)
	Cover of invasive alien species of habitat in % (list of invasive alien invasive species)
	heavy damage
Spain	Surface of the dune system
	Length of the active dune system
	Width of the active dune system
	Coastal trend over last 10 years
	Modal height of the dunes in the dune system
	Percentage of dune front with eroded slopes (recommended)
	Continuity in plant successions
	Presence of rabbits
	Presence of invertebrates, reptiles and bird nests in the dune system
	Percentage of plants with exposed roots
	Degree of fragmentation of the dune system

Italy	Physical characteristics of the substrate (in terms of dynamism, stability and compactness)
	Total cover of vegetation, presence and coverage of dominant and typical species, species indicative of disturbance and alien species
	Presence of relevant animal species, e.g. molluscs, reptiles, insects, birds.
	Typical species. Elymus farctus subsp. farctus (=Agropyron junceum, A. junceum subsp. mediterraneum, Elytrigia juncea, E. mediterranea), Otanthus maritimus (= Achillea maritima)
	Landscape metrics: area, shape and contacts between patches
	Anthropic activities. Presence and intensity of anthropic disturbance activities (trails) and urbanization.
Greece	Coverage of ammophilous species above a threshold value
	Multi layered vegetation structure
	Height of vegetation
	Height of dunes
	Specific spatial patterns of succession
	Presence of plant species stabilizing sand dunes
	Resistance to inundation
	Presence of typical species

Table 4. Variables used in Mediterranean MS for assessment of dunes condition

3.2.2. Proposal for harmonisation of the methodology for assessment and monitoring

Common methodologies to assess and monitor the habitat condition (structure and functions) should include the following elements:

- Variables to assess the relevant habitat characteristics:
  - abiotic: physical, chemical
  - biotic: composition, structure and functions
  - other: pressure-based variables ...
- Methods and metrics used – how the variable is measured, frequency.
- Reference values, thresholds, condition indicators - rescaled values of the variables.
- Aggregation of variables: local & supra-local scale.
- Monitoring methods and protocols, selection of monitoring localities.
- Use of existing data sources.

Euphorbia peplis. Gulf of Cadiz. Spain
Authorship: Juan Bautista Gallego Fernández

Table 5 includes a proposal of a minimum set of variables to assess abiotic and biotic relevant habitat characteristics (considering the main ecological characteristics and processes of embryo dunes, as described in Section 2). These are for the assessment and monitoring of structure and functions of 2110 embryo dune habitats.

Type		Name of variable
Abiotic	1	Presence of embryo dunes: Types and % occupation ■ Ramps ■ Terraces ■ Nebkhas ■ Ridges
	2	Presence of marine debris (drift material)
	3	Coastal trend (m/year)
Biotic	4	% of total vegetation cover and psammophilous species cover of: ■ Pioneers ■ Builders ■ Binders ■ Non-psammophilous species ■ Exotics
	5	Presence of nesting fauna

Table 5. Proposal of variables to assess structure and functions of embryo dune habitats.

The following methods, metrics, range of expected values, and related gaps are:

1. Presence of embryo dunes. Types (ramps, terraces, nebkhas, ridges) and % occupation.

Description of the variable: Determination of the presence (or absence) of embryo dunes during the moment of observation, and prevailing morphological types in every zone. Being naturally dynamic habitats, the absence can indicate alterations in sediment availability or the lack positive sediment budgets and sand availability for dune construction (see Section 2.2.2).

Minimum mappable surface: 500 m² (0,05 ha).

Method: Visual inspection using high-resolution aerial images (like Google Earth, vertical aerial photographs), detailed digital elevation models (LiDAR models, with sub-metric errors) and field inspection. Visual estimation of the percentage represented by different morphological types (ramps, terraces, nebkhas, ridges).

Frequency: Preferably annually, at the end of the summer period.

2. Presence of marine debris

Description of the variable: Assessment of the presence of organic marine debris, encompassing halo-nitrophilous species and beach-cast seagrass (i.e. Posidonia oceanica). These accumulations can serve as a substratum and a source of organic and inorganic nutrients, facilitating the development of other vegetal species and serving as a nucleus for the establishment of colonizing plants.

Minimum mappable surface: Given the typically small dimensions of these accumulations, the minimum surface should be determined by the method's sensitivity limit.

Method: Visual assessment, preferably through field campaigns. While some very high-resolution aerial images could be also used, digital elevation models prove unsuitable for this purpose, regardless of their resolution. The estimation should be made qualitatively, and ranges for assigning values should be established based on knowledge about favourable conditions (Section 3.2.4).

Frequency: Annually, before the humid period, preferably at the end of the summer period.

Eryngium maritimum. Portugal. Authorship: Catarina Meireles

3. Coastal trend (m/year)

Description of the variable: This variable provides information about the sedimentary input to the coastal system, which is a primary factor for the formation and maintenance of dunes. Advancing coastlines result from a sediment surplus and lead to wider beaches, which increase the space available for embryo dune habitat development. Coastal retreat has been shown to increase coastal vulnerability (Bertacchi et al., 2016; Prisco et al., 2016).

Changes to storminess (frequency and magnitude) affect sandy shorelines and therefore may have an effect on embryo dune development that should be investigated in the MED region (e.g., Garcia-Lozano et al., 2018; Roig-Munar et al., 2022).

Method: Units in m/year: advance (progradation) >0, retreat <0. The assessment must be conducted using vertical aerial photographs spanning the last 10 years, by comparing them through transects perpendicular to the shoreline. The ideal procedure should start with the delineation of a baseline parallel to the shoreline and located some distance landward (500 m to 1 km), passing through easily identifiable fixed, control points. Perpendicular to the baseline, the transects will be positioned at intervals of 50 m alongshore. Measurements must be made from the baseline to the shoreline, identified as the water/land contact. In tidal coasts it is recommended to make several measures to different indicators. Especially representative is the outer limit of the embryo dune, marked by the transition between the first vegetated sand accumulation and the beach.

Comparisons between historical shorelines from different photogrammetric flights must be made, and rates of change must be quantified, preferably using GIS. It is recommended to use ArcView software, through the tool "Digital Shoreline Analysis System", DSAS 2.2.1. This tool uses the positions of historical shorelines referred to an arbitrary baseline, calculating shoreline trends via various statistical parameters. To avoid local, non-representative situations in the oldest and youngest photos, the Linear Regression Rate (LRR) option is recommended. The final estimation should consider ranges for assigning values that are established based on knowledge about favourable conditions (Section 3.2.4).

Frequency: A new estimation of coastal trend should be made after at least 6 years from the last measurement, depending on the disposal of new available aerial photos.

4.4. Presence of vegetation

Description of the variable: This variable provides information on the composition and abundance of vegetation. Plants act as barriers to sand movement, influencing embryo dunes' initiation, lateral and vertical growth, and maintenance. The number, abundance and type of plant species generally depends on sand supply, the degree of stability of the system, and climatic conditions. In areas with high sand supply, embryo dunes have low species richness, primarily dominated by dune builders such as Ammophila arenaria and Elytrigia juncea (=Elymus farctus), along with pioneer species such as Cakile maritima, Polygonum maritimum and Salsola kali, the latter prevalent the areas closest to the shore. Conversely, reduced sand input leads to increase in stabilising species (binders) like Calystegia soldanella, Echinophora spinosa, Eryngium maritimum, Pancratium maritimum, Matthiola sinuata and Silene niceensis (=S. nicaeensis), among others. The presence of native non-psammophilous and exotic species is linked to dune disturbance caused by trampling, fine sediment, nutrient or water influx resulting from human actions, and the direct or indirect introduction of exotic species.

Methods: The Braun-Blanquet abundance scale is adopted as the basis for monitoring. This method is widely used in vegetation ecology to quantify the abundance of plant species within a given area. It provides a standardized way to assess vegetation cover, and it typically ranges from 1 to 5, with each number representing a different level of abundance:

1. Occasional (1-5% of the area): Species cover is sporadic and occurs only in isolated patches within the area. Individuals tend to appear isolated.
2. Common but not frequent (cover of 5-25% of the area): Species cover is common but occurs sporadically within the area. Individuals tend to gather in groups.
3. Frequent but not constant (cover of 25-50% of the area): Species cover is frequent, but there are gaps in its distribution within the area. Individuals tend to crow together in small colonies.
4. Frequent (cover of 50-75% of the area): Species cover is frequent throughout the area, but not dominant. Species tend to form carpets or extensive colonies.
5. Dominant (cover of 75-100% of the area): Species cover is so extensive

Modifiers such as "+" or "-" could be added to indicate slightly stronger or weaker abundances within each category. The assessment should be carried out by field sampling in early summer to ensure the presence of annual species. The ideal procedure is to make: i) an estimate of the percentage of total plant cover in the embryonic dune zone, and ii) an estimate of the percentage cover of pioneers, builders, binders, non-psammophilous and exotics. This estimation can be done using transects or plots in sufficient number to record all the heterogeneity of the area. The final estimation

Portugal. Authorship: Catarina Meireles

should consider ranges for assigning values that are established based on knowledge about favourable conditions (Section 3.2.4), and that should consider the percentage of plant cover of embryo dunes by:

- Pioneer species: e.g., *Cakile maritima, Polygonum maritimum, Salsola kali*
- Dune builders: e.g., *Elymus farctus, Ammophila arenaria, Otanthus maritimun*
- Binders: e.g., *Calystegia soldanella, Crucianella marítima, Cutandia maritima, Echinofora spinosa, Eryngium maritimum, Pancratium maritimum, Mathiola sinuata, Medicago marina, Silene nicaeensis, Thinopyrum junceum, Sporobolus pungens, Euphorbia paralias*
- Exotics: e.g., *Carpobrotus edulis, Arctoteca calendula, Xanthium orientale, Oenothera drummondii.*

A major challenge with habitat type 2110 is that intense fluctuations in its floristic composition (and even occurrence) are expected and are part of natural processes. This restricts the use of permanent plots that otherwise are an excellent alternative for monitoring vegetation. This has been further noted in Section 3.2.4.

5. Presence of nesting fauna

Description of the variable: This variable offers insights into the suitability of the embryonic dune area for nesting bird and sea turtle species, serving as an indicator of habitat quality. Nesting of bird species such as Kentish Plover (Charadrius alexandrinus), Little ringed plover (Charadrius dubius), Little Tern (Sternula albifrons) and Collared Pratincole (Glareola pratincola) usually occurs from February to July. The nesting of loggerhead turtles (Caretta caretta), green turtles (Chelonia mydas) and Mediterranean tortoises not only contributes to the preservation of these species but also enhances dune vegetation development through nutrient supply from the nesting activities. Turtle nesting in the Mediterranean primarily takes place during the summer.

Method: on an annual basis, the observation of adults and the location and counting of nests should be carried out during the breeding period, based on standard methodologies and/or ongoing monitoring programs. The estimation should be made qualitatively, giving values and ranges that are established based on knowledge about favourable conditions (Section 3.2.4).

Additional items for assessment and monitoring of habitat condition

Once defined and agreed the variables and set the reference levels and thresholds to assess their condition, it will be necessary to define aggregation methods to calculate composite indexes to determine when the habitat is in good or bad condition. This is firstly done at the local scale, i.e. at the level of the plot or location where the variables are measures, and then at supra-local scale, i.e. at the level of the biogeographical region.

According to the guidelines for reporting under Art. 17 of the Habitats Directive, the habitat structure and functions is in favourable status in the biogeographical region when it has been assessed in good condition on 90% of its area. On the other hand, if 25% of habitat surface is assessed in bad condition, the overall assessment of structure and functions in the biogeographical region is favourable.

Moreover, harmonisation of monitoring methods and protocols, including the criteria for the selection of monitoring localities will also be necessary.

Malcolmia littorea. Portugal. Authorship: Catarina Meireles

3.2.3. Trends analysis

Based on the reporting by MS in the last two reporting periods (2007-2012 and 2013-2018), the overall conservation status of embryo dunes has deteriorated in all the countries where it has been assessed. Both area and structure and functions are in unfavourable status in all the MS and the assessment of these two parameters has deteriorated in four MS from the reporting in 2013 to 2019..

3.2.4. Gap analysis and future needs

There is a need to develop and apply standard methods across EU MS for the assessment and monitoring of habitat condition (structure and functions) and trends. These include gathering information that would allow the establishment of adequate ranges for providing a diagnosis of presence of marine debris and vegetation, coastal trends, and the presence of nesting fauna. Additionally, there is a need to address the lack of quantitative data gaps such as changes to dune cover and the reasons for it (e.g., González-Villanueva et al., 2023) at a MED regional scale.

As indicated in point 4 – Presence of vegetation, a significant challenge relates to extreme fluctuations in the habitat's floristic composition and occurrence, related to natural processes of dune building and destruction. This restricts the use of permanent plots that otherwise are an excellent alternative for monitoring vegetation. Future work should consider assessing the completeness of typical species at slightly broader geographical scales, as for example in a complex of plots within a beach. Considering relative percentage of categories (functional traits) of taxa at this level is important and could be done ad-hoc.

3.3. Future prospects: analysis of pressures and threats

3.3.1. Identification and assessment of current pressures and threats (under art. 17 reporting)

Pressures and threats are reported by EU Member States every six years for each habitat and species protected under the Habitats Directive, according to Article 17 of the Directive, using a standard list (available at **https://cdr.eionet.europa.eu/help/habitats_art17**).

Pressures have acted within the reporting period and have an impact on the long-term viability of the habitat and its typical species; threats are future/foreseeable impacts (within the next 12 years) that are likely to affect the long-term viability of the habitat and its typical species. The assessment of pressures and threats must consider the percentage of area affected and their influence (high, medium, low).

In the last Article 17 – reporting period (2013-2018) the EU Mediterranean Member States reported the pressures indicated in table 6 (with high and medium importance) on the embryonic shifting dunes.

Pressures reported in at least 2 Mediterranean MS (2013-2018)	n. of MS
E01 – Roads, paths, railroads and related infrastructure (e.g. bridges, viaducts, tunnels)	4/8
F01 – Conversion from other land uses to housing, settlement or recreational areas	2/8
F05 – Creation or development of sports, tourism and leisure infrastructure	3/8
F06 – Development and maintenance of beach areas for tourism and recreation incl. beach nourishment and beach cleaning	6/8
F07 – Sports, tourism and leisure activities	7/8
F08 – Modification of coastline, estuary and coastal conditions for development, use and protection of residential, commercial, industrial and recreational infrastructure and areas (including sea defenses or coastal protection works and infrastructures)	3/8
F22 – Residential or recreational activities and structures generating marine macro- and micro- particulate pollution (e.g. plastic bags, Styrofoam)	2/8
I01 – Invasive alien species of Union concern	2/8
I02 – Other invasive alien species (other than species of Union concern)	5/8
L01 – Abiotic natural processes (e.g. erosion, silting up, drying out, submersion, salinization	6/8
N04 – Sea-level and wave exposure changes due to climate change	2/8

Table 6. Most frequent pressures reported on Embryonic shifting dunes

Although some general description of these pressures is provided in the standard list, it is used for all habitat types in the EU and it would be necessary to have a common interpretation of how they apply to the embryonic dunes.

3.3.2. Methodologies used in each MS for the assessment of Pressures and Threats on embryo dunes

Based on the information collected for the elaboration of this action plan and on the latest Article 17 reports, the following methodologies have been recently used in the Mediterranean MS to assess pressures and threats on embryonic dunes.

Croatia: Assessment was mainly based on expert opinion.

Cyprus: Monitoring Protocols were completed for reporting in each site where the habitat type exists and all sandy beaches. The list of pressures and threats was compiled on the basis of field observations at 40 plots sampled within the distribution area of the habitat type (according to Art. 17 report).

Greece: In several localities (assessment locations) in every SAC as well as outside of the N2000 network, field evaluators record the P/T they anticipate. Alongside the record of the pressures and threats, evaluators are also asked to record the following criteria:

- Timing: impacting the habitat type in the past but now suspended due to measures; ongoing; expected to impact the habitat type in future.
- Scope (proportion of area affected): >90%; 50–90%; <50%.
- Influence (on area or habitat condition): intensity of the impact of each P/T in each sampling location (High, Medium, Low).
- Moreover, field evaluators collect specific, in situ information regarding the occurrence, and the cover/abundance of invasive alien species of Union concern or other invasive species.

To upscale from the local to the national level in order to select and list the 20 most important P/T in the national report, the following rules can be applied:

- P/T recorded in >25% of the total number of assessment protocols of the habitat type with high influence are included in the final list.

- P/T recorded in >50% of the total number of assessment protocols of the habitat type with high or medium influence and with a scope >90% or 50-90% are included in the final list.

The list is compiled with additional P/T by means of expert opinion if the rules do not result in 20 P/T (Dimopoulus et al., 2018).

Italy: Starting from data reported in the Standard Forms of Natura 2000 sites, each administrative Region provided a list of pressures and threats affecting embryonic dunes. The information has been aggregated at biogeographical level and weighted according to the frequency of pressures/threats reported, and with the surface area of the dune habitat within the regions. For example, pressures/threats provided by a region with high surface of sand dunes have been taken into more account than those provided by a region with mostly rocky coasts (Prisco et al., 2020).

Malta: Information on the pressures and threats on the embryonic shifting dunes was obtained through literature records and confirmed through field surveys. The intensity of pressures and threats is mainly evaluated through expert opinion.

3.3.3. Main pressures and threats and their impacts on embryonic dunes

In view of the possible different interpretation of the main pressures and threats affecting the embryonic dunes, it may be useful to identify and describe them more in detail as well as the main impacts they cause.

There have been multiple reviews on human impacts on coastal dunes, and various indices have been developed to identify dune areas that require restoration (e.g., Nordstrom, 1994, 2000; Gracia et al., 2009; Martínez et al., 2013; Pessoa and Lidon, 2013; Lithgow et al., 2014; Delgado-Fernandez et al., 2019; Calderisi et al., 2021). Most human impacts on foredunes similarly affect embryo dunes (e.g., habitat degradation linked to tourism and residential uses). Table 7 summarises some of the multiple anthropogenic activities related to embryo dune degradation. The rationale for their inclusion in the Action Plan (AP) can be found in section 3.3.3.

Impact	Description	P&T Art. 17
1. Trampling	damages vegetation and creates a path network. Disturbance eliminates vegetation cover and species and reduces biodiversity. Disturbs wildlife. Can be done by feet, wheels, cattle, horses (recreational), etc.	E01, F07
2. Driving & beach car parking	car parking at the beach often limits dune formation and leads to pollution and sand compaction.	E01
3. Beach mechanical cleaning	destroys embryo dune vegetation and removes seedlings, natural debris, and sources of organic matter.	F06
4. Litter/garbage	presence of litter affects fauna/flora and dune development; pollution.	F22
5. Cattle grazing	overgrazing eliminates vegetation and creates deflation areas; vegetation and propagules are destroyed, biodiversity decreases, fragmentation, erosion	A09
6. Permanent infrastructures	permanent infrastructures at the back-beach can destroy embryo dunes and interfere with natural sand movement, dynamics, and dune building processes. The system can lose connectivity along- and cross-shore. Permanent infrastructure includes urbanisation and the installation of hard structures like seawalls, promenades, etc.	E01, F01, F05

Impact	Description	P&T Art. 17
7. Temporary infrastructure on the back-beach	damages coastal dunes, eliminates vegetation, interrupts sediment dynamics. Creates artificial shadow zones and scouring. Can lead to beach grooming.	F05
8. Inadequate beach nourish-ment	increases beach width but eliminates seeds, modifies granulometry, and changes storm/tide dynamics	F06
9. Alien species	modify ecological processes (e.g., succession) and cycles (nutrient, carbon, water). Invasive species, both plant and animal, can outcompete and displace native species, altering the natural dune ecosystem.	G24, I01, I02
10. Plantations	Similar to pressure n. 9, plantations can modify ecological processes and alter the natural dune ecosystem.	B03,
11. Sand extraction	Habitat destruction. Loss of sediment needed for natural dune maintenance (erosion).	C01
12. Water dischar-ge at the beach	Pollution from coastal development, sewage, and runoff can degrade water and sediment and negatively affect dune vegetation and wildlife.	F12
Other indirect activities	**Potential impacts**	
Lagoon and es-tuary dredging	Water flow and sediment dynamics are modified. Can lead to embryo dune erosion.	E03
Infrastructures along the shore-line	Wave and sediment dynamics can be modified.	F05, F08
Relative sea level rise increase	In areas with no accommodation space, this can lead to embryo dune environments squeeze.	N04

Table 7. Human impacts on embryo dune habitats. The main correspondences with Pressures and Threats under article 17 have been indicated.

3.3.4. Description of main pressures and threats on embryonic dunes

1. Trampling

Trampling is a direct human activity that heavily damages embryo dunes and is particularly widespread and miss-managed, especially in touristic coastlines with significant visitor pressure. Human occupancy of the back-beach competes with the space needed for embryo dune development and is particularly damaging to plants sprouting there. Incipient foredunes depend on single plants or small groups of plants. Stepping on plants can break them and interfere or stop the formation of incipient dunes. Trampling can be done on foot, wheels (point 2), by pets and cattle (point 5), and can also help spread invasive species (Figure 11).

Euphorbia paralias. Gulf of Cadiz. Spain
Authorship: Juan Bautista Gallego Fernández

Figure 11. Up-Left: Embryo dune trampling, Puntal de Somo (Cantabria, Spain); Up-Right: seasonal occupation of the embryo dune area, Noja (Cantabria). Down: embryo dune occupation and trampling at Sefton Dunes (NW England). Photos by Javier Gracia (above) and Irene Delgado-Fernandez (below).

Further information about the need to develop a methodology to obtaining precise assessment of the impact created by this pressure across all countries is in section 3.3.4.

2. Passage and parking of vehicles

The passage and parking of vehicles strongly affects dune plants, leading to the disappearance or deterioration of vegetation communities and an increased exposure of the sediment to wind and wave erosion. The passage of vehicles also disturbs dune fauna, including nesting turtles and birds such as plovers that travel to the shore for food. The presence of stringent controls on vehicle parking and driving is crucial for the conservation of embryo dunes.

Figure 12. Up: Wheel trampling of embryo dune vegetation at Atunara Beach (left) and passage of vehicles over the embryo dune area at Sperlonga, Lazio (Italy). Photos by Javier Gracia and Irene Prisco, respectively.

Silene littorea. Portugal. Authorship: Catarina Meireles

Method: Qualitative observations in the field, potentially informed by management plans in the area. The timing should be adjusted so adequate data can be obtained to inform this factor (further information in section 3.3.4).

3. Beach cleaning, method (manual/machine) frequency

Mechanical beach "cleaning" is effective at removing litter, but it also eliminates seeds and plant fragments (Nordstrom and Jackson, 2021), which has a significant impact on embryo dune vegetation development and can delay the geomorphic recovery of embryo dunes following storms. Additionally, other important interconnected habitats like the upper beach and drift line play a vital role in coastal biodiversity, and these are also affected if not completely removed from the beach system in the presence of mechanical cleaning (Figure 13).

Figure 13. Mechanical beach cleaning at la Línea de la Concepción (left) and Huelva coastline (right). Photos by Javier Gracia (left) and Juan Bautista Gallego Fernández (right).

Recent investigations by Joyce et al., (2022) in NE Florida (USA) following hurricane Irma, indicate that artificial wrack removal reduces embryo dune recovery. In plots where storm deposits such as rhizomes and wood were "cleaned", embryo dunes had a 14% lower average height compared to intact areas. Instead, the redistribution of wrack deposits from various ecosystem types (e.g., seagrasses, macroalgae) promoted the growth of specific grass species that contributed to dune formation over months, and that enhanced the geomorphological recovery of coastal dunes.

Additionally, the upper beach and drift line play an essential role on coastal biodiversity. Species richness is small here, but the proportion of endangered species and rarity values are high (Acosta et al., 2009). Along Mediterranean shores, beach-cast seagrass organic matter serves as a fertiliser for embryo dune and foredune vegetation (Cardona and García, 2008). The removal of Posidonia oceanica remains from mediterranean beaches (e.g., Figure 14) increased their vulnerability and disturbs the fauna/flora that depends on them (Roig-Munar and Martín Prieto, 2005).

Figure 14. Seagrasses like Posidonia oceanica naturally grow in the Mediterranean Sea and are transported by waves and currents to beaches, and by winds to coastal dunes. These natural deposits form important sources of organic matter for both beach and dune ecosystems. Photo by Javier Gracia (location: Ebro Delta, Spain).

Método: en este caso podría implantarse una evaluación semicualitativa basada en observaciones sobre el terreno, preferiblemente basada en los planes de gestión de la zona (véase el Apartado 3.3.4).

4. Dumping of solid waste and litter

The percentage of dune area littered by solid waste and garbage (examples in Figure 15) depends on location (e.g., more littler could be expected in urban beaches compared to remote ones, or on beaches close to river mouths). The origin of waste can be different too, either directly brought by people or by the sea.

Figure 15. Left: litter on beaches brought by the sea in the relative remote areas of the Ebro Delta (Spain; photo by Javier Gracia). Right: Litter on back beach and embryo dune area in Marina di Chieuti, Puglia (Italy; photo by Irene Prisco).

Method: The presence of litter can be visually estimated twice a year (preferably before and after the touristic season) to calculate an approximate percentage of embryo dune area affected by it. Like other variables in this section, a quantitative or semi-quantitative methodology should be developed in the near future (Section 3.3.4).

5. Presence of grazing cattle

Livestock grazing contributes to the loss of annual plants and reduces vegetation cover. The presence of cattle also leads to increases in excrements (Gracia et al., 2009). Heavy trampling can prevent the settlement and growth of new dune plants by removing plant fragments, affecting the process of embryo dune development (Figure 16).

Figure 16. Cattle on the embryo dune and dune area at Bolonia beach (left) and cattle grazing on embryo dune vegetation at Playa de los Lances (Tarifa, right), Spain. Photos by Javier Benitez (left) and J. García de Lomas (right).

Method: The presence of cattle can be identified during site visits, supported by local records of this activity. Further information about the need to develop a methodology to obtaining precise assessment of the impact created by this pressure across all countries is in Section 3.3.4.

6. Permanent infrastructures

Permanent infrastructures built along the back beach can destroy embryo dunes and entirely disrupt these habitats. The interference can lead to the loss of connectivity both along the shoreline and across it. Permanent infrastructure prevents the natural exchange of sand and organisms, as well as natural beach-dune interaction that are key to the process of embryo dune evolution. Infrastructure commonly includes urbanization and the construction of rigid structures such as seawalls and promenades. This infrastructure can be located right on top of a former embryo dune area, or a few meters landwards of the embryo dune area (Figure 17).

Figure 17. Rota Beach (left), with a promenade occupying the embryo dune area. La Barrosa Beach (right), where the promenade is a few meters landwards and into the former dune zone, and embryo dunes can have a space to develop. Photos by Irene Delgado Fernández (right) and Google Earth Imagery (right).

Method: The presence of permanent infrastructure on top of embryo dunes can be identified during site visits and other information sources such as aerial photography (Section 3.3.4).

7. Temporary infrastructures on the back beach

Beach-dune systems are popular destinations, especially along Mediterranean coastlines. During the touristic season, temporary infrastructures to cater to visitors is common (Figure 18). This often includes beach kiosks and beach equipment, temporary facilities such as public toilets and beach accesses, etc. The presence of temporary infrastructures can encroach upon the public domain and stress embryo dune environments.

A recent study by Sanromualdo-Collado et al., (2022) quantified the significant effect of beach kiosks on dune ecosystems at Playa del Inglés (Gran Canaria, Spain). Kiosks eliminated vegetation, disrupted aeolian processes and altered sand movement towards the dunes. Among other effects, the kiosk structure contributed to the formation of shadow zones, scouring and deflation surfaces, and dune fragmentation. The presence of beach kiosks can also lead to beach grooming and the introduction of alien vegetation species (point 9).


Figure 18. Left: Touristic occupation of the back-beach and embryo dune area at Circeo, Lazio (Italy; photo by Alicia Acosta). Right: example of a beach kiosk in Cortadura Beach, Cadiz (Spain), protruding into the back-beach and compartmentalising the embryo dune area. Photo from Google Earth.

Method: The presence of permanent infrastructures on top of embryo dunes can be identified during site visits and other information sources such as aerial photography (Section 3.3.4).

8. Inadequate beach nourishment

Beach nourishment is primarily used to increase beach width and protect human infrastructures (e.g., Schipper et al., 2021). However, beach nourishment can eliminate seeds, modify granulometry, and change storm/tide dynamics. Sand nourishment can lead to a decrease in coastal dune growth, because of an accumulation of veneers and lag deposits on the beach surface (e.g., Nolet, 2020). The increase in supply-limiting conditions such as surface crusts and sediment cementation (van der Wal (1998, 1999, 2004) leads to an increase wind threshold for aeolian transport (Hoonhout and de Vries, 2017)

Further information about the need to develop a methodology to obtaining precise assessment of the impact created by this pressure across all countries is in Section 3.3.4.

9 & 10. Exotic species and plantations

The presence of invasive species poses a threat to the integrity of natural dune ecosystems by disrupting ecological processes such as succession and altering nutrients, carbon, and water cycles. Invasive species (both plant and animal) can outcompete and displace native flora and fauna, leading to changes in the structure and functions of dune environments. As they establish dominance, invasive species can modify soil composition, nutrient availability, and water retention capacity.

Additionally, invasive species can modify embryo dune morphology and evolution (Figure 19).

Linaria polygalifolia subsp. *lamarckii* . Portuguese Algarve. Portugal
Authorship: Juan Bautista Gallego Fernández

Figure 19. Example of alterations to embryo dune morphology due to the introduction of an alien species. Above: dunes with native Ammophila arenaria. Below: dunes with invasive Oenothera drummondii, Huelva coastline. Photos by Juan Bautista Gallego-Fernandez.

Exotic species can also be introduced by "gardening" and planting on beaches and dunes (Figure 20). This displaces native species and can weaken ecological and morphological interactions between the beach, embryo dune and foredune area.

Figure 20. Tres Piedras Beach (Chipiona, Spain). Introduction of alien vegetation at the beach. Photo by Juan Bautista Gallego Fernández.

Further information about the need to develop a methodology to obtaining precise assessment of the impact created by this pressure across all countries is in Section 3.3.4.

11. Sand extraction and water discharge

Sand extraction leads to direct habitat destruction. Removing sediment from embryo dunes and associated habitats disrupts their ecology and removes sediment that is essential for the natural maintenance of embryo dunes. Coastal developments can be accompanied by the discharge of sewage and runoff, which pose a significant threat to embryo dunes and other coastal environments. Pollution negatively impacts dune vegetation and wildlife. Pollutants can directly affect the health of flora/fauna and exarcebate the vulnerability of embryo dune habitats.

3.3.5. Gap analysis and future needs

There is a need to develop a standard methodology to assess pressures and threats. Many of the variables described above have impacts that vary depending on the severity of the actions, the specific site, their frequency, and other controls. There is a need for an appropriate assessment of the pressure they exert on embryo dunes, as well as future efforts to establish ranges to standardize their measurement and their use as diagnostic variables.

Additional to pressures and threats identified in the previous section, there is a need to evaluate the effect of global processes on embryo dune habitats across the MED, such as increases in sea-level rise and changes in storminess.

Finally, embryo dunes are interconnected with other coastal and terrestrial habitats via coastal currents, waves, and winds. Indirect activities such as lagoon and estuary dredging (affecting submerged sediment budgets) and the location of infrastructures along the coastline (potentially modifying the littoral drift) can profoundly affect the evolution of beach-dune systems and hence embryo dunes.

Need of harmonised methods for the assessment of pressures/threats intensity and impacts

The assessment of pressures and threats is necessary to evaluate the 'Future perspectives', one of the key parameters to determine the conservation status of each habitat type. The definition of pressures and threats for MS reporting and the guidelines for assessment of their influence as high, medium or low are very imprecise and it seems necessary to develop a method that allows obtaining more precise assessments, which should be applied in all countries.

Standard procedures for assessing the intensity and impact of each pressure/threat on the area, structure and functions of the habitat type should be developed. A Conceptual framework for assessment of pressures and threats on forests has been recently developed within the framework of the system for monitoring conservation status of habitat types in Spain (Chacón et al., 2019).

In a first step, based on the reference list available for reporting pressures and threats for habitat types under the Habitats Directive, those relevant pressures and threats that can cause a change in the conservation status at the biogeographical level shall be identified and briefly described for each of the three parameters: 'Range', 'Occupied area', 'Structure and function'.

The analysis of intensity and impact of pressures and threats on the area and condition (structure and function) of the habitat could address the following main steps:

1. Compilation of information sources and databases: GIS Layers, Inventories of pressures and threats available, statistical models, considering appropriate scales, frequency, extent, etc.
2. Determine the overlapping of pressures and threats with habitat distribution
3. Evaluate the sensitivity of the habitat type to each pressure and define critical thresholds that determine the categories H (high), M (medium) and L (low), e.g. considering regulations, bibliography, etc.

3.4. Conclusions on the assessment of conservation status and trends

The literature review conducted as part of this AP underscored the abundance of research on human impacts on coastal dunes in a broader context. These multiple studies offer insights applicable to the specific case of embryo dunes. However, working meetings highlighted significant challenges specific to embryo dunes across the MED. In particular, there is a need to develop standardised procedures and clear methods to assess human impacts on embryo dunes. Additionally, both the literature review and working meetings emphasized the variability in vulnerability among different embryo dune areas to various threats. Future assessments should also integrate recovery potentials and global impacts, some identified as main gaps in current knowledge.

Larus audouini. Authorship: Freepik image bank

Tenebrionidae dunes
Authorship: Banco de imágenes Freepik

4

Conservation objectives

4.1. Restoration and conservation objectives and the corresponding measures

4.1.1. Recovery of the Favourable Reference Area by 2050

Mediterranean coastal dune systems have undergone a significant reduction in the last decades particularly due to urbanisation and use of coastal areas for tourism and recreational activities (Delbosc et al., 2021; Prisco et al., 2021). The habitat area has been assessed in unfavourable status in all the Mediterranean Member States. Although some valuable restoration initiatives have been carried out, still significant efforts are needed to restore the habitat in order to ensure a favourable status of its occupied area.

This objective will first require determining Favourable Reference Area and then implement the necessary restoration measures, as described below.

Necessary measures to achieve this objective

- **Determine the favourable reference area** of embryonic dunes, by analysing their historical evolution in the last decades (from the 1980's onwards), according to the methodology described in Section 3.1.6 in this action plan. It will also be necessary to determine the current occupied area, as described in section 4.2.1 to estimate the restoration needs.
- Identify potential restoration areas in all the Mediterranean MS and **prepare restoration plans**, which shall describe the necessary restoration actions and consider the feasibility and the means required to carry out the restoration actions. The costs and financial resources to carry out the planned actions shall be estimated in the best possible detail and the necessary permits and agreements shall be envisaged.
- **Implementation of restoration actions** planned with the involvement of public authorities at the national, regional and local level, as appropriate.

4.1.2. Maintain in good condition at least 90% of the habitat surface

Embryonic shifting dunes have been assessed in unfavourable condition (structure and functions) in all the Mediterranean Member States. According to the guidelines for conservation status assessment (European Commission, 2017), at least 90% of the habitat surface must be in good condition to consider the habitat structure and functions in favourable status. This requires improving the conditions in a significant proportion of the habitat areas, which are currently degraded or not in good condition. Figure 21 shows examples of potential management actions leading to the preservation of the habitat.

Necessary measures to achieve this objective

- **Identify degraded areas with recovery potential** and assess the main pressures that cause their degradation, in order to prepare appropriate recovery plans, considering the necessary means and resources for their implementation.
- Develop recovery actions by the **removal and reduction of the relevant pressures** and implement **recovery/ restoration measures** as required to improve the condition in the selected areas.
- **Agreements with local authorities** will be especially useful to carry out some conservation and recovery measures, such as managing beach cleaning in the appropriate way to avoid the destruction and degradation of embryonic dunes, installation of elevated boardwalks and beach accesses, etc.
- Establish **coordination mechanisms** between regional and local administrations and relevant stakeholders for the management and conservation of dune areas, to improve management and implement in a coordinated manner the necessary conservation measures.

Figure 21. Examples of management actions leading to the preservation of embryo dunes: Upper row, left: elevated boardwalk and beach access at Flecha del Rompido (photo by Juan Bautista Gallego Fernández). Upper row, right: example of manual beach cleaning on foot from the NGO "Natura sin Basura" (Spain). Center, left: vegetation and organic matter remains on coastal dunes, brought by currents and waves from the nearshore onto the beach, and by winds from the beach into the dune area (photo by Javier Gracia). Centre, right: information panes at Greenwich Dunes in Canada (photo by Irene Delgado-Fernandez). Bottom row: virtual fencing at the Sand Motor in the Netherlands (photo by Irene Delgado-Fernandez).

4.1.3. Improve protection and management inside and outside Natura 2000

According to the data provided by the Mediterranean Member States under article 17 reporting, the percentage of the habitat area included in Natura 2000 varies from less than 20% to 100% (see Table 3). Considering the vulnerability of this habitat and its significant regression in the past, it is considered necessary to increase its protection by designating Natura 2000 sites in areas particularly important for its conservation, including all the restoration areas and areas that contribute to improve the habitat connectivity.

The elaboration, update and implementation of management plans for Natura 2000 sites with embryonic dunes will also be necessary to ensure proper management of all these sites.

Considering the fragmentation of embryonic dunes across its distribution area, there is also a need to improve the coherence of the Natura 2000 and the connectivity of the sites designated for this habitat to ensure its long-term conservation and viability. This could be done through development of plans to improve the coherence of the Natura 2000 Network for dunes.

Necessary measures to achieve this objective

- In order to **improve the protection of embryonic**, it will be necessary to Identify all current areas with the habitat outside Natura 2000 and designate the corresponding SCIs. The designation of new Natura 2000 sites shall also include all the areas subjected to the restoration of embryonic dunes.
- **Analyze the coherence** (representativeness, connectivity, resilience, rarity and redundancy) of the Natura 2000 Network for embryonic dunes to improve the connectivity of the network itself. This will be a first step **elaborate and implement plans for improving coherence and connectivity** for embryonic dunes.

4.1.4. Promote adaptation to climate change

Considering the future climate change scenarios and the impact they can have on the conservation of embryonic dunes in the Macaronesian region, as well as on the entire dune system, this action plain aims to promote the conservation and restoration of the habitat in favourable areas expected in the new climate conditions.

Necessary measures to achieve this objective

- **Analyse and predict changes in the potential habitat area in the climate change scenarios**, though modeling techniques, in order to identify favorable areas for the occurrence of embryonic dunes in those scenarios and preàre the measures required to ensure adaptation of embryonic dunes to climate change.
- Based on the predictive analysis of changes in the embryonic dunes areas resulting from new climate conditions, **prepare an adaptation plan** to implement the necessary **adaptation, conservation and restoration actions in the new favorable areas** identified in the plan. The costs, financial resources and means to carry out the planned actions shall be estimated and envisaged in detail.

Larus audouini. Authorship: Freepik image bank

4.2. Objectives and measures to improve knowledge and monitoring

Despite the knowledge accumulated during these last decades about the dune habitats in the Mediterranean region, there are still important knowledge gaps in several issues related to the characterisation, ecological requirements, area occupied, condition, pressures and threats of this habitat type. The following objectives and measures are proposed in this action plan.

4.2.1. Improve knowledge about ecological diversity and ecological requirements of embryonic dunes

The study and analysis of the key ecological processes and requirements for maintenance of embryonic dunes in good condition at the relevant scales is essential to properly address their conservation.

Necessary measures to achieve this objective

- Develop and apply a **common methodology to delimit and map the dune systems** in all the Mediterranean coast. Identify the key characteristics of the habitat in each country and describe its diversity.
- **Study and analysis of ecological requirements and processes** for maintaining embryonic dunes in favourable conservation status, considering the integration of embryo dunes in the whole dune system and their relationship with other coastal ecosystems (beach, coastal lagoons, marshes…)

4.2.2. Improve assessment and monitoring of embryonic dunes conservation status, including improving knowledge about pressures and their impacts on embryonic dunes

The lack of harmonized methodologies used for assessment of conservation status in the three archipelagos harbouring embryonic dunes prevents obtaining comparable results across the Mediterranean region.

Achieving a detailed knowledge about current pressure affecting embryonic dunes across their distribution areas and foreseeable threats in the future is also essential to identify the actions needed to ensure their conservation.

Necessary measures to achieve the objective

- Develop and implement a **harmonised, standard methods and protocols to evaluate conservation status** of embryonic dunes for a proper assessment of all the parameters: area, structure and functions, and

Portugal. Authorship: Catarina Meireles

future prospects, based on the analysis of pressures and threats.

- Develop and apply a **standard methodology to harmonise the calculation of the habitat** area in the Mediterranean countries, as proposed in Section 3.1.4 of this action plan
- Develop and apply a common standard procedure for the assessment and monitoring of embryonic dunes **habitat condition (structure and functions)** in the Mediterranean region. This will require an agreement on the use of a common set of variables and the development of thresholds, aggregation methods, monitoring and sampling protocols, etc. for their implementation in the entire region (see also Section 3.2.2) .
- **Study, analyze and map pressures and threats** that affect embryonic dunes across its range, developing standard procedures to quantify the intensity and impacts (high, medium, low) of pressures and threats on habitat surface, structure and function (see also Section 3.3.4).
- Create of a **joint working group** to develop the standard methodologies that are considered necessary to improve assessment and monitoring of the habitat conservation.

4.3. Dissemination and awareness-raising objectives and measures

4.3.1. Increase awareness about the importance of embryonic dunes conservation

The dissemination of information about the value and vulnerability of embryo dunes and the importance of their conservation in the Mediterranean region is considered necessary to raise awareness among the population, local administrations and stakeholders, that can support the conservation of this unique coastal habitat.

Necessary measures to achieve the objective

- **Elaboration and dissemination of information and awareness raising materials** on the importance of embryonic dunes to support their conservation. These materials should be designed and targeted to the local administrations, local population and visitors, and relevant stakeholders.
- **Promote and support the implementation of the actions** by the regional and local Administrations, relevant stakeholders and NGOs through the dissemination of information on the current status and conservation needs of embryonic dunes and the action plan itself.

Resources and tools for implementation

5.1. Costs of measures and funding sources

The estimate of costs of the measures proposed in this action plan could not be carried out during its preparation but it will need to be addressed before its implementation. A number of studies and analyses are proposed to improve knowledge as well as to guide and support the implementation of the necessary actions, which can be budgeted considering similar studies carried out on other habitats and contexts. A precise quantification of the needs in terms of restorations and conservation measures will be necessary to estimate their costs, which can also be based on the unit costs of other similar experiences and projects. The final budget will also depend on the ambition in the implementation of the planned actions throughout the execution of the action plan.

Among the potential sources of financing, the EU Regional Development Fund, including INTERREG, and national funds can be used for restoration, conservation management and monitoring of the habitat and to raise public awareness. The LIFE programme provides support for integrated approaches, pilot, demonstration and best practice projects that contribute to the implementation of biodiversity objectives and climate change mitigation strategies and action plans at regional or national level. Support to improve knowledge is also available from Horizon Europe funding.

5.2. Implementation tools and supportive measures

Possible measures to enable and support the implementation of the action plan can include legal and administrative measures, incentives, communication, stakeholders' involvement, etc.

Legal and administrative measures will be necessary to improve protection and support the implementation of management plans in Natura 2000 sites.

Agreements with public authorities can be useful for the implementation of restoration and conservation measures in some embryonic dunes areas. Local authorities can be involved in the implementation of some of the conservation measures proposed in the action plan.

Doñana. Spain. Authorship: Irene Delgado

Linaria polygalifolia subsp. *lamarckii* . Portuguese Algarve. Portugal
Authorship: Juan Bautista Gallego Fernández

6

Monitoring and review of the action plan

Portugal. Authorship: Catarina Meireles

A monitoring plan should be designed at the start of the action plan to assess the implementation and effectiveness of the planned actions, including relevant indicators and time frames for the assessment.

To assess the effectiveness of the planned measures, it would be useful to carry out a scientifically supervised monitoring of the results on the habitat. Some possible indicators to assess the effectiveness of the implemented measures could include the following:

- Area of habitat in favourable condition.
- Surface area where conservation and restoration measures are implemented.
- Increase or maintenance of favourable status in managed areas.
- Diversity of habitat-typical, endangered or rare species.

As regards the review of the action plan, it would seem appropriate to review and update the action plan every twelve years, to cover two reporting cycles (under Article 17 of the Habitats Directive), given the slow time for habitats to react to changes. Nevertheless, the implementation of the actions could be reviewed every six years in order to check the activities implemented and intermediate results, detect possible gaps, difficulties and constraints that would need to be resolved, and revise and adjust the actions as required.

Cakile maritima. Gulf of Cadiz. Spain
Authorship: Juan Bautista Gallego Fernández

7 Governance for implementation of the action plan

To make the action plan operational at national and regional level, it is necessary to agree on the responsibilities for implementation. The relevant bodies and people responsible for the implementation and monitoring of the action plan should be clearly identified.

The national and regional authorities of the Mediterranean MS should identify and designate those responsible for the implementation of the actions. A specific body or a steering committee could be in charge of the plan. Regular exchange of information about the implementation of the actions and a yearly meeting for its review could be foreseen to monitor the implementation of the action plan.

This governance system should be defined and established at the start of the action plan. The following steps could be considered:

- Set up a governance system for the action plan implementation: identify the relevant bodies and people responsible for implementation and monitoring of the action plan. MS should designate those responsible for the implementation of the planned actions.
- Define a decision-making process.
- Set up the procedures and responsibilities for monitoring, evaluation and review of the action plan (e.g. yearly exchange and review of the action plan implementation).

Euphorbia paralias. Gulf of Cadiz . Spain
Authorship: Juan Bautista Gallego Fernández

Doñana. Spain
Authorship: Irene Delgado

8

Framework for action

An operational framework including the objectives, actions, geographical scope, responsibilities, and timescales is included in the next pages

ACTION PLAN FOR CONSERVATION OF HABITAT 2210 – Embryonic shifting dunes

FRAMEWORK FOR ACTION (2024-2030) – Goal: Achieve favourable conservation status in all the distribution area

Conservation and restoration objectives				
Key actions	Activities, means and input required	Geographical scope	Responsibilities	Timescale
Objective 1: Recovery of the Favourable Reference Area by 2050				
Increase the area to reach the **FRA**	Determine the FRA using the standard method	All Mediterranean MS	National and regional Administrations, Scientific experts	2025
	Identify potential restoration areas and prepare a **restoration plan**			2027
	Start developing **restoration actions**		National, regional and local Administrations, relevant stakeholders and NGOs	2028
Objective 2: Maintain in good condition at least 90% of the habitat surface, to reach a favourable conservation status by 2050				
Recovery of areas in bad condition (degraded)	Identify potential recovery areas and main pressures and threats that cause their degradation, and prepare a **recovery plan**	All Mediterranean MS	National and regional Administrations, Scientific experts	2026
	Develop **recovery actions:** remove/reduce pressures and implement recovery/restoration measures		National, regional and local Administrations, relevant stakeholders and NGOs	2030
Establish **coordination** mechanism for dune conservation	Creation of **steering committees** with representatives the relevant administration and stakeholders to coordinate conservation, knowledge and monitoring activities	All Mediterranean MS	National, regional and local Administrations, relevant stakeholders and NGOs	2024
Objective 3: Improve protection and management inside and outside the Natura 2000 network				
Include important dune areas in **Natura 2000** –considering connectivity and restoration areas	Identify current areas outside Natura 2000 and **designate** the corresponding SCIs	All Mediterranean MS (as appropriate)	Regional Administrations	2026
	Include all the restored areas in Natura 2000	All restored areas	Regional Administrations	2028

Key actions	Activities, means and input required	Geographical scope	Responsibilities	Timescale
Elaboration, update and implementation of **management plans** for Natura 2000 sites with dunes	Update and **adopt management plans** for all Natura 2000 sites with dunes	All Mediterranean MS	National and regional Administrations	2028
	Implement conservation measures, including measures to reduce/remove main pressures and threats		National, regional and local Administrations, relevant stakeholders and NGOs	2030
Develop plans to improve the **coherence of the Natura 2000** Network for dunes	Analyse the coherence (representativeness, connectivity, resilience, rarity and redundancy) of the Natura 2000 Network for dune habitats	Natura 2000 Network in the Mediterranean	National, regional Administrations, scientific experts	2027
	Elaborate and implement **plans for improving coherence and connectivity** for dunes in Natura 2000			2028
Objective 4: Adaptation to climate change				
Promote the **adaptation measures** to the new climate conditions	Analyse and forecast changes in dune area in the climate change scenarios and develop an **adaptation plan**.	All Mediterranean MS	National and regional Administrations, with support from scientific experts	2026
	Implement adaptation **measures** according to the plan	All Mediterranean MS	National, regional and local Administrations, relevant stakeholders and NGOs	2030

Knowledge improvement objectives				
Key actions	Activities, means and input required	Geographical scope	Responsibilities	Timescale
Objective 5: Improve knowledge about eco-diversity and ecological requirements of embryonic dunes				
Study the **key ecological processes and requirements** for maintenance of dunes in good condition	Analyse and determine the key ecological requirements and processes for maintaining embryo dunes in a favourable conservation status, including the integration of embryo dunes in the whole dune system and their relationship with other coastal ecosystems (beach, coastal lagoons, marshes…)	All Mediterranean MS	National and regional Administrations, Scientific experts	2030

Key actions	Activities, means and input required	Geographical scope	Responsibilities	Timescale
Delimit the main dune systems in all the Mediterranean coast	Develop and apply a **common methodology** to delimit and map the dune systems in each country. Identify all the habitat types present in each system and describe their diversity	All Mediterranean MS	National and regional Administrations, Scientific experts	2026
Objective 6: Improve knowledge about pressures and their impacts on embryonic dunes				
Study and typification of the **pressures and threats** that affect the embryo dunes	Analysis, description and mapping of pressures and threats on embryo dunes in all their distribution area	All Mediterranean MS	National and regional Administrations, Scientific experts	2027

Assessment and monitoring of embryonic dunes conservation status

Key actions	Activities, means and input required	Geographical scope	Responsibilities	Timescale
Objetivo nº. 7: mejorar la evaluación y el seguimiento del estado de conservación de las dunas embrionarias				
Develop and apply **standard methods and protocols** to evaluate conservation status of embryo dunes	Creation of a **joint working group** to develop the standard methodology	All Mediterranean MS	National Administrations, Scientific experts	2024
	Definition and implementation of a **standard methodology for assessment and monitoring** of the area, structure and functions, pressures and threats and future perspectives of embryo dunes.		National Administrations, Scientific experts	2026

Dissemination and awareness-raising

Key actions	Activities, means and input required	Geographical scope	Responsibilities	Timescale
Objective 8: Increase awareness about the importance of embryonic dunes' conservation and monitoring				
Disseminate the **value and vulnerability of embryo dunes** and the importance of their conservation	Elaborate and disseminate awareness raising materials on the **importance of embryo dunes for conservation**	All Mediterranean MS	National, regional and local Administrations, relevant stakeholders and NGOs	2024
	Disseminate the current status **and conservation needs** of embryo dunes, and the **action plan**			2024

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Abbreviations

BR: Biogeographical Region

CS: Conservation Status

FCS: Favourable Conservation Status

FRV: Favourable Reference Values

HCI: Habitat type of Community interest

HD: Habitats Directive

MS: Member States

Habitat action plan

2110 Embryonic shifting dunes

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