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 Mihai Doroftei, Silviu Covaliov,  Simona Dumitrița Chirilă, Florentina Tudose

Coastal vascular plant diversity of the Danube Delta Biosphere Reserve: rare plants, vegetation mosaics and conservation priorities

Mihai Doroftei¹, Silviu Covaliov¹, Simona Dumitrița Chirilă¹, Florentina Tudose¹

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Corresponding author: Mihai Doroftei (mihai.doroftei@ddni.ro)

¹ Danube Delta National Institute for Research and Development, Tulcea, Romania

Abstract

The coastal area of the Danube Delta Biosphere Reserve is a narrow but highly diverse ecological corridor at the contact between the delta, the Razim-Sinoe lagoon system and the Black Sea. This paper synthesises project-derived field data on coastal-area investigations and situates them within the published floristic, phytosociological and habitat literature on the Danube Delta and Dobrogea. The investigated sector extends from Musura Island to Corbu, while the final mapping stage covered 86.92 km of coastal area. The project dataset recorded 661 vascular plant species and 47 plant associations, distributed across beaches, embryonic dunes, fixed dunes, wet interdunes, saline depressions, coastal grasslands and shrub communities. Overall, 58 taxa had a Romanian Red List status, and 43 priority taxa were selected for discussion. Examples include *Alyssum borzaeanum*, *Argusia sibirica*, *Crambe maritima*, *Centaurea pontica*, *Asparagus brachyphyllus*, *Convolvulus persicus*, *Dianthus bessarabicus*, *Eryngium maritimum*, *Limonium bellidifolium*, *Polygonum maritimum* and *Stachys maritima*. The main pressures are shoreline erosion, mechanical beach cleaning, uncontrolled tourist access, vehicle traffic on sand, grazing pressure, ruderalisation and local habitat fragmentation. The conservation value of the coastal area lies in the fine-scale mosaic of habitats and microhabitats that sustains specialised coastal flora. Management should therefore combine periodic mapping, rare-species monitoring, visitor guidance, grazing regulation, avoidance of damaging mechanical interventions, and complementary in situ and ex situ conservation measures.

Keywords: Danube Delta Biosphere Reserve; coastal area; vascular flora; rare plants; dune vegetation; saline habitats; conservation management.

Introduction

The Danube Delta Biosphere Reserve (DDBR) is widely known for its wetlands, lakes, reedbeds and river branches, but its maritime margin is equally important for biodiversity conservation. The vascular flora of the delta has been documented in regional floristic syntheses and checklists, which emphasise both the richness of the flora and the need for continued inventory and monitoring (Ciocârlan 2011; Doroftei et al. 2011). Historical botanical exploration of the delta and its coastal sectors dates back to early works such as Pallis (1916), Prodan (1935) and Panțu et al. (1936).

The coastal area forms a narrow transition zone between marine, lagoonal and deltaic influences. Because of this position, it contains habitats that are nationally rare and strongly dependent on natural coastal dynamics. Its vegetation is shaped by sand movement, salt accumulation, groundwater level, temporary flooding, wave exposure, wind action and local human use. These factors generate a mosaic of plant communities rather than a continuous and uniform vegetation belt. Open beach vegetation,

embryonic dunes, fixed dunes, saline depressions, humid interdunes and coastal shrubs can occur in close contact, often changing over only a few tens of metres.

This landscape mosaic is especially important for plants with narrow ecological requirements. Some species colonise bare or weakly stabilised sand; others are restricted to saline or brackish depressions, dune edges or relatively undisturbed backshore habitats. Several of these taxa have small populations, fragmented distributions, or conservation statuses that require attention, as shown by regional conservation works and Romanian red-list sources (Oltean et al. 1994; Petrescu 2007; Dihoru and Negrean 2009; Petrescu 2015; Făgăraş et al. 2010). Their persistence depends not only on protected-area boundaries, but also on the maintenance of natural microhabitats and coastal processes.

This article uses the DDNI coastal-area project dataset as a basis for field data and interprets it in light of the published floristic, habitat and vegetation literature. Its role is distinct from a more analytical coastal-conservation manuscript focused on a specific habitat interface. Here, the purpose is broader and regional: to present the phytodiversity of the coastal area, the most relevant rare plant species, the main pressures and the practical conservation priorities in a format suitable for *Revista Delta Dunării*.

Materials and methods

The synthesis uses unpublished project-derived field data from 2009 to 2018. These data covered methodology, literature review, floristic and phytocoenological inventory, ecology of conservation-relevant plant species, assessment of anthropogenic pressures and management measures for the conservation of coastal phytodiversity. The project reports are not listed in the References section; instead, the bibliography below includes published and web-findable works used to frame and support the interpretation.

The broader sector considered in the field dataset extends from Musura Island in the north to Corbu in the south. This sector is approximately 166 km long and represents a major part of the Romanian Black Sea coast. The final detailed mapping stage covered 86.92 km of coastal area, distributed among the Musura, Sulina-Sfântu Gheorghe, Sacalin, Perişor-Periteaşca and Periboina-Corbu sectors.

The original investigations combined field surveys in different seasons, itinerary mapping, GPS observations, vegetation relevés, floristic records, analysis of selected soil and habitat conditions, and interpretation of aerial and satellite imagery. The botanical information was compared with classical Romanian floras (Ciocârlan 1994, 2000, 2009; Sârbu et al. 2013), red lists and habitat classification systems, including the Romanian habitat typology and Natura 2000 habitat interpretation used at the time of the project (Doniţă et al. 2005; European Commission 2013; Gafta and Mountford 2008). The interpretation of coastal halophytic vegetation also follows published studies on the Danube Delta coastal zone and Dobrogea salt marshes (Făgăraş 2016; Ciocârlan et al. 2013).

Table 1. Main characteristics of the source material used for this synthesis.

Element	Information used in the article
General coastal sector	Musura Island - Corbu
Detailed mapped length	86.92 km in the final mapping stage
Main mapped sectors	Musura; Sulina-Sfântu Gheorghe; Sacalin; Perişor-Periteaşca; Periboina-Corbu
Floristic richness reported	661 vascular plant species
Vegetation diversity reported	47 plant associations
Conservation-relevant taxa highlighted	58 taxa with Romanian Red List status; 42 priority taxa selected for discussion
Methods behind the dataset	Field surveys, GPS mapping, relevés, aerial and satellite interpretation, literature synthesis

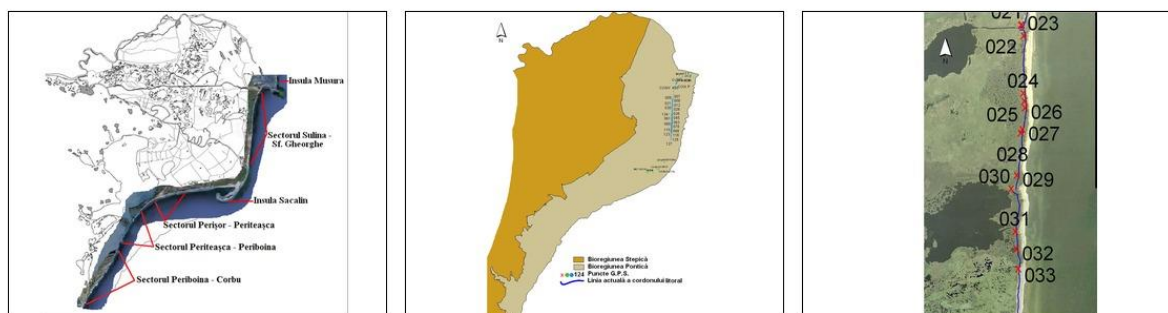


Figure 1. Study areas within the coastal area. a) Main coastal sectors; b) biogeographical context; c) example of GPS points in the Sulina-Sfântu Gheorghe / Canal Sondei area.

Floristic and vegetation value of the coastal area

The final floristic total of 661 vascular plant species in the project dataset confirms the botanical importance of the DDBR coastal area. This richness is high relative to the narrowness of the coastal strip and reflects the juxtaposition of several ecological groups: psammophilous plants of open sand, halophytes of salt-affected soils, hygrophilous species of wet depressions, grassland species, shrub species, and ruderal elements that occur locally under human influence. The broader significance of this floristic diversity is supported by published syntheses of the flora of the Danube Delta (Ciocârlan 2011).

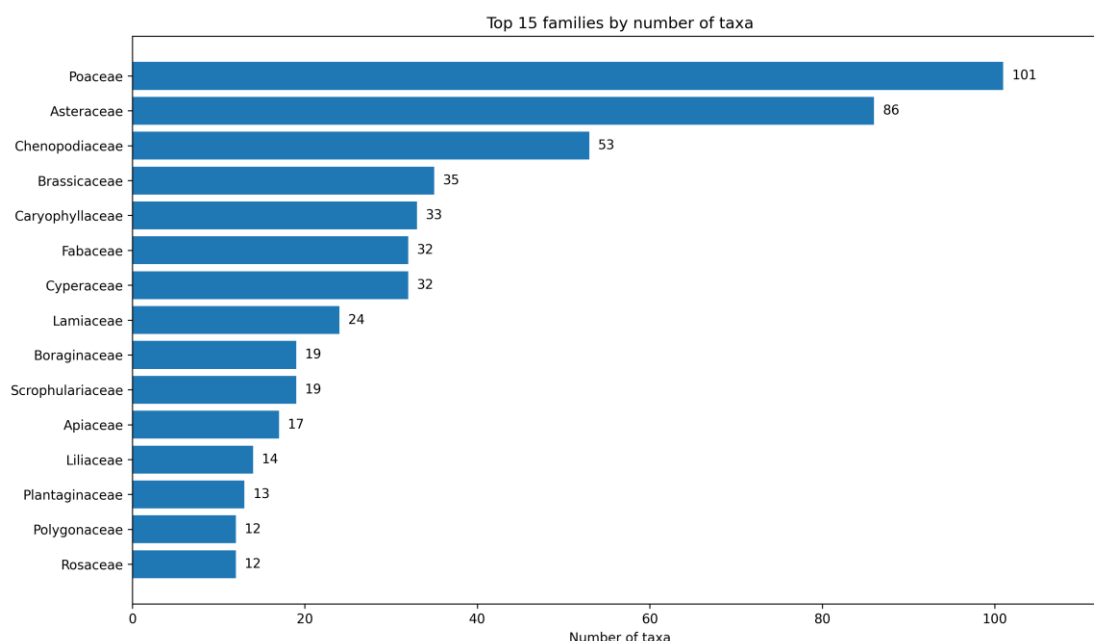


Figure 2. Dominant plant families within the coastal area

The 47 plant associations recorded in the project dataset indicate that the coastal vegetation is not a simple linear sequence from sea to inland areas. Instead, it forms a discontinuous mosaic. Annual pioneer communities develop on open beaches and freshly disturbed sand; dune-building communities occur where sand begins to accumulate; perennial dune grasslands occupy more stable sites; saline depressions support halophilous assemblages; and locally developed shrubs mark sectors with greater substrate stability or lagoonal influence. Similar phytosociological diversity in deltaic and coastal sectors has been documented by Popescu et al. (1997), Sârbu et al. (1995, 2000), Sanda and Arcuş (1999), Popescu and Sanda (1976) and Făgăraş (2016).

This mosaic structure is essential for conservation. Some habitats are small, temporary, or spatially fragmented, yet they may support rare species and ecological processes that are absent from more

uniform coastal landscapes. For this reason, the value of the coastal area should not be judged only by habitat area. Rarity, ecological function, microhabitat diversity and vulnerability must also be considered.

The most valuable sectors are those where natural beach dynamics, dune development and saline or wet depressions coexist. In such places, several vegetation types can occur side by side, providing conditions for a large number of specialised species. Conversely, sectors subject to repeated mechanical disturbance, trampling or overgrazing tend to lose this fine-scale structure and become floristically simplified. This interpretation is consistent with Petrescu's (2015) broader assessment of natural-habitat value and threats in Tulcea County.

Representative vegetation groups

Beach and strandline vegetation represent the first living cover above the active shore. These communities are often sparse and seasonal, but they are ecologically important because they initiate colonisation of open sand and may trap organic material and sediment. They are also among the most vulnerable communities to mechanical beach cleaning and intensive recreational use. Their interpretation as conservation-relevant coastal habitats follows the European and Romanian Natura 2000 habitat frameworks (European Commission 2013; Gafta and Mountford 2008).

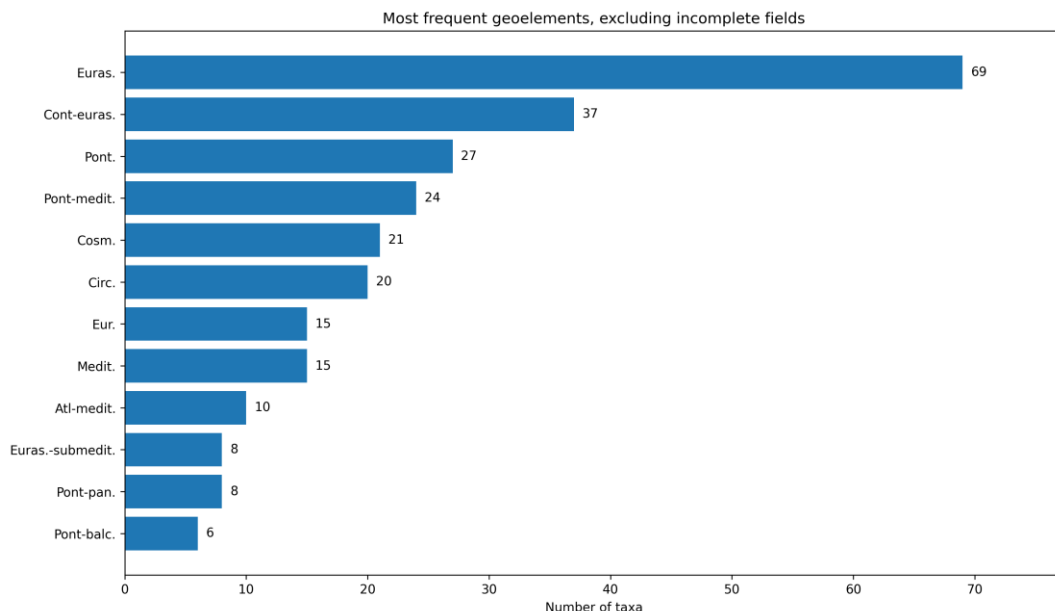


Figure 3. Most frequent geoelements within the coastal area

Embryonic dunes and mobile dune communities form where sand accumulation becomes more stable. Their plants tolerate burial, wind exposure and low nutrient availability. By capturing sand and reducing substrate mobility, they create conditions for later stages of vegetation. Damage to these communities can disrupt dune formation and increase the shoreline's vulnerability. Published beach-dune studies on the Danube Delta coast underline the importance of such functional zones for the persistence of rare psammophilous species (Strat 2016).

Semi-fixed and fixed dune vegetation supports a richer flora, including many perennial psammophytes and species of high conservation value. These habitats may appear visually modest, but they are important reservoirs of coastal biodiversity. Their stability depends on the balance between natural disturbance and the absence of excessive human pressure.

Wet interdune depressions and saline flats add ecological complexity to the area. They are controlled by temporary flooding, groundwater mineralisation, evaporation and microrelief. These sites can host

halophytes, hygrophilous species and mixed communities that differ strongly from the adjacent dry dunes: coastal shrubs and *Tamarix*-related vegetation further increase habitat structure in protected sectors or lagoon-facing positions. The ecological importance of salt-affected coastal surfaces in the Danube Delta region is also demonstrated by studies of *Juncus maritimus* vegetation and other halophytic systems (Făgăraş 2016; Ciocârlan et al. 2013).

Table 2. Representative vegetation groups and their conservation interpretation.

Vegetation group	Ecological role	Management note
Annual beach and strandline vegetation	Early colonisation of open sand and drift-line deposits	Avoid or limit mechanical cleaning in sensitive sectors
Embryonic dune vegetation	Initiates sand capture and dune development	Restrict trampling and vehicle access
Mobile and semi-fixed dune vegetation	Stabilises sand and supports psammophilous flora	Maintain natural dune processes
Fixed dune grasslands	Reservoirs of rare and specialised coastal plants	Prevent overgrazing and fragmentation
Wet interdune depressions	Microrefugia for hygrophilous and mixed coastal flora	Maintain hydrological and microrelief variability
Saline depressions and flats	Habitat for halophytes and salt-tolerant communities	Avoid drainage, infilling and excessive trampling
Coastal scrub and <i>Tamarix</i> vegetation	Adds structural diversity in more stable sectors	Manage carefully; avoid unnecessary removal

Rare and conservation-relevant species

The project dataset identified 58 taxa with a Romanian Red List status and selected 42 priority taxa as particularly important to the phytodiversity of the DDBR coastal area. They include species with restricted distribution, taxa listed in red lists, plants characteristic of natural beaches and dunes, halophytes of maritime depressions and species with small or vulnerable local populations. Their presence gives the coastal area scientific, ecological and educational value. The interpretation of their conservation relevance was cross-checked against Romanian red-list sources and regional conservation literature (Oltean et al. 1994; Petrescu 2007; Dihoru and Negrean 2009; Petrescu 2015; Făgăraş et al. 2010).

Alyssum borzaeum, *Crambe maritima*, *Argusia sibirica*, *Centaurea pontica*, *Asparagus brachyphyllus*, *Convolvulus persicus*, *Dianthus bessarabicus*, *Eryngium maritimum*, *Stachys maritima* and *Limonium bellidifolium* represent different conservation situations. Some are psammophytes of open maritime sands; others are halophytes of salt-affected depressions or taxa with Pontic, Ponto-Caspian, Atlantic-Mediterranean or regional endemic affinities. Together, they show that the conservation value of the coastal area is distributed across many ecological niches. The region should therefore be managed as a multi-species, multi-habitat system rather than as a set of isolated rare-plant points (Petrescu 2007; Ciocârlan 2011).

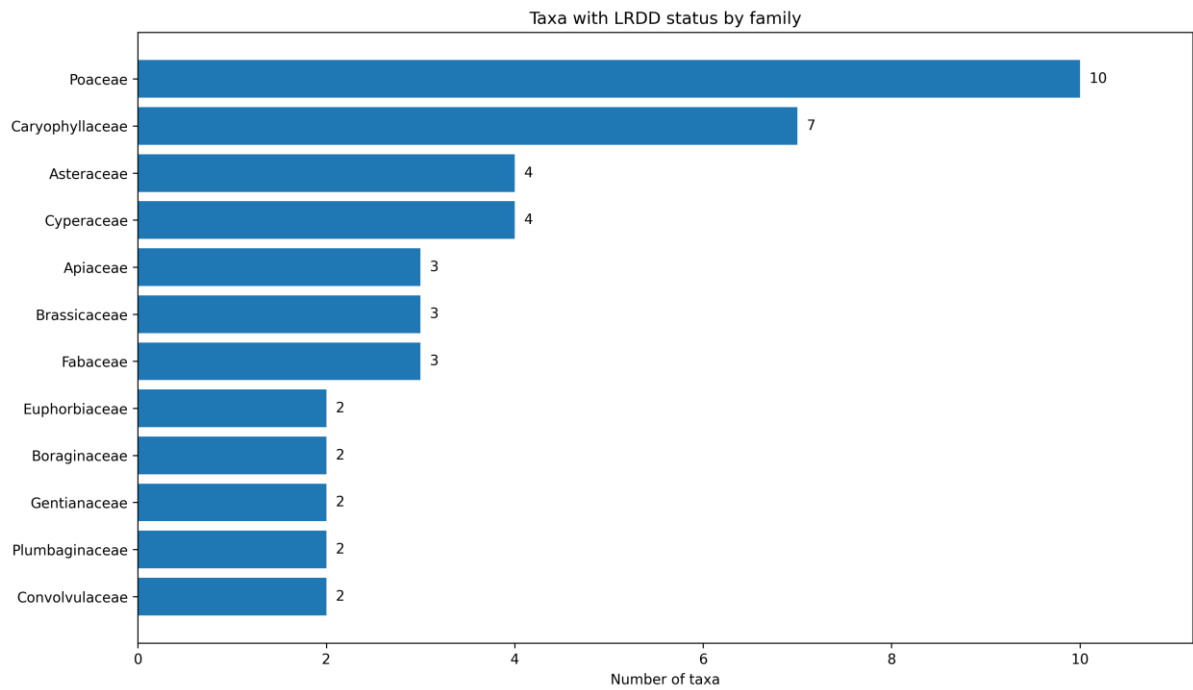


Figure 4. The number of Red List species by families within the coastal area

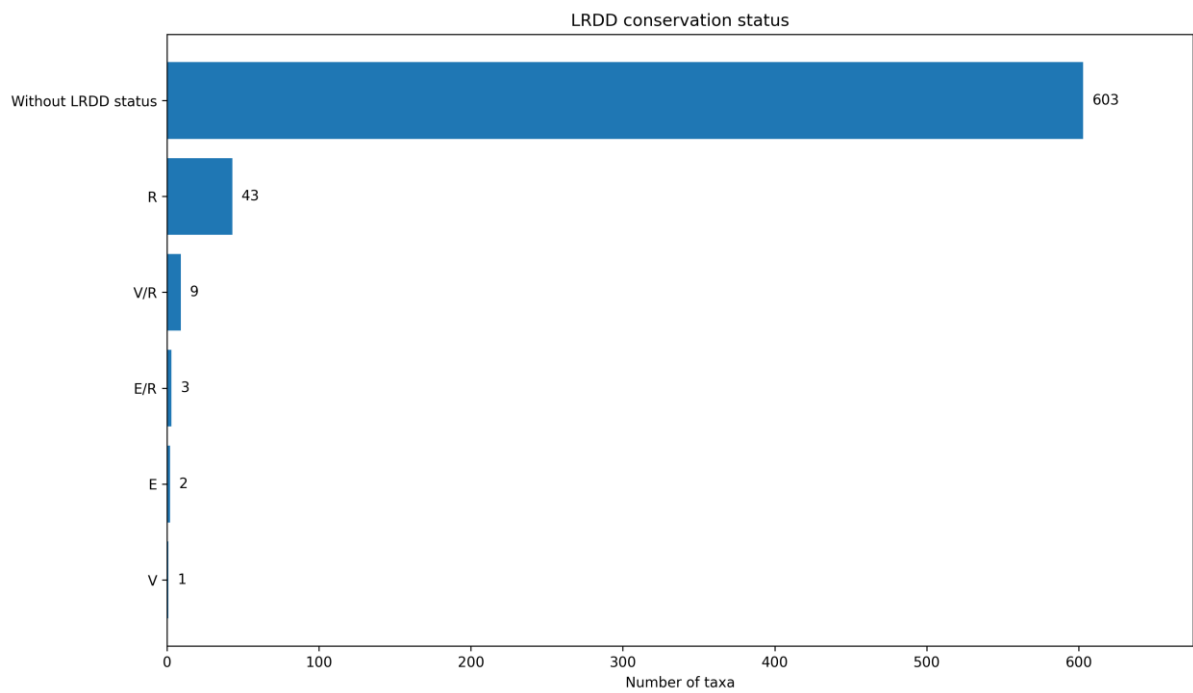


Figure 5. Red list conservation status within the coastal area

Table 3. Selected rare or conservation-relevant taxa of the DDBR coastal area.

Species	Ecological setting	Conservation significance	Main sensitivity
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<i>Alyssum borzaeanum</i>	Dry sandy coastal sites	Rare taxon of scientific value	Trampling, loss of open sand
<i>Argusia sibirica</i>	Beach and moist dune sands	Characteristic maritime species; sand-fixer	Beach alteration, tourist pressure
<i>Crambe maritima</i>	Natural beaches and dunes	Flagship coastal plant	Picking, waste and habitat degradation
<i>Centaurea pontica</i>	Pontic sandy habitats	Regional endemic/national phytogenetic value	Urbanisation, small populations
<i>Asparagus brachyphyllus</i>	Saline coastal habitats	Indicator of specialised salt-affected sites	Restricted habitat, salinity/hydrology change
<i>Convolvulus persicus</i>	Dry maritime sands and foredunes	Ponto-Caspian relict and sand-fixer	Ruderalisation, beach cleaning
<i>Dianthus bessarabicus</i>	Coastal sands and psammophilous grasslands	Subendemic / rare ornamental species	Tourism development, ruderalisation
<i>Eryngium maritimum</i>	Beach and dune edges	Typical dune plant with ornamental value	Urbanisation, trampling
<i>Stachys maritima</i>	Beaches and dunes	Rare sandy-habitat specialist	Very small populations, low dispersal
<i>Limonium bellidifolium</i>	Saline flats and depressions	Rare halophyte of scientific value	Reduction of salt-marsh biotopes
<i>Polygonum maritimum</i>	Upper beaches and maritime sands	Rare strandline and foredune specialist	Mechanical cleaning, trampling and habitat loss

Selected species accounts

The Romanian notes inserted in the working manuscript have been reorganised below as concise English species accounts. They keep the main information on conservation status, chorology, confirmed localities, habitat, ecology, limiting factors and recommended management, while avoiding the repetition of raw report-style text.

Alyssum borzaeanum

Alyssum borzaeanum is a rare psammophilous taxon of the Romanian Black Sea coast, associated mainly with open, dry or weakly stabilised sandy habitats. Within the DDBR coastal mosaic, it is relevant because it occupies early and semi-stabilised dune stages where vegetation cover remains discontinuous and natural sand movement is still active. The species may occur together with other dry-sand and dune plants, including *Convolvulus persicus*, *Centaurea arenaria* subsp. *borysthena*, *Euphorbia seguieriana*, *Secale sylvestre* and *Silene conica*. Its conservation value is primarily scientific, reflecting rarity, habitat specialisation and the vulnerability of open sandy microhabitats. The main pressures are trampling, vehicle access, mechanical beach cleaning, loss of open sand and ruderalisation of foredunes. Management should maintain known populations in situ, avoid unnecessary stabilisation or levelling of sandy surfaces, and include the species in periodic coastal-plant monitoring (Oltean et al. 1994; Dihoru and Negrean 2009; Ciocârlan 2011; Strat 2016).



Figure 6. *Alyssum borzaeanum* on coastal sands of the DDBR: a) habitus; b) flower detail; c) distribution points mentioned in the project dataset.

Crambe maritima

Crambe maritima is a characteristic maritime species of natural beaches, upper shore zones and dune margins, with high value as a flagship plant for coastal conservation and public interpretation. In the DDBR coastal area it indicates sectors where natural beach processes, drift material and relatively low mechanical disturbance still allow strandline and pioneer vegetation to develop. It may occur in contact with other beach and foredune species, including *Eryngium maritimum*, *Stachys maritima*, *Polygonum maritimum* and *Ammophila arenaria* subsp. *arundinacea*. The species is sensitive to picking, waste accumulation, intensive recreation, beach levelling and mechanical cleaning, all of which can remove seedlings or reduce the natural substrate heterogeneity needed for establishment. Conservation measures should prioritise selective cleaning in sensitive sectors, visitor guidance, and protection of upper-beach vegetation patches from trampling and vehicles (Petrescu 2007; Dihoru and Negrean 2009; Făgăraș et al. 2010; Strat 2016).



Figure 7. *Crambe maritima* on natural beaches of the DDBR coastal area: a) habitus; b) flower detail; c) distribution points mentioned in the project dataset.

Polygonum maritimum

Polygonum maritimum is a rare strandline and foredune species linked to natural upper beaches and maritime sands. In the project synthesis it is important because it helps characterise the transition between open beach vegetation and embryonic dune communities, where small changes in disturbance, sand mobility and drift-line material can strongly influence plant persistence. It occurs in the same broad ecological setting as *Crambe maritima*, *Eryngium maritimum*, *Stachys maritima* and *Asparagus brachyphyllus*, and it contributes to the conservation value of relatively undisturbed beach-dune interfaces. The species is especially sensitive to mechanical beach cleaning, trampling, vehicle circulation and removal of natural debris. The recommended measures are to avoid intensive cleaning in sectors with natural strandline vegetation, maintain undisturbed upper-beach strips, and include the

species in rare-plant monitoring routes (Burduja 1954; Popescu and Sanda 1976; Dihoru and Negrean 2009; Strat 2016).

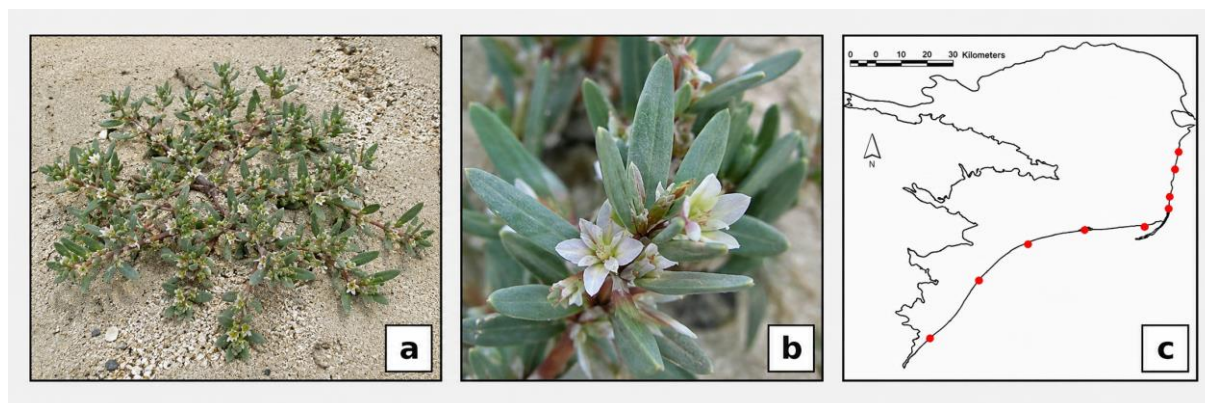


Figure 8. *Polygonum maritimum* on upper beaches and maritime sands of the DDBR coastal area: a) habitus; b) flower detail; c) distribution points mentioned in the project dataset.

Argusia sibirica

Argusia sibirica (L.) Dandy is a characteristic maritime species of high conservation value, considered critically endangered in the Romanian Red Book and rare in older floristic sources. It was known from the Black Sea coast at Sulina, Sfântu Gheorghe, Ciotic, Portița, Sacalin Island, Letea and Grindul Lupilor, and the project dataset confirmed it in all these areas, as well as on Musura Island and between Perișor and Periteașca. The species is linked to the Black Sea coast, central Russia, northern Anatolia and a broader Eurasian range extending eastwards to Japan (Panțu et al. 1936; Dihoru and Negrean 1976b; Ciocârlan 2011). Ecologically, it behaves as a perennial heliophilous plant in moderately moist, neutral, nutrient-poor sandy soils. It has strong affinities for moist and slightly saline substrates, occurring in arenicolous communities with *Bassia sedoides*, *Chenopodium glaucum*, *Eryngium maritimum*, *Lactuca tatarica*, *Salicornia europaea*, *Scolymus hispanicus* and *Suaeda maritima*, and locally in dune vegetation with *Centaurea arenaria* subsp. *borysthena*, *Euphorbia seguieriana*, *Gypsophila perfoliata*, *Leymus racemosus* subsp. *sabulosus*, *Secale sylvestre* and *Silene conica*. The field notes characterise it as perennial, amphimictic, barochorous, hydrochorous, and entomophilous, with flowers from May to August. Its conservation value is related to sand fixation, fragrant flowers, melliferous potential and its occurrence in ecologically sensitive coastal areas. Limiting factors include its position at the western edge of the range, mechanical beach cleaning, intense tourism, sand compaction and destruction of young plants. In situ conservation should focus on protecting and clearly marking the sites where the species occurs, especially near tourist facilities.



Figure 9. *Argusia sibirica* on the Black Sea coast at Sfântu Gheorghe: a) habitus; b) flower detail; c) distribution points mentioned in the project dataset.

Centaurea pontica

Centaurea pontica Prodan & Nyár. is one of the most important endemic elements of the Romanian coastal flora. The project notes treat it as endangered or threatened in several conservation systems. Its distribution is limited to south-eastern Romania, with records in the DDBR from Sulina and Ciotic, south of Sfântu Gheorghe. The field observations confirmed the presence of the species in the Sulina urban area, particularly near the basin and the belt-channel bridge. In contrast, at Ciotic, renewed field verification is required. This taxon represents a Dobrogean coastal endemic and a component of Romania's specific phytogenetic heritage (Prodan 1935; Dihoru and Pârvu 1987; Dihoru and Negrean 2009). It grows on maritime sands, often ruderalised and sometimes nearly bare, within the broader vegetation of the coastal belt, including *Cakiletea maritimae* and psammophilous communities such as *Cynodontetum dactyli*, *Lactuco tataricae-Glaucietum flavae* and *Argusio sibiricae-Petasitetum spuriae*. In the project dataset, it is described as a biennial species, amphimictic, entomophilous and barochorous-anemochorous, flowering from July to November. Its conservation value is both scientific and educational, while its ornamental and melliferous qualities can support public interpretation. Main threats include urban expansion in Sulina, unmanaged tourism, a lack of local awareness, and a very small population. Recommended measures include seed collection, experimental ex situ cultivation, regular monitoring, and reinforcement or introduction at ecologically similar sites where scientifically justified.



Figure 10. *Centaurea pontica* recorded at Sulina: a) habitus; b) flower detail; c) distribution points mentioned in the project dataset.

Asparagus brachyphyllus

Asparagus brachyphyllus Turcz. is a rare coastal plant associated with saline and moist maritime sands. It is treated as critically endangered in the Romanian Red Book and as rare in older floristic sources. Earlier records mention Istria and Grindul Chituc; however, the project observations did not reconfirm their presence at these historical sites. Instead, a few individuals were identified in the Periteașca-Perișor sector, making this one of the most important field confirmations in the dataset. Biogeographically, the species has a range from south-eastern Romania towards Kazakhstan and may be interpreted as a Dobrogean-Pontic-Caspian coastal element (Ciocârlan 1994; Dihoru and Negrean 2009; Sârbu et al. 2013). The species is heliophilous and thermophilous, occurring on moderately moist, neutral and nutrient-poor soils, especially on more or less saline maritime sands. It may occur with *Euphorbia peplis*, *Lolium loliaceum* and *Polygonum maritimum*, and also in salt-affected vegetation with *Aeluropus littoralis*, *Aster tripolium*, *Juncus gerardi*, *Juncus littoralis*, *Phragmites australis*, *Puccinellia gigantea* and *Scirpus maritimus*. The project field scores indicate low abundance and moderate cover, and the species is described as a perennial, amphimictic, entomophilous and anemochorous plant, flowering from July to August. Its conservation value is mainly scientific, due to rarity and the restricted habitat. Limiting factors include the narrow habitat range and birds' consumption of fruit. The most viable conservation option is to combine strict protection of existing sites with seed

collection, ex situ cultivation in botanical gardens and carefully planned reintroduction into ecologically similar habitats.



Figure 11. *Asparagus brachyphyllus* at Periteașca: a) habitat / habitus; b) detail; c) distribution point in the project dataset.

Convolvulus persicus

Convolvulus persicus L. is a critically endangered Ponto-Caspian coastal plant and one of the most significant psammophilous species of the Romanian Black Sea coast. Historical and regional sources mention it from Sfântu Gheorghe, Mila 23, Sulina, C.A. Rosetti, Letea, Caraorman, Cardon, Sfiștofca, Perișor and Portița. The project dataset confirmed it at Sfântu Gheorghe, Sulina, north of Sfântu Gheorghe, Perișor and Sacalin Island. The notes indicate that one monitored site had already lost the species, that Perișor hosted only a few individuals, and that Sacalin supported numerous individuals on compact surfaces. This confirms the highly uneven and vulnerable distribution of the species along the DDBR coast (Panțu et al. 1936; Prodan 1935; Dihoru and Negrean 1976b; Strat 2016). Ecologically, it is a psammophilous, xeromesophilous, thermophilous and heliophilous species of dry, neutral and nutrient-poor sands. It co-occurs with *Alyssum borzaeanum*, *Bromus tectorum*, *Centaurea arenaria* subsp. *borysthena*, *Euphorbia seguieriana*, *Medicago falcata*, *Secale sylvestre* and other dry-sand species, and is connected with *Convolvuletum persici* and related dune communities. The field notes describe it as perennial, with both sexual and vegetative reproduction, flowering from June to July. Its conservation value is high: it is decorative, fixes sand and is interpreted as a Tertiary relict. Threats include its position at the western limit of the range, ruderalisation and mechanical beach cleaning. Conservation should focus on maintaining all current sites, avoiding disturbance of foredunes and repopulating or reinforcing existing populations where local decline is evident.

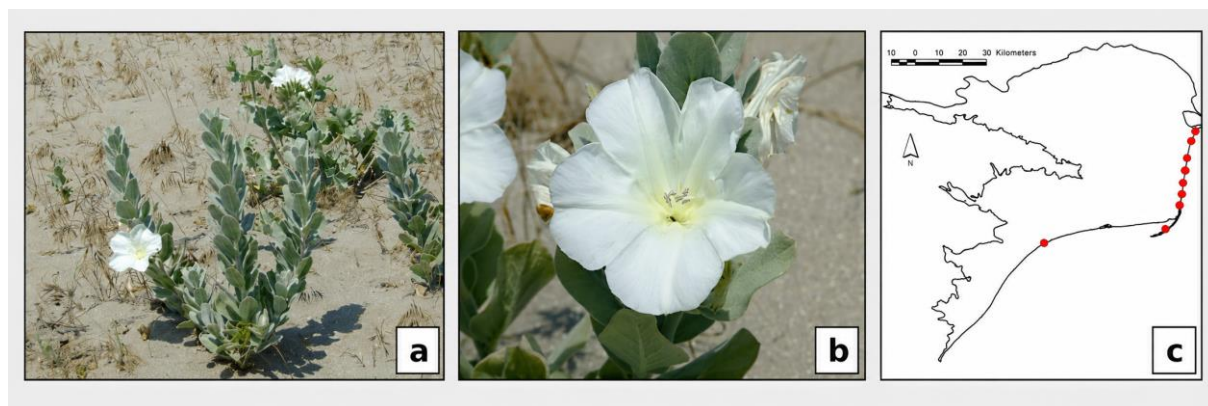


Figure 12. *Convolvulus persicus* north of Sfântu Gheorghe: a) habitus; b) flower detail; c) distribution points mentioned in the project dataset.

Dianthus bessarabicus

Dianthus bessarabicus (Kleopow) Klokov is a rare and subendemic psammophilous species of the coastal sands. The project notes indicate records from Perișor, Sulina, Sfântu Gheorghe, Grindul Sărăturile, Grindul Lupilor, Cardon, Sfiștofca, C.A. Rosetti, Periprava, Letea and Caraorman. Field confirmation was obtained in the Sfântu Gheorghe, Grindul Sărăturile, Perișor, Periteașca and Sulina sectors. The taxon is interpreted as a Geto-Dobrogean element and is treated as threatened or rare in regional conservation sources (Prodan 1935; Sârbu et al. 2000; Dihoru and Negrean 2009). It is a perennial, psammophilous, xeromesophilous and heliophilous species of nutrient-poor sandy soils. It frequently occurs with *Medicago marina*, *Polygonum maritimum*, *Artemisia tschernieviana*, *Silene thymifolia*, *Stachys maritima*, *Salsola kali*, *Alyssum desertorum*, *Apera spica-venti* subsp. *maritima*, *Astragalus varius*, *Bromus tectorum*, *Centaurea arenaria* subsp. *borysthenaica*, *Linaria genistifolia*, *Linum austriacum* and *Plantago arenaria*, within psammophilous communities such as *Aperetum maritimae* and *Festucetum arenicolae*. The species flowers from June to August and has scientific and ornamental value. The main limiting factors are tourism development and the ruderalisation of sandy vegetation. Because artificial population reinforcement may be difficult, the most important practical measure is to protect the beaches and dune sectors where the species still occurs.



Figure 13. *Dianthus bessarabicus* recorded at Perișor: a) habitus; b) flower detail; c) distribution points mentioned in the project dataset.

Eryngium maritimum

Eryngium maritimum L. is a typical coastal-dune species, considered vulnerable or rare in Romanian conservation sources. Bibliographic records mention Grindul Chituc, Sulina, Letea, Caraorman, Sfântu Gheorghe and Grindul Lupilor. The project dataset confirmed the species on the Sulina beach, where several tens of individuals were observed, but the population appeared to be in regression; it was also recorded in scattered populations at Sfântu Gheorghe, poorly represented populations on Grindul Lupilor, compact and numerous populations along the Sulina-Sfântu Gheorghe sector, and in the Periteașca-Perișor sector. Its broader geoelement is associated with the coastal sands of Europe up to approximately 60°N, including the shores of the Atlantic, Baltic, Mediterranean, Black Sea, and Caspian (Burduja 1954; Sârbu et al. 2000; Dihoru and Negrean 2009). The species grows on maritime dunes and in pioneer vegetation. It is a heliophilous perennial co-occurring with *Centaurea arenaria* subsp. *borysthenaica*, *Plantago arenaria*, *Secale sylvestre*, *Silene conica*, *Apera spica-venti* subsp. *maritima*, *Argusia sibirica*, *Artemisia tschernieviana*, *Bassia laniflora*, *Cakile maritima* subsp. *euxina*, *Euphorbia seguieriana*, *Festuca arenicola*, *Leymus racemosus* subsp. *sabulosus* and *Salsola kali* subsp. *ruthenica*. It flowers from June to September and has scientific, ornamental and medicinal value. Threats include anthropisation, urbanisation and insufficient attention to its protection. Conservation should maintain existing sites and may also use the species as an ornamental native plant in carefully managed beach facilities, avoiding extraction from natural populations.

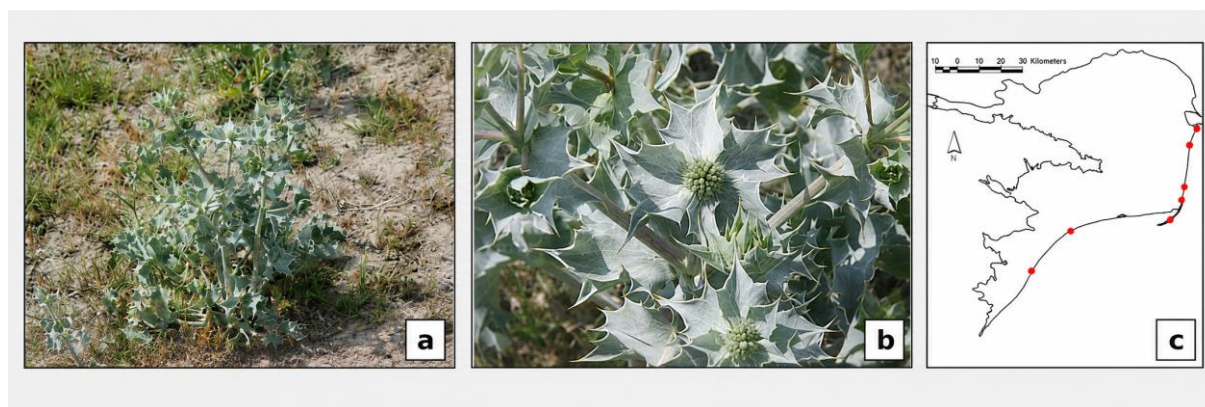


Figure 14. *Eryngium maritimum* on the beach at Sfântu Gheorghe: a) habitus; b) detail; c) distribution points mentioned in the project dataset.

Stachys maritima

Stachys maritima Gouan is one of the rarest sandy-habitat specialists recorded in the project dataset. It is treated as critically endangered in the Romanian Red Book and as rare in other floristic sources. In the studied sector it was found at Portița and Corbu, where the population is very small. Biogeographically, it is a Mediterranean-Black Sea coastal element. It grows on maritime sands together with *Asparagus brachyphyllus*, *Ammophila arenaria* subsp. *arundinacea*, *Astrodaucus littoralis*, *Crambe maritima*, *Eryngium maritimum*, *Medicago marina* and *Polygonum maritimum*, within *Elymion gigantei*-type dune vegetation. Its rarity and localised distribution have also been highlighted in studies of psammophilous vegetation and rare coastal plants (Burduja 1954; Popescu and Sanda 1976; Sârbu et al. 2000; Dihoru and Negrean 2009). The project notes describe it as a perennial, thermophilous and heliophilous plant of moderately moist, neutral and nutrient-poor sandy soils, flowering from May to June. Its main conservation value is scientific, due to rarity.



Figure 15. *Stachys maritima* on the beach at Portița: a) habitus; b) flower detail; c) distribution point in the project dataset.

The limiting factors are a narrow habitat niche and limited long-distance dispersal. The population is indirectly protected by the fence separating the Portița resort from the area where it grows. Still, the small number of individuals makes extracting biological material risky. Any ex situ or reinforcement programme should, where possible, rely on more robust populations outside the DDBR.

Limonium bellidifolium

Limonium bellidifolium (Gouan) Dumort. is a rare halophilous species, treated as critically endangered in the Romanian Red Book and as subendemic or rare in other conservation sources. The project notes mention bibliographic records from Letea, Sfiștofca, Grindul Saele, Grindul Lupilor and Caraorman. Field observations confirmed the presence of the species at Sfântu Gheorghe, Sacalin Island,

Grindul Lupilor, Sulina, and Grindul Sărăturile, usually in small numbers. Its distribution is associated with the Black Sea and Mediterranean coasts, southern Russia and eastern England, and it may be interpreted as an Atlantic-Mediterranean-Ponto-Caspian coastal element. Recent taxonomic and ecological discussions also treat Danube Delta populations under *Limonium bellidifolium* subsp. *danubiale* (Roman 1992; Ciocârlan et al. 2013; Drăgulescu 1998; Sârbu et al. 2000). The species is thermophilous and heliophilous, growing on moderately moist, neutral soils with moderate nitrogen content, especially in halophytic communities with *Aeluropus littoralis*, *Artemisia santonicum*, *Halocnemum strobilaceum*, *Halimione verrucifera*, *Salicornia europaea* and *Suaeda maritima*. It is linked to *Obionetum verruciferae*, *Salicornietum prostratae* and *Puccinellion limosae*-type vegetation. It flowers from July to August. Its conservation value is scientific, due to restricted range and rarity. Main limiting factors are the general reduction of suitable saline biotopes and the narrow ecological amplitude. Conservation should maintain current habitats under effective protection and consider replanting only in sites with clear potential for natural expansion.

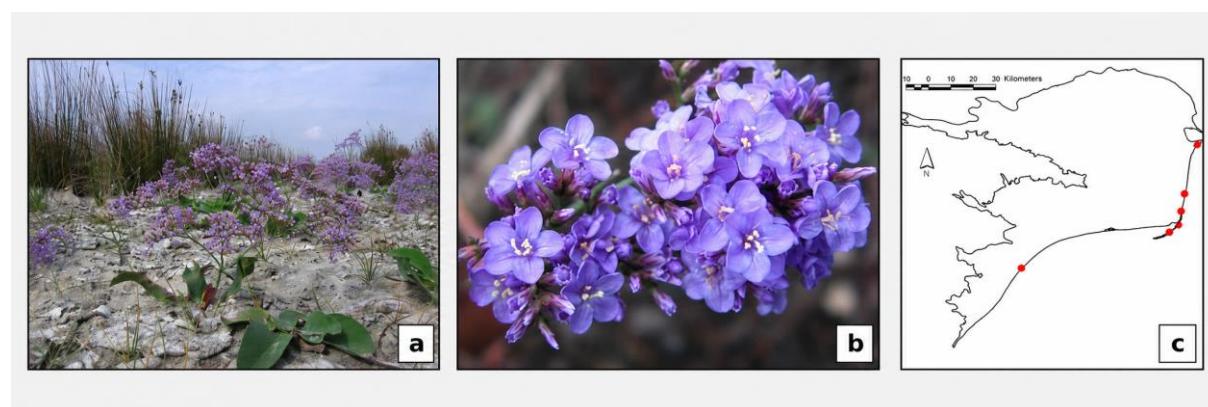


Figure 16. *Limonium bellidifolium* at Sfântu Gheorghe: a) habitat / habitus; b) flower detail; c) distribution points mentioned in the project dataset.

Pressures affecting coastal phytodiversity

The coastal area is naturally dynamic. Erosion, storm action, overwash, sediment redistribution, wind transport and temporal changes in humidity are part of the system's normal functioning. These processes create open habitats and maintain the early successional stages required by many coastal plants. Natural disturbance should therefore not be confused with degradation.

Anthropogenic pressure becomes problematic when it intensifies disturbance, simplifies microhabitats or prevents natural recovery. The project data identified several important pressures: uncontrolled tourism, dune circulation, vehicle access on sand, mechanical beach cleaning, grazing, trampling, waste deposition, ruderalisation, local infrastructure and habitat fragmentation. Similar pressures are discussed for Tulcea County habitats and for the coastal zone of the Danube Delta (Petrescu 2015; Strat 2016).

Mechanical beach cleaning is especially relevant because it can remove seedlings, seeds and organic material needed for the development of pioneer vegetation. While cleaning may be necessary in recreational sectors, it should be selective and should avoid natural beaches with rare species or embryonic dune vegetation.

Grazing also requires careful interpretation. Moderate grazing may keep some grassland habitats open, but excessive grazing leads to compaction, nutrient enrichment, ruderalisation and the loss of sensitive plants. Similarly, tourist access is not necessarily damaging when it is guided and concentrated on resistant routes, but becomes destructive when it spreads across dunes and rare-species microhabitats.

The most vulnerable situations occur where small, rare-plant populations coincide with accessible beaches, narrow dunes or fragmented habitats. In such cases, even an apparently minor local disturbance can produce disproportionate conservation effects.

Table 4. Main pressures and recommended management responses.

Pressure or process	Possible effect	Recommended response
Shoreline erosion and storms	Natural habitat turnover; local loss of populations	Monitor sensitive sectors; allow natural dynamics where possible
Mechanical beach cleaning	Removal of seedlings, seeds and drift material	Use selective/manual cleaning in conservation sectors
Tourist trampling	Damage to dunes and rare-plant microhabitats	Create guided paths and seasonal restrictions
Vehicle circulation	Compaction and destruction of dune microrelief	Strict prohibition and enforcement
Overgrazing	Ruderalisation, compaction and loss of specialists	Adaptive grazing limits and rotation
Waste deposition	Habitat degradation and visual impact	Improve collection, enforcement and public awareness
Habitat fragmentation	Isolation of small populations	Maintain habitat continuity and avoid new access corridors

Conservation and management priorities

The first management priority is periodic updating of the floristic and habitat inventory. The 2009-2018 project dataset provides an essential baseline, but coastal systems change quickly. Repeated mapping should focus on rare-species locations, embryonic dune sectors, saline depressions, wet interdunes and heavily visited beaches.

The second priority is microhabitat protection. Rare plants on the coastal area often depend on small, local conditions rather than on large, continuous habitat blocks. A small dune ridge, a moist hollow, a salt-affected patch or an undisturbed upper beach may be critical for a local population. Such places should be treated as functional micro-reserves in management practice.

The third priority is better visitor management. Natural beaches with vegetation may look less “clean” than mechanically maintained recreational beaches, but they are far more valuable ecologically. Information panels, guided routes and communication with local tourism operators can reduce accidental damage and increase appreciation for coastal plants.

The fourth priority is combining in situ and ex situ conservation. In situ measures include protecting known populations, avoiding destructive interventions and maintaining habitat processes. Ex situ measures may include seed collection, storage in germplasm banks and cultivation in botanical gardens, especially for taxa with very small or declining populations.

Finally, the coastal area should be interpreted as part of the natural heritage of both the Danube Delta and Dobrogea. This perspective is important because it links scientific information with regional identity, education and museum-based communication. The rare plants of the coastal area are not only botanical records; they are part of the cultural and natural image of the Danube Delta coast.

Conclusions

The coastal area of the Danube Delta Biosphere Reserve is a high-value phytodiversity corridor. The project dataset synthesised in this article recorded 661 vascular plant species, 47 plant associations and 58 taxa with Romanian Red List status, including 42 priority taxa selected for discussion. These values demonstrate the exceptional botanical importance of this narrow coastal system.

The main conservation value of the area lies in its habitat mosaic. Beaches, embryonic dunes, fixed dunes, wet interdunes, saline depressions, coastal grasslands and shrub communities provide complementary ecological niches. Rare species such as *Alyssum borzaeanum*, *Argusia sibirica*, *Crambe maritima*, *Centaurea pontica*, *Asparagus brachyphyllus*, *Convolvulus persicus*, *Dianthus bessarabicus*, *Eryngium maritimum*, *Limonium bellidifolium*, *Polygonum maritimum* and *Stachys maritima* depend on the persistence of these microhabitats.

The most important threats are not only large-scale changes such as erosion, but also repeated local pressures: mechanical cleaning, trampling, vehicles, uncontrolled tourism, overgrazing and habitat fragmentation. Because some rare species occur in small and vulnerable populations, local management decisions can have major consequences.

For future conservation, the priority should be an integrated and practical approach: updated mapping, monitoring of rare species, protection of microhabitats, differentiated management of beaches and dunes, regulation of grazing, public interpretation, and complementary in situ and ex situ measures. This article, therefore, presents the coastal area as a living natural archive of the Danube Delta, one that deserves continued scientific and educational attention.

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Conflicts of interest

The authors declare that they have no competing interests.

Data availability

The manuscript synthesises project-derived field data and information archived in project reports at the Danube Delta National Institute for Research and Development. The main data relevant to the article are summarised in the text, tables and figures.

Ethics statement

No ethical approval was required for this study because it is based on field observations of vascular plants, habitat records and literature-derived information.

Author contributions

Mihai Doroftei led the manuscript synthesis, ecological interpretation and writing. Silviu Covaliov contributed to spatial data processing, GIS interpretation and figure preparation. Simona Dumitrița Chirilă and Florentina Tudose contributed to floristic and ecological interpretation, data organisation, literature checking and manuscript revision. All authors reviewed and approved the final manuscript.

Declaration on the use of AI-assisted technologies

AI-assisted tools were used only for language polishing, editorial structuring and formatting support. The authors reviewed, corrected and approved all content and remain fully responsible for the scientific accuracy and integrity of the manuscript.

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