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SALTISH: The SALt-affected vegeTatIon dataset of Tuscany coaStal Habitats, central Italy*

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Abstract

Surveying vegetation is essential for documenting plant diversity, especially for coastal vegetation that results among the most threatened ecosystems globally. To support conservation and management programs, we developed the SALt-affected vegeTatIon dataset of Tuscany coaStal Habitats (SALTISH). This dataset comprises 734 newly sampled vegetation plots of 4 m^2 (2 m × 2 m) from the Tuscany region in central Italy, including 569 sand dune plots and 165 salt marsh plots, recorded between 2018 and 2023. In total, the dataset contains 4,541 occurrences of vascular plant taxa. Overall, it comprehends 257 vascular plant taxa belonging to 165 genera and 56 families. The Poaceae family is the most diverse, represented by 50 taxa, while the most represented genus is *Juncus*, with seven species. Species richness within individual plots ranges from one to 55 species, with 622 plots (84%) containing fewer than 10 species. *Juniperus macrocarpa* emerges as the most frequent and dominant species in the dataset. *Helichrysum stoechas*, *Festuca fasciculata*, and *Medicago littoralis* are present in over 20% of the plots, whereas 157 taxa are recorded in fewer than 1% of plots. The dataset includes noteworthy taxa: four Italian endemics (*Centaurea aplolepa* subsp. *subciliata*, *Limonium etruscum*, *L. multiforme*, and *Solidago virgaurea* subsp. *litoralis*), eight taxa listed as threatened in the Italian Red List, and 18 archaeophyte and neophyte alien species. SALTISH provides critical data for monitoring and conserving threatened coastal habitats in Tuscany. This resource will facilitate comparisons of biodiversity status and vegetation changes over time and will aid in identifying habitats harboring rare and endangered plant species.

Keywords

Coastal dunes, Italy, Tuscany, salt marshes, vegetation dataset, vegetation plot

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Introduction

Coastal habitats are increasingly threatened by global changes. These areas face direct and indirect impacts from sea-level rise (Jones et al. 2013), as well as anthropogenic activities such as coastal development, habitat degradation, and agricultural practices (Seitz et al. 2014; Gennai et al. 2022). Coastal sand dunes and salt marshes support numerous rare and endangered plant species (Acosta et al. 2009), and they serve as important nurseries for juvenile fish and invertebrates (Lefcheck et al. 2019). However, approximately 86% of European coastal habitats are at high or moderate risk from unsustainable coastal construction and development (Seitz et al. 2014). The 21% reduction in the quality of coastal dunes in Italy over the last 50 years affected negatively about half of the current area, and they can be categorised as vulnerable (Gigante et al. 2018; Sarmati et al. 2025). To address these threats, the EU Natura 2000 network of protected areas aims to conserve the most endangered species and habitats.

In recent decades, vegetation archives containing ecological plot data have significantly expanded. Advances in software and techniques for data storage and analysis have enabled researchers to create new vegetation databases and cover under-sampled regions (Hennekens and Schaminée 2001; Tichý 2002; Peterka et al. 2015; Marcenò and Jiménez-Alfaro 2017). Vegetation plot datasets are fundamental resources for vegetation syntheses (Bonari et al. 2021; Kavgacı et al. 2021; Jiroušek et al. 2022; Novák et al. 2023b; Peterka et al. 2023) and have proven invaluable for biodiversity and macroecology research (Wüest et al. 2020; Cai et al. 2023). The European Vegetation Archive (EVA; Chytrý et al. 2016) is the primary repository for vegetation data in Europe, containing many national and regional datasets. Nevertheless, efforts to survey under-sampled vegetation types, digitize data, and develop new datasets continue at various scales across Europe and other continents (Bonari et al. 2019; Gholizadeh et al. 2019; Alessi et al. 2022; Novák et al. 2023a; Bagella et al. 2024).

Italy has over 7,900 km of coastline, and the coastal habitats of the Tuscany region support a significant portion of the human population as well as numerous tourism-related activities (Cipriani et al. 2013; Cappucci et al. 2024). This long and accessible coastline has attracted botanists for decades. Although many vegetation plots from this part of the Mediterranean coast are available, they vary in size and do not adequately cover the inner zones of the coastal gradient (Prisco et al. 2012; Marcenò and Jiménez-Alfaro 2017; Alessi et al. 2022).

Coastal areas play a critical role in the provision of habitat for biodiversity, carbon sequestration, water supply, and enabling socio-economic activities (Everard et al. 2010; Ford et al. 2012). To ensure the preservation of these functions, it is crucial to create and maintain updated vegetation datasets. Such data help monitor the distribution of plant communities and habitats, as well as endangered and invasive alien plant species, track their invasiveness, and assess the potential transformations of vegetation types. In Tuscany, human pressure on these habitats has led to a steady reduction in their number and area since the early 20th century (Bertacchi et al. 2021).

Tuscany's coastal zone includes a variety of protected areas, such as regional parks, state nature reserves, and special areas for conservation. Generally, the southern part of the region is better preserved than the north, where human activities are more intensive (Ciccarelli et al. 2014). Nevertheless, recent studies have identified sites with high conservation value that remain unprotected (Pafumi et al. 2024).

The MONITORARE project (2017–2018) and the NATNET project (NATura Network Toscana 2019–2024) were launched to develop a dataset for monitoring and conserving plant and animal species and their habitats in the Tuscany region of central Italy. These initiatives, conducted in collaboration with the Tuscan Regional Administration and researchers from the Universities of Siena, Florence, and Pisa, aim to fill gaps in knowledge and improve conservation efforts (Gennai et al. 2022). This paper presents the structure and content of the SALt-affected vegeTatIon dataset of Tuscany coaStal Habitats (SALTISH), which contains recently collected vegetation plots as part of these projects.

Study area

The study area is about 450 km long and includes protected areas and unprotected regions throughout the coastline of Tuscany, central Italy. The map of the study area is shown in Suppl. material 1. The macrobioclimate of the area is Mediterranean with upper meso-mediterranean thermotype and ombrotype ranging from lower humid to upper dry in the North and South, respectively (Pesaresi et al. 2017). Geologically, Late Quaternary sands, pebbles, and muds cover most of the coastal areas in the Tuscany region. However, some small patches with ocean-derived sand rocks and other substrates exist in these areas (Carmignani et al. 2013).

Different habitat and vegetation types occur along the coastal areas of Tuscany. Following the sea-inland gradient, the annual vegetation of drift lines, stable coastal grasslands, coastal dune scrubs and woods, salt meadows and steppes, and heliophilous scrubs can be found in these areas (Bertacchi et al. 2021; Gennai et al. 2022; Pafumi et al. 2024).

Data collection and preparation

Following a stratified random sampling design and several field excursions to cover most parts of the region, all vegetation plots in our dataset were surveyed between April 2018 and October 2023 during the coastal vegetation season. Plot data were gathered with a positional accuracy ranging from 0 to 79 meters (mean = 4.7 meters) using a hand-held GPS unit in the field for the MONITORARE and NATNET projects. These projects focused

on habitat monitoring and developing a comprehensive vegetation dataset for various coastal ecosystems and habitats (Gennai et al. 2022). The dataset includes two main habitat types in coastal areas: 569 plots were sampled in sand dunes, while 165 plots were sampled in salt marshes.

To minimize the influence of plot size on species richness and other vegetation parameters, all plots were sampled within a standardized 4 m^2 area (2 m × 2 m) (Dengler et al. 2008; Acosta et al. 2009), which is also recommended in the Monitoring Manual of Italy for coastal areas (Angelini et al. 2016). Vascular plant taxa were recorded based on the percentage cover of each species within the plots.

Scientific plant names and taxonomical concepts were standardized following the Portal to the Flora of Italy (2024). Life forms, chorotypes, alien species categories, and conservation status for each taxon were assigned based on Pignatti et al. (2017–2019) and Orsenigo et al. (2018; 2020). To assess species dependency on salinity in both habitats, salinity relationships and salinity indicator values for taxa were extracted from the FloraVeg.EU database (Chytrý et al. 2024; FloraVeg 2024).

Furthermore, each plot's habitat type was classified according to the EUNIS habitat classification at level 3, applying the EUNIS Expert System (Chytrý et al. 2020), the 92/43/EEC habitat classification adapted for Italy (Biondi et al. 2009), and expert-based classification for the remaining 76 unclassified plots. The EUNIS classification was performed in R 4.3.2 (R Core Team 2023) using R code implemented by Bruelheide et al. (2021).

Structure and content of the dataset

The SALTISH dataset is based on the standard header data fields of TURBOVEG 2.166 (Hennekens and Schaminée 2001). It encompasses 28 data fields, including elevation, geographic coordinates, slope, and aspect as topographic variables, the percentage cover of total vegetation, tree, shrub, and herb layers, and other plot-level information, including the protection status (Suppl. material 2). The dataset includes 734 georeferenced vegetation plots, including 257 vascular plant taxa with 4,541 occurrence data.

The species richness of plots varies between one and 55, with 622 (85%) plots having less than 10 species and three plots having 20 or more taxa. The average species richness per plot in sand dunes and salt marshes is 6.9 and 3.8, respectively (Fig. 1A).

A total of 257 vascular plant taxa belonging to 165 genera and 56 families were identified. Among these, 53 families belong to the Angiosperms, two families (Cupressaceae with four taxa and Pinaceae with two taxa) are Gymnosperms, and one family (Equisetaceae, represented by a single species found exclusively in sand dunes) is a fern. While 219 taxa of 53 families were recorded in sand dunes, only 72 taxa of 22 families were found in salt marshes. Poaceae is the largest family in both habitats with 37 taxa in sand dunes and 25 taxa in salt marshes. Asteraceae and Amaranthaceae are the second-largest families in sand dunes and salt marshes, respectively. Fabaceae, the third-largest family with 19 taxa in sand dunes, has no species in salt marshes (Fig. 1B).

Juncus with seven taxa is the most diverse genus in the dataset. However, the most abundant genera are different in sand dunes and salt marshes. *Juncus* with six taxa in sand dunes and *Sporobolus* with four taxa in salt marshes are the most abundant genera. *Medicago* and *Trifolium*, with six and five taxa respectively, are other abundant genera in sand dunes, and they are missing in salt marshes. However, *Euphorbia* with six taxa is one of the second-abundant genera in the dataset with almost similar abundance in sand dunes and salt marshes (Fig. 1C).

The dominant life forms are Therophytes (40%) and Hemicryptophytes (27%) in sand dunes and conversely Hemicryptophytes (37%) and Therophytes (31%) in salt marshes. Geophytes and Phanerophytes are the less frequent life forms in these habitats, respectively. However, Phanerophytes with 16% have a relatively good proportion of life forms in sand dunes (Fig. 1D).

The phytogeographical distribution of taxa shows Mediterranean (44%) and Eurasian (18%) elements are the most common chorotypes in the dataset, as well as in sand dunes and salt marshes, separately (Fig. 1E). Moreover, the dataset contains four Italian endemics (*Centaurea aplolepa* subsp. *subciliata*, *Limonium etruscum*, *L. multiforme*, and *Solidago virgaurea* subsp. *litoralis*), and a total of eight threatened taxa of Italian Red List (Table 1).

Table 1. The endemic and threatened taxa and their categories from the Italian Red List (Orsenigo et al. 2018, 2020), as well as their distribution and frequency in each habitat. Plant taxa were ordered alphabetically according to chorotype (Pignatti et al. 2017–2019). SD: sand dunes; SM: salt marshes.

Plant taxa	Chorotype	IUCN threat category	Distribution (Species frequency)
Centaurea aplolepa subsp. *subciliata*	Endemic	Endangered (EN)	SD (4)
Limonium etruscum	Endemic	Critically Endangered (CR)	SM (9)
Limonium multiforme	Endemic	Vulnerable (VU)	SD (1), SM (1)
Solidago virgaurea subsp. *litoralis*	Endemic	Endangered (EN)	SD (5)
Chamaerops humilis subsp. *humilis*	Mediterranean	Near Threatened (NT)	SD (2)
Euphorbia barrelieri	Mediterranean	Endangered (EN)	SD (1)
Triglochin barrelieri	Mediterranean	Endangered (EN)	SM (4)
Samolus valerandi	Wide distribution	Least Concern (LC)	SD (1)

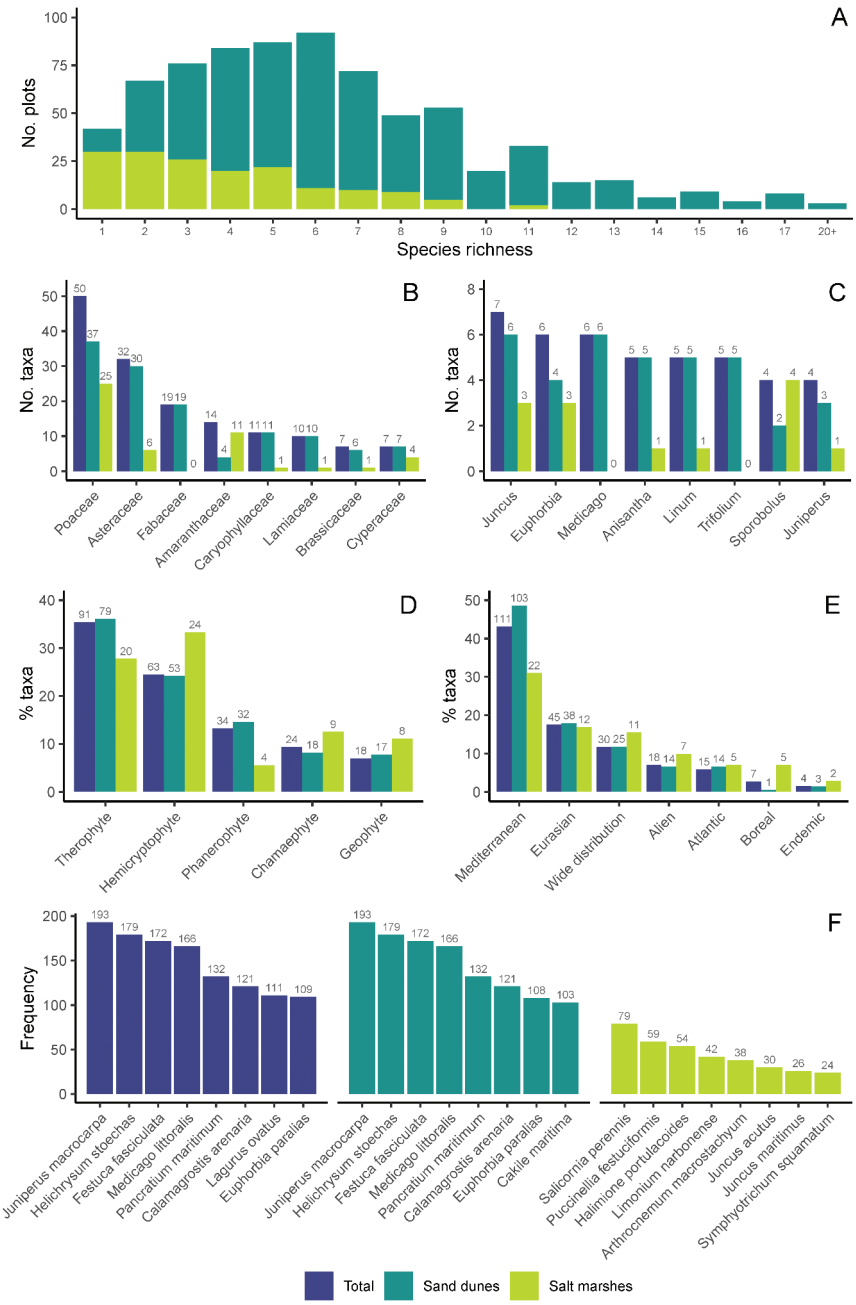

Figure 1. Species richness per plot (**A**), the contribution of the eight most frequent families (**B**), the eight most abundant genera (**C**), the proportion of different life forms (**D**), chorological spectrum (**E**), and the eight most frequent taxa (**F**). The subspecies designations for *Cakile maritima* subsp. *maritima* and *Calamagrostis arenaria* subsp. *arundinacea* are not reported in the figure for graphical reasons.

There are also 18 archaeophyte and neophyte alien species that are categorised as invasive and naturalised in Italy (Table 2).

The most frequent taxa (present in at least 30% of plots) including *Juniperus macrocarpa*, *Helichrysum stoechas*, and *Festuca fasciculata* in sand dunes, and *Salicornia perennis*, *Puccinellia festuciformis*, and *Halimione portulacoides* in salt marshes only have been recorded in one habitat (Fig. 1F). Moreover, the five most dominant taxa in the dataset containing *J. macrocarpa* and *Calamagrostis arenaria* subsp. *arundinacea* in sand dunes, and *S. perennis*, *Arthrocnemum macrostachyum*, and *H. portulacoides* in salt marshes were distributed only in one of them.

According to salinity relationship classification, plants adapted to growing in non-saline areas are the most common in both habitats. However, approximately 60% of the taxa in salt marshes are classified as those adapted to saline and slightly saline or brackish areas. On the other hand, for 12 taxa in our dataset, salinity indicator values are recorded as seven or more, and most of these are present only in salt marshes. Among these species with a high tolerance to salinity, four species including *Limonium multiforme*, *L. narbonense*, *Galatella tripolium* (one occurrence), and *Sporobolus pungens* (63 occurrences) are recorded in sand dunes (Fig. 2A, B).

Table 2. The alien taxa and their associated status (Portal to the Flora of Italy 2024) in Italy and Tuscany, as well as their distribution and frequency in each habitat. Plant taxa were ordered alphabetically. SD: sand dunes; SM: salt marshes.

Plant taxa	Alien species status (in Italy / Tuscany)	Distribution (Species frequency)
Ambrosia psilostachya	Neophyte species (Invasive / Naturalized)	SD (12)
Arundo donax	Archaeophyte species (Invasive / Invasive)	SD (1)
Avena fatua	Archaeophyte species (Naturalized / Alien)	SD (1)
Avena sterilis	Archaeophyte species (Naturalized / Naturalized)	SD (9)
Crepis sancta subsp. *nemausensis*	Neophyte species (Invasive / Invasive)	SD (1)
Erigeron canadensis	Neophyte species (Invasive / Invasive)	SD (9), SM (3)
Erigeron sumatrensis	Neophyte species (Invasive / Invasive)	SD (2)
Euphorbia serpens subsp. *serpens*	Neophyte species (Naturalized / Naturalized)	SM (5)
Oxalis stricta	Neophyte species (Invasive / Casual)	SM (1)
Paspalum vaginatum	Neophyte species (Naturalized / Naturalized)	SD (1)
Phalaris canariensis	Neophyte species (Invasive / Naturalized)	SD (1)
Pinus pinea	Archaeophyte species (Naturalized / Naturalized)	SD (11)
Pittosporum tobira	Neophyte species (Naturalized / Naturalized)	SD (3)
Sporobolus indicus	Neophyte species (Naturalized / Naturalized)	SM (1)
Sporobolus pumilus	Neophyte species (Invasive / Invasive)	SD (12), SM (1)
Symphyotrichum squamatum	Neophyte species (Invasive / Invasive)	SM (24)
Xanthium orientale	Neophyte species (Invasive / Invasive)	SD (61), SM (3)
Yucca gloriosa	Neophyte species (Invasive / Invasive)	SD (5)

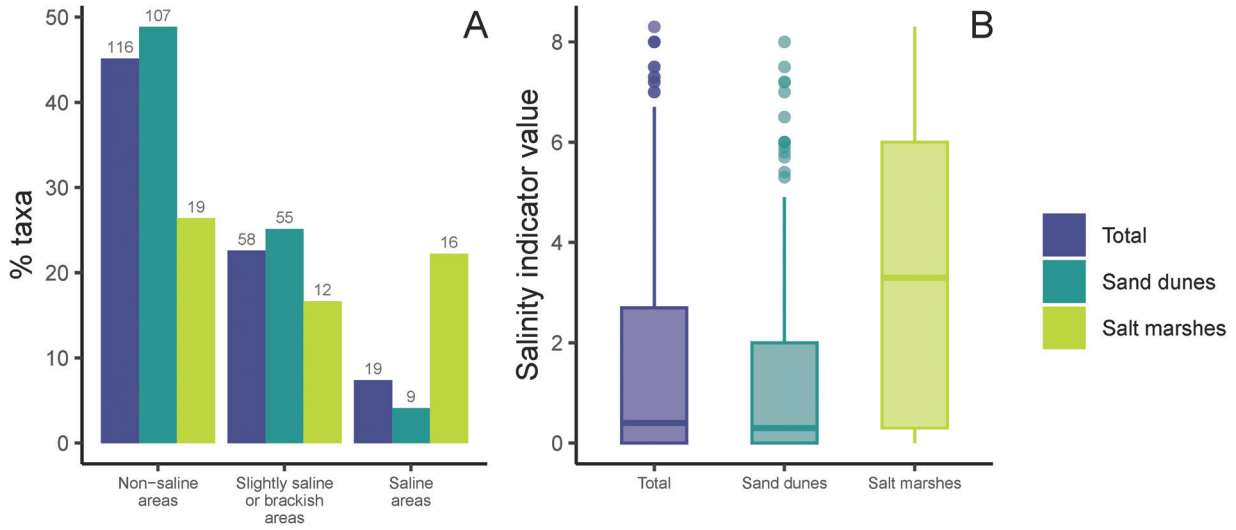

Figure 2. Salinity dependency status of plant taxa: **A)** Occurrence in different areas (64 taxa missed information), **B)** Salinity indicator value (40 taxa missed information).

The vegetation plots are mainly included in protected areas (549 protected *vs* 185 non-protected plots). Those protected areas are distributed across different designation types of protected areas. Specifically, five designation types are present in the study area: Special Protection Area, Special Area for Conservation, State Nature Reserve, Regional Nature Reserve, and Regional Park. Moreover, 482 plots of 549 plots in protected areas, are protected by two (81 plots), three (398 plots), or four (3 plots) types of protection (Fig. 3).

The classification of habitat types for each vegetation plot identified 14 92/43/EEC habitat types and seven EUNIS habitat types. 370 plots classified under 92/43/EEC codes were sampled from areas designated as Special Protection Areas, Special Areas for Conservation, or both. However, 27.4% of the plots could not be classified into any 92/43/EEC habitat type, and 3% could not be assigned to any EUNIS habitat type (Table 3).

Table 3. Classification of the vegetation plots according to 92/43/EEC and EUNIS habitat typologies. Habitats are sorted by decreasing the number of assigned vegetation plots.

	92/43/EEC	No. plots (%)	EUNIS	No. plots (%)
Sand dunes	2250	135 (18.4)	N16	319 (43.5)
	2110	79 (10.8)	N14	109 (14.9)
	2120	67 (9.1)	N1B	64 (8.7)
	2210	38 (5.2)	N12	48 (6.5)
	1210	21 (2.9)	N1J	7 (1)
	2230	13 (1.8)	N1G	6 (0.8)
	2260	12 (1.6)	MA25	4 (0.5)
	2270	8 (1.1)	Not-classified	12 (1.6)
	Not-classified	196 (26.7)		
Salt marshes	1420	88 (12)	MA25	147 (20)
	1410	52 (7.1)	N1J	8 (1.1)
	1310	8 (1.1)	Not-classified	10 (1.4)
	6420	6 (0.8)		
	1510	6 (0.8)		
	Not-classified	5 (0.7)		

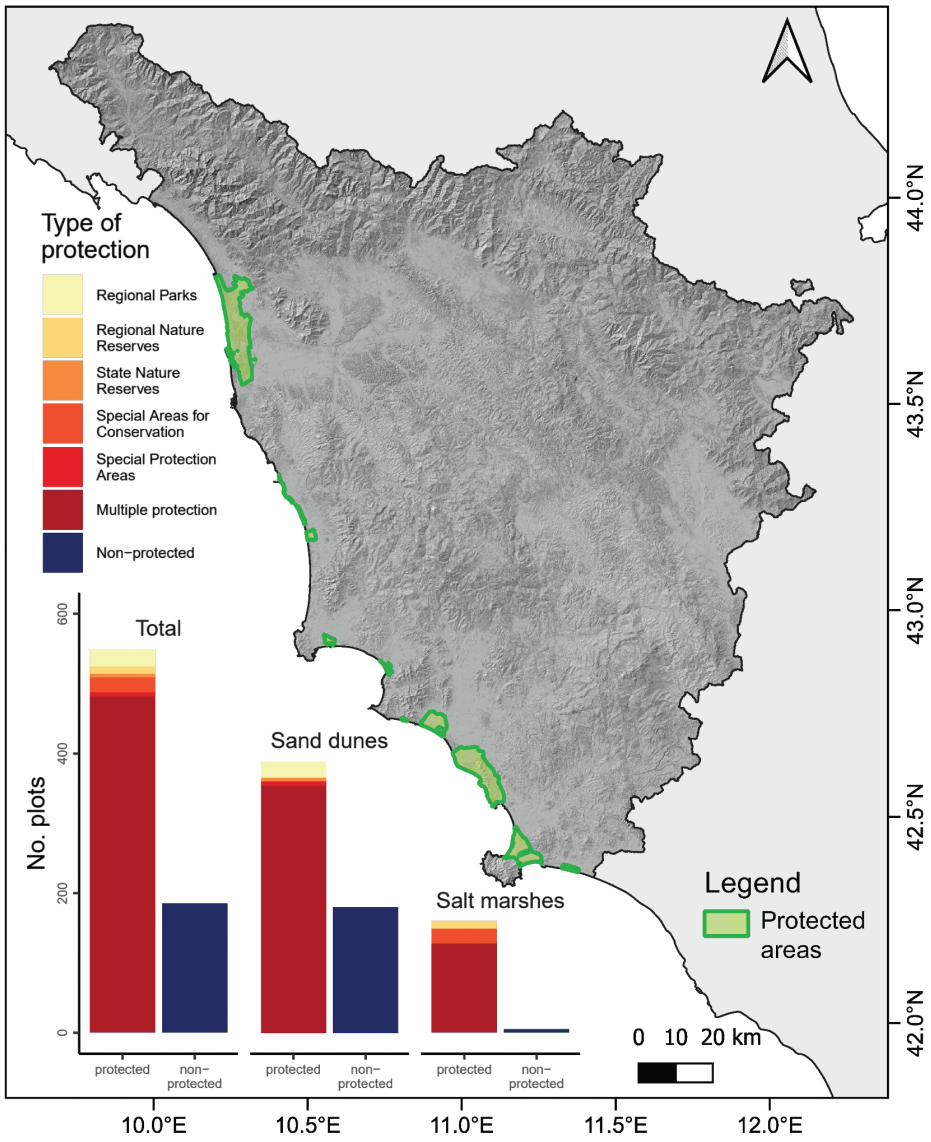

Figure 3. Number of plots in protected and non-protected areas and types of protection. The protected areas are shown on the map.

Conclusions

The information present in the SALTISH dataset strengthens the knowledge of habitat diversity in the Tuscany coastal habitats. This dataset, which compiles comprehensive data on plant species, community composition, and habitat types, is crucial for understanding the diverse ecosystems that characterize Tuscany region's coasts. It also helps defining all vegetation units of Tuscany's sand dunes and salt marshes. It can be used to document changes over time and monitor shifts in vegetation patterns, which can be influenced by factors such as climate change, human activity, and invasive species. Moreover, the SALTISH dataset facilitates biodiversity assessments and helps identify areas of ecological importance that require conservation efforts. Additionally, this dataset serves as a reference for conservation programs of threatened coastal habitats in central Italy. It can support decisions regarding land use, coastal protection, and the restoration of degraded areas. It also provides a basis for future studies on the effects of environmental stressors on plant communities and their resilience. In conclusion, the SALTISH dataset is not only an essential resource for scientific research but also an effective tool for promoting nature conservation. However, data collection and storage in SALTISH is still ongoing process. Future efforts should be directed towards rush communities to assess the entire sea-inland gradient fully.

Data availability

Data will be available by contacting the authors.

Author contributions

HG led the writing with contributions from GB, EP, CA, and SM. The data was collected by AB, CA, PC, DC, LDD, GF, SS, BF, TF, MM, and DV. TF, BF, SS, and EF identified plants in the lab. HG and EP did the analysis. HG, MG, BF, SS, and TF prepared the dataset. TF classified plots remained unclassified. EP prepared the figures. CA and

SM provided funding. All authors reviewed and approved the manuscript before submission.

Competing interest

The authors have declared that no competing interests exist.

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Supplementary material 1

Location of the 734 vegetation plots along the Tuscan coast (central Italy)

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Data type: docx

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Supplementary material 2

Data stored in the SALTISH dataset

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