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Authors: Spanou, Sofia, Verroios, Georgios, Dimitrellos, Georgios, Tiniakou, Argyro, and Georgiadis, Theodoros

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SOFIA SPANOU, GEORGIOS VERROIOS, GEORGIOS DIMITRELLOS, ARGYRO TINIAKOU & THEODOROS GEORGIADIS

Notes on flora and vegetation of the sand dunes of western Greece

Abstract

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For twenty coastal dune sites in Epirus, Sterea Ellada, Peloponnesos and the Ionian islands Paxi, Antipaxi, Kerkyra, Zakynthos and Lefkada, a flora list of 182 taxa, including two Greek endemics is presented. Characteristics and conservational aspects of the vegetation are discussed.

Key words: flora, psammophytes, vegetation, life forms, conservation.

Introduction

Sand dunes are one of nature's most dynamic and intriguing phenomena. They are found in most climates of the world, usually at the sea or in arid regions (deserts). Coastal dunes are created by the action of sea and wind. Material carried by rivers is deposited through the interaction of coastal currents, waves and wind along the coastline, forming dunes. Grains of sand between 0.062 and 2 mm in diameter are not cohesive and easily transported by wind. Finer grains of silt and clay (< 0.050 mm) are cohesive and resist wind erosion, and larger grains are too heavy. This property of sand explains why dune sand is composed predominantly of particles between 0.125-0.250 mm (Tsoar 2003). The main factors influencing dune morphology are velocity of onshore winds and grain size distribution of the available sediments.

Coastal sand dunes protect the land by acting as natural barriers to salt water intrusion and aeolian erosion. The sandy coast between shoreline and dunes absorbs wave energy and without this protection unconsolidated sediments would be eroded rapidly. Even small disruptions in the dune system can cause salt-water intrusion into the groundwater, thus threatening local irrigated agriculture. The dunes are home to a multitude of species, in both flora and fauna. Their importance has been acknowledged in recent years and they are now priority habitats for conservation

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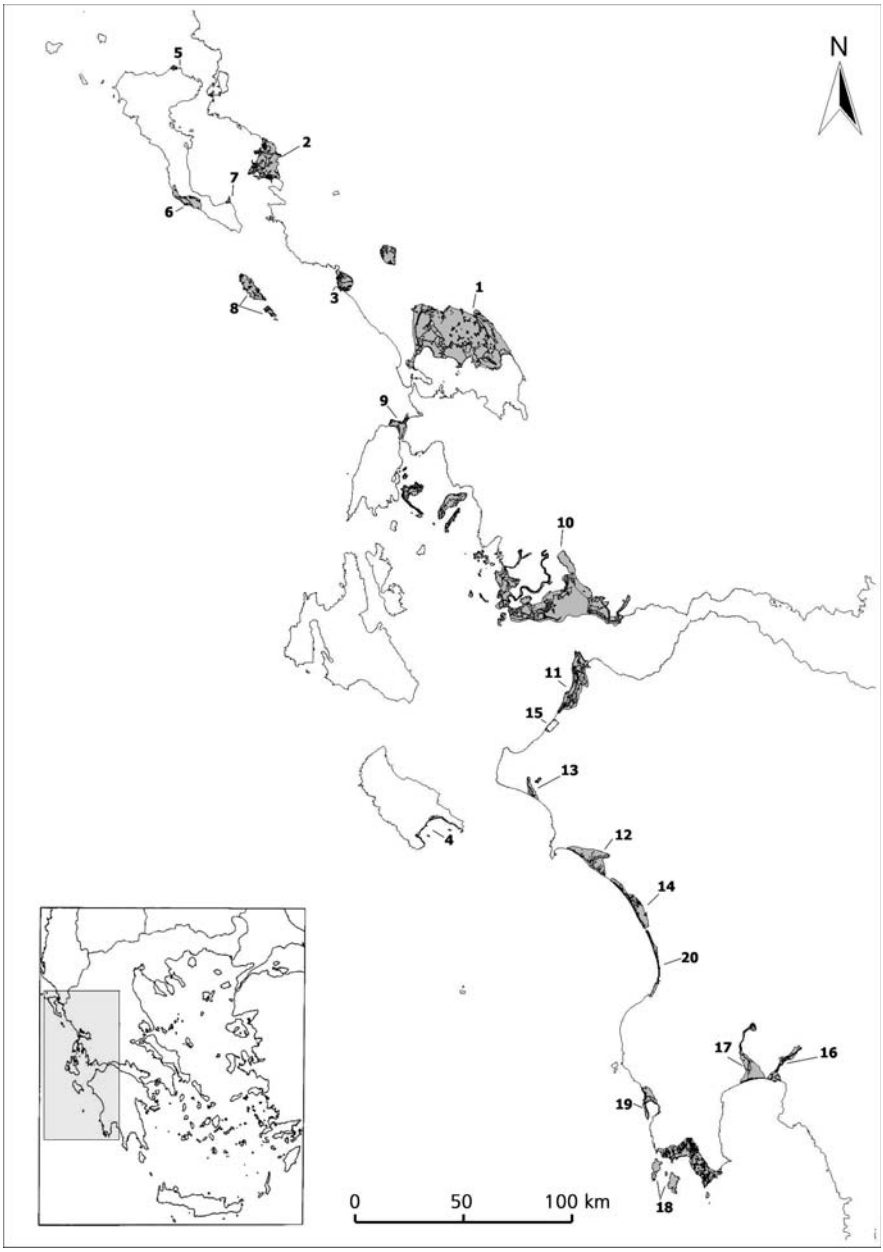


Fig. 1: The study sites. 1: Amvrakikos Kolpos, Delta Lourou and Aracthou; 2: Ekvoles (Delta) Kalama; 3: Ekvoles Acheronta (and Stena Acheronta); 4: Kolpos Lagana Zakinthou, islands Marathonisi and Pelouzo; 5: Limnothalassa Antinioti (Kerkira); 6: Limnothalassa Korission (Kerkira); 7: Aliki Lefkimis (Kerkira); 8: islands Paxi and Antipaxi; 9: Limnothalasses Stenon Lefkadas and Alikes Lefkadas; 10: Delta Acheloou, Limnothalassa Mesolongiou-Aitolikou and Ekvoles Evinou; 11: Limnothalassa Kalogrias, Dasos Strofilias and Elos Lamias; 12: Ekvoles (Delta) Alfeiou; 13: Ekvoles (Delta) Pineiou; 14: Thines and Paraliako Dasos Zacharos, Limni Kaiafa; 15: Limnothalassa Kotichi; 16: Farangi and Ekvoles Nedona; 17: Piges and Ekvoles Pamisou; 18: islands Sapienza and Schiza, Akrotirio Akritas; 19: Limnothalassa Pilou (Divari) and Nisos Sfaktiria; 20: Thines Kiparissias.

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in the European Union. However, human activities such as sand extraction, trampling, vehicle driving (e.g. moto-cross) and uncontrolled use of surrounding public or private lands are inducing erosion at a large scale.

In spite of its small size, Greece has a long coastline. Sand dunes exist in many places along this coastline. On the coast of western Greece in particular rocky beaches and cliffs alternate with sandy beaches, providing a great variation in form, height and vegetation structure. The region has a Mediterranean subhumid climate with cool to mild winters (Emberger 1954). Southwesterly to northwesterly winds prevail, inducing high precipitation during the winter. Snow and frost are very rare phenomena in this area.

Many papers have been published on the coastal dune habitats and wetlands of western Greece (Gehu 1986, Biondi 1989, Georgiadis & al. 1990), three of which are Ramsar sites (Amvrakikos gulf, Acheloos river delta and Kotychi lagoon). Sand dunes are treated by Sýkora & al. (2003) for the whole of Greece and by Lavrentiades (1964, 1971, 1979) for western Greece.

Lavrentiades (1971) distinguished four types of dunes on the coasts of western Peloponnesos: very low, embryonic dunes formed by sea water through swash and backwash activity; low dunes at a distance of 5-10 m from the sea; high mobile sand dunes (white, shifting dunes) at 8-10 m from the sea, and stabilized dunes, which occur further inland. This pattern seems to apply, with minor differences, also to the other coasts of western Greece. The low, embryonic dunes are characterized by a vegetation cover of the Agropyrion juncei alliance. White, shifting dunes are covered by Ammophilion arenariae (Ammophiletum arenariae association) and stabilized dunes by Ammophilion arenariae and/or Crucianellion maritimae (on Kerkira Island and around Kiparissia). Further inland Juniperion lyciae and Oleo-Ceratonion become more important. Not all of these vegetation zones occur on all sites. Their presence depends also on the degree of disturbance.

Within the frame of the Natura 2000 vegetation mapping project, twenty coastal sand dune ecosystems of western Greece have been studied, delimitated and mapped by the authors. The locations of these sites are shown in Fig. 1. These studies are still ongoing, and details of the relevés and maps are still unpublished. Here we present a preliminary summary of our findings so far and evaluate aspects of the sand dune flora and vegetation of the area with relevance for conservation.

Material and methods

This study is based on unpublished collections and field observations made by the authors from 1999 to 2004, partly within the frame of the Natura 2000 project for vegetation and habitat identification and mapping. The nomenclature follows Strid & Tan (1997, 2002), Greuter & al. (1984-89) and Tutin & al. (1968-80, 1993). Life-form categories follow Raunkiaer (1934), while the classification of the chorological types is in accordance with Pignatti (1984). Voucher specimens are deposited at the Herbarium of the University of Patras (UPA).

The comments on phytosociological units are based on 185 vegetation samples (relevés) taken in all the study sites, following Braun-Blanquet (1964) and Westhoff & Van der Maarel (1978). Details of the phytosociological work are to be published in a forthcoming publication. Habitat types were identified using the “Interpretation Manual of EU Habitat Types” (EEC 2003) and “Mapping Technical Guide” (Dafis & al. 2001). The location of the twenty study sites is shown in Fig. 1.

Results and discussion

Flora

The vascular flora of the investigated coastal dunes of western Greece comprises the following 182 taxa, belonging to 128 genera and 39 families.

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Gymnospermae

Cupressaceae

Juniperus oxycedrus subsp. *macrocarpa* (Sm.) Ball – Life-form: P caesp/P scap. – Chor.: Eu. Med. – Sites: 6, 10, 11.

J. phoenicea L. – Life-form: P caesp/P scap. – Chor.: Eu. Med. – Sites: 6, 10, 11, 13, 14.

Pinaceae

Pinus halepensis Mill. – Life-form: P scap. – Chor.: St. Med. – Site: 14.

Angiospermae

Dicotyledones

Anacardiaceae

Pistacia lentiscus L. – Life-form: P caesp (P scap). – Chor.: S-Medit. – Sites: 3, 6, 10, 18, 20.

Boraginaceae

Alkanna tinctoria Tausch – Life-form: H scap. – Chor.: St. Med. – Sites: 3, 4, 14, 19, 20.

Anchusella variegata (L.) Bigazzi & al. – Life-form: Thscap. – Chor.: E. Med. – Sites: 6, 13.

Echium arenarium Guss. – Life-form: Thscap. – Chor.: St. Med. – Sites: 10, 12, 13.

E. italicum L. – Life-form: H bienn. – Chor.: Eu. Med. – Site: 12.

Heliotropium dolosum De Not. – Life-form: Thscap. – Chor.: Med.-Turan. – Site: 5.

H. europeum L. – Life-form: Thscap. – Chor.: Eu. Med.-Turan. – Site: 11.

Caryophyllaceae

Arenaria serpyllifolia L. – Life-form: Thscap. – Chor.: Subcosmop. – Site: 14.

Petrorhagia glumacea (Bory & Chaub.) P. W. Ball & Heywood – Life-form: Thscap. – Chor.: Greek. – Site: 11.

P. obcordata (Margot & Reut.) Greuter & Burdet – Life-form: Thscap. – Chor.: Balkan. – Sites: 4, 10, 12, 13, 14.

Polycarpon tetraphyllum (L.) L. – Life-form: Thscap. – Chor.: Eu. Med. – Site: 12.

Silene colorata Poir. – Life-form: Thscap. – Chor.: St. Med. – Sites: 6, 9, 11, 12, 13, 14, 16, 18, 20.

S. nicaeensis All. – Life-form: Thscap. – Chor.: St. Med. – Sites: 1, 10, 11, 16, 18, 19.

S. sedoides Poir. – Life-form: Thscap. – Chor.: St. Med. – Sites: 10, 11, 19.

Spergularia salina J. Presl & C. Presl – Life-form: Thscap. – Chor.: Subcosmop. – Sites: 1, 10, 11, 16.

Chenopodiaceae

Arthrocnemum macrostachyum (Moric.) K. Koch – Life-form: Chsucc. – Chor.: Med.-Turan. – Site: 15.

Atriplex patula L. – Life-form: Thscap. – Chor.: Circumbor. – Site: 2.

A. portulacoides L. – Life-form: Chfrut-Fr. – Chor.: Med. (Eu.)-Atl. – Sites: 5, 6, 9, 10, 11, 15.

A. prostrata L. – Life-form: Thscap. – Chor.: Paleotemp. – Sites: 1, 4, 5, 6, 10.

Beta vulgaris subsp. *maritima* (L.) Arcang. – Life-form: Hscap. – Chor.: Eu. Med. – Sites: 6, 10.

Salsola kali L. – Life-form: Thscap. – Chor.: Paleotemp. – Sites: 1, 2, 3, 4, 5, 10, 11, 12, 13, 15, 16, 17, 19.

Sarcocornia fruticosa (L.) A. J. Scott – Life-form: Chsucc. – Chor.: Eu. Med. – Sites: 5, 6, 10, 11, 20.

Cistaceae

Cistus salvifolius L – *Life-form:* Nphan. – Chor.: St. Med. – Sites: 18.

Fumana thymifolia (L.) Spach – Life-form: Chsuffr. – Chor.: St.Med. – Sites: 18, 20.

Helianthemum nummularium (L.) Mill. subsp. *nummularium* – Life-form: Chsuffr. – Chor.: Europ.-Caucas. – Site: 3.

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Compositae

Aetheorhiza bulbosa (L.) Cass. – Life-form: G bulb. – Chor.: E. Med. – Sites: 5, 6, 11, 14, 20.
Anthemis peregrina L. – Life-form: Thscap. – Chor.: E. Med. – Sites: 4, 5, 10, 12, 16, 18, 19, 20.
A. tinctoria L. – Life-form: Hscap. – Chor.: C-Europ-Pontica. – Site: 5.
Calendula officinalis L. – Life-form: Hbienn. – Chor.: Cosmop. – Site: 2.
Carlina graeca Heldr. & Sart. – Life-form: H scap. – Chor.: E. Med. – Sites: 12, 13.
Centaurea sonchifolia L. – Life-form: H scap. – Chor.: St. Med. – Sites: 4, 10, 11, 12, 13, 14, 19, 20.
Chondrilla juncea L. – Life-form: Hscap. – Chor.: Paleotemp. – Sites: 11, 12, 13.
Cichorium spinosum L. – Life-form: Chsuffr. – Chor.: St. Med. – Site: 20.
Crepis capillaris (L.) Wallr – Life-form: Thscap. – Chor.: Centro-Europ. – Site: 14.
C. foetida L. – Life-form: Thscap. – Chor.: Eu. Med. – Site: 9.
Dittrichia viscosa (L.) Greuter – Life-form: H scap. – Chor.: Eu. Med. – Sites: 6, 12, 14, 15, 20.
Hedypnois cretica (L.) Dum. Cours. – Life-form: Thscap. – Chor.: W-Medit. (Steno-). – Sites: 2, 3, 4, 12, 16, 19.
Helichrysum stoechas subsp. *barrelieri* (Ten.) Nyman – Life-form: Chsuffr. – Chor.: E. Med. – Site: 11.
H. orientale (L.) Gaertn. – Life-form: Chsuffr. – Chor.: E. Med. – Site: 18.
Hypochaeris glabra L. – Life-form: Thscap. – Chor.: Eu. Med. – Site: 11.
Limbarda crithmoides (L.) Dumort. – Life-form: Chsuffr. – Chor.: Med. Atl. – Sites: 5, 7, 10, 12, 15, 19.
Otanthus maritimus (L.) Hoffmanns. & Link – Life-form: Chsuffr. – Chor.: Med.-Atl. – Sites: 1, 5, 6, 9, 10, 11, 12, 13, 14, 18, 19, 20.
Phagnalon graecum Boiss. & Heldr. – Life-form: Chsuffr. – Chor.: E. Med. – Sites: 4, 20.
Picnomon acarna (L.) Cass. – Life-form: H scap. – Chor.: St.Med. – Site: 20.
Reichardia picroides (L.) Roth – Life-form: H scap. – Chor.: St. Med. – Sites: 6, 11, 12, 13, 18, 19, 20.
Rhagadiolus stellatus (L.) Gaertn. – Life-form: Thscap. – Chor.: Eu. Med. – Sites: 10, 12, 13.
Scolymus hispanicus L – Life-form: Hbienn. – Chor.: Eu. Med. – Sites: 9, 10, 15.
Senecio vernalis Waldst. & Kit – Life-form: Thscap. – Chor.: Euras. – Site: 14.
Silybum marianum (L.) Gaertn. – Life-form: Hbienn. – Chor.: Med.-Turan. – Sites: 11, 14, 19.
Sonchus asper (L.) Hill – Life-form: Thscap. – Chor.: Paleotemp. – Site: 15.
Urospermum picroides (L.) Scop. – Life-form: Thscap. – Chor.: Eu. Med. – Site: 11.
Xanthium strumarium L. – Life-form: Thscap. – Chor.: Paleotemp. – Sites: 1, 3, 5, 7, 9, 10, 11, 12, 14, 19.

Convolvulaceae

Calystegia soldanella (L.) R. Br. – Life-form: Grhiz. – Chor.: Cosmop. – Sites: 5, 6, 10.
Convolvulus althaeoides L. – Life-form: Hscand. – Chor.: St.Med. – Site: 10.

Cruciferae

Brassica geniculata (Desf.) Snogerup & B. Snogerup – Life-form: Hscap. – Chor.: Eu. Med. – Sites: 2, 5, 10, 11, 17, 20.
Cakile maritima Scop. subsp. *maritima* – Life-form: Thscap. – Chor.: Med.-Atl. – Sites: 1, 5, 9, 10, 11, 12, 13, 15, 16, 17, 18, 20.
Malcolmia maritima (L.) R. Br. – Life-form: Thscap. – Chor.: E. Med. – Site: 20.
M. nana (DC.) Boiss. – Life-form: Thscap. – Chor.: E. Med. – Sites: 6, 11, 14, 19, 20.
Matthiola tricuspidata (L.) R. Br. – Life-form: Thscap. – Chor.: St. Med. – Sites: 1, 5, 9, 10, 14, 15, 16, 17, 18, 19, 20.
Raphanus raphanistrum L. – Life-form: Thscap. – Chor.: Paleotemp. – Site: 11.
Sinapis arvensis L. – Life-form: Thscap. – Chor.: Eu. Med. – Site: 9.

Dipsacaceae

Knautia integrifolia (L.) Bertol – Life-form: Thscap. – Chor.: Eu. Med. – Site: 4.
Lomelosia argentea (L.) Greuter & Burdet – Life-form: Hbienn. – Chor.: S-Eur.-S-Siber. – Site: 11.

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Euphorbiaceae
Euphorbia paralias L. – Life-form: Chfrut-Fr. – Chor.: Eu. Med.-Atl. – Sites: 1, 2, 4, 5, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20.
E. peplis L. – Life-form: T rept. – Chor.: Eu. Med. – Sites: 1, 2, 9, 10, 11, 12, 13, 19.
E. terracina L. – Life-form: Thscap. – Chor.: St. Med. – Sites: 5, 10, 11, 14.

Fagaceae
Quercus coccifera L. – Life-form: Pcaesp. – Chor.: St. Med.-Occid. – Sites: 13, 20.

Fumariaceae
Hypecoum procumbens L. – Life-form: Thscap. – Chor.: Paleotemp. – Site: 20.

Gentianaceae
Centaurium tenuiflorum (Hoffmanns. & Link) Fritsch – Life-form: Thscap. – Chor.: Eu. Med. – Site: 10.
C. erythraea Raf. – Life-form: Hbienn/Thscap. – Chor.: Paleotemp. – Site: 11.

Geraniaceae
Erodium cicutarium (L.) L'Hér. – Life-form: Thscap. – Chor.: Subcosmop. – Site: 5.
E. laciniatum (Cav.) Willd. – Life-form: Thscap. – Chor.: Eu. Med. – Sites: 14, 20.

Labiatae
Satureja vulgaris (L.) Fritsch – Life-form: Hscap. – Chor.: Circumbor. – Site: 11.
Coridothymus capitatus (L.) Rchb. f. – Life-form: Chfrut. – Chor.: St. Med.-Orient. – Sites: 4, 5, 12, 13, 14, 18, 20.
Prasium majus L. – Life-form: Chfrut. – Chor.: Eu. Med. – Sites: 13, 14, 20.
Sideritis romana L. – Life-form: Thscap. – Chor.: St. Med. – Site: 1.

Leguminosae
Anthyllis hermanniae L. – Life-form: Chfrut. – Chor.: St. Med. – Site: 20.
Lotus creticus L. – Life-form: Chsuffr. – Chor.: St. Med. – Sites: 19, 20.
L. cytisoides L. – Life-form: Thscap. – Chor.: Eu. Med. – Sites: 5, 13, 16, 19, 20.
L. edulis L. – Life-form: Thscap. – Chor.: St. Med. – Site: 11.
L. ornithopodioides L. – Life-form: Thscap. – Chor.: Eu. Med. – Site: 20.
Medicago littoralis Loisel. – Life-form: Thscap. – Chor.: Eu. Med. – Sites: 3, 5, 6, 14, 18, 19, 20.
M. marina L. – Life-form: Chrept. – Chor.: Eu. Med. – Sites: 3, 5, 6, 8, 9, 10, 11, 12, 13, 14, 15, 16, 18, 19, 20.
M. orbicularis (L.) Bartal. – Life-form: Thscap. – Chor.: Eu. Med. – Sites: 15, 6.
M. polymorpha L. – Life-form: Thscap. – Chor.: Subcosmop. – Sites: 2, 3, 11.
Onobrychis caput-galli (L.) Lam. – Life-form: Thscap. – Chor.: St. Med. – Sites: 3, 11.
Ononis reclinata L. – Life-form: Thscap. – Chor.: S-Medit.-Turan. – Sites: 6, 12.
O. variegata L. – Life-form: Thscap. – Chor.: St. Med. (Atl.). – Sites: 5, 6, 11, 14, 20.
Scorpiurus muricatus L. – Life-form: Thscap. – Chor.: Eu. Med. – Sites: 3, 11.
Trifolium angustifolium L. – Life-form: Thscap. – Chor.: Eu. Med. – Site: 9.
T. arvense L. – Life-form: Thscap. – Chor.: Paleotemp. – Site: 14.
T. cherleri L. – Life-form: Thscap. – Chor.: Eu. Med. (Atl., Ir. Anat.). – Site: 14.
T. hirtum All. – Life-form: Thscap. – Chor.: Eu. Med. – Site: 13.
T. lappaceum L. – Life-form: Thscap. – Chor.: Eu. Med. – Site: 15.

Linaceae
Linum strictum L. – Life-form: Thscap. – Chor.: St. Med./Eu. Med. – Sites: 6, 10, 13, 20.
L. bienne Mill. – Life-form: H scap. – Chor.: Med.-Atl.(Eu.). – Site: 6.

Malvaceae
Malva sylvestris L – Life-form: H scap. – Chor.: Subcosmop. – Site: 16.

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Papaveraceae
Glaucium flavum Crantz – Life-form: Hscap. – Chor.: Eu. Med. – Sites: 5, 9, 16, 17, 20.
Papaver dubium L. – Life-form: Thscap. – Chor.: E. Med.-Turan. – Site: 20.

Plantaginaceae
Plantago afra L. – Life-form: Thscap. – Chor.: Eu. Med. – Site: 14
P. bellardii All. – Life-form: Thscap. – Chor.: Eu. Med. – Site: 11.
P. coronopus L. – Life-form: Thscap/H bienn/H ros. – Chor.: Eu. Med. – Site: 9.
P. crassifolia Forssk. – Life-form: Hros. – Chor.: St. Med. – Site: 20.
P. lagopus L. – Life-form: Thscap. Eu. Med. – Chor.: – Site: 5.
P. lanceolata L. – Life-form: Hros. – Chor.: Cosmop. – Site: 14.

Plumbaginaceae
Limonium narbonense Mill. – Life-form: Chsuffr. – Chor.: med-submed. – Site: 15.
L. sinuatum (L.) Mill. – Life-form: Hscap. – Chor.: St. Med. – Site: 9.
L. virgatum (Willd.) Fourr. – Life-form: Hros (Chsuffr). – Chor.: Eu. Med. – Site: 19.

Polygonaceae
Persicaria hydropiper (L.) Spach – Life-form: Thscap. – Chor.: Circumbor. – Sites: 17.
Polygonum arenarium Waldst. & Kit – Life-form: Thrept. – Chor.: SE-Europ.-Centroasiat. – Sites: 6, 10.
P. aviculare L. – Life-form: Thscap. – Chor.: Cosmop. – Sites: 1, 6, 10, 11.
P. maritimum L. – Life-form: Hrept. – Chor.: Subcosmop. – Sites: 5, 12, 13, 17, 20.
Rumex bucephalophorus L. – Life-form: Thscap. – Chor.: Medit.-Macarones. – Sites: 10, 12, 13, 14, 18, 19, 20.
R. conglomeratus Murray – Life-form: H scap. – Chor.: Euras. Centro-occid. – Site: 15.
R. pulcher L. – Life-form: H scap. – Chor.: Eu. Med. – Site: 10.

Primulaceae
Anagallis arvensis L. – Life-form: T rept. – Chor.: Subcosm. – Sites: 6, 10, 13, 20.

Ranunculaceae
Nigella damascena L. – Life-form: Thscap. – Chor.: Eu. Med. – Sites: 1, 3.

Resedaceae
Reseda alba L. – Life-form: Thscap. – Chor.: Eu. Med. – Site: 9.

Rosaceae
Sarcopoterium spinosum (L.) Spach – Life-form: NP. – Chor.: SE-Medit. – Sites: 11.

Rubiaceae
Crucianella maritima L. – Life-form: Thscap. – Chor.: E. Med. – Sites: 6, 9.
Valantia hispida L. – Life-form: Thscap. – Chor.: St. Med. – Sites: 6, 9.

Scrophulariaceae
Bellardia trixago (L.) All. – Life-form: Thscap. – Chor.: Eu.Med. – Site: 6.
Verbascum blattaria L. – Life-form: Hbiennn. – Chor.: Paleotemp. – Site: 12.
V. pinnatifidum Vahl – Life-form: Hbiennn. – Chor.: Eu. Med. – Site: 3.
V. sinuatum L. – Life-form: H bienn. – Chor.: Eu. Med. – Sites: 2, 5, 6, 13.

Tamaricaceae
Tamarix parviflora DC. – Life-form: N/MPh. – Chor.: E. Med. – Site: 17.

Umbelliferae
Crithmum maritimum L. – Life-form: Chsuffr. – Chor.: Eu. Med. – Site: 20.
Daucus carota L. – Life-form: H bienn-B. – Chor.: Subcosmop. – Sites: 3, 9.
D. guttatus Sm. – Life-form: Thscap. – Chor.: E. Med. or St. Med.-Orient. – Site: 10.

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Echinophora spinosa L. – Life-form: Hscap. – Chor.: Eu. Med. – Sites: 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 19, 20.
Eryngium amethystinum L. – Life-form: Hscap. – Chor.: NE. Med. – Site: 3.
E. maritimum L. – Life-form: G rhiz. – Chor.: Med.-Atl. – Sites: All sites.
Orlaya daucoides (L.) Greuter – Life-form: Thscap. – Chor.: Eu. Med. – Sites: 11, 12, 13.
O. daucorlaya Murb. – Life-form: Thscap. – Chor.: E. Med. – Sites: 2, 9.
Pseudorlaya pumila (L.) Grande – Life-form: Thscap. – Chor.: St. Med. – Sites: 2, 3, 4, 5, 6, 10, 11, 12, 13, 14, 15, 18, 19, 20.

Verbenaceae
Vitex agnus-castus L. – Life-form: Pcaesp. – Chor.: St. Med.-Turan. – Site: 11.

Monocotyledones

Amaryllidaceae
Pancratium maritimum L. – Life-form: Gbulb. – Chor.: St. Med. – Sites: 1, 3, 4, 5, 6, 10, 11, 12, 13, 14, 15, 18, 19, 20.

Cyperaceae
Cladium mariscus (L.) Pohl – Life-form: G rhiz. – Chor.: Subcosmop. – Site: 16.
Cyperus capitatus Vand. – Life-form: Grhiz. – Chor.: St. Med. – Sites: 4, 6, 11, 12, 13, 14, 15, 18 , 19, 20.
Schoenus nigricans L. – Life-form: Hcaesp. – Chor.: Subcosmop. – Site: 6.
Scirpoides holoschoenus (L.) Soják – Life-form: Grhiz. – Chor.: Eu. Med. – Sites: 11, 12, 13.

Gramineae
Ammophila arenaria (L.) Link – Life-form: Grhiz. – Chor.: Eu. Med. – Sites: 1, 6, 10, 11, 12, 13, 14, 15, 19, 20.
Arundo donax L – Life-form: G rhiz. – Chor.: Centroasiat/Subcosmop. – Sites: 16, 17.
Avena barbata Link – Life-form: Thscap. – Chor.: Eu. Med. – Site: 15.
A. sterilis L – Life-form: Thscap. – Chor.: Med-Turan. – Site: 17.
Brachypodium distachyon (L.) P. Beauv. – Life-form: Thscap. – Chor.: St. Med.-Turan – Site: 14.
B. retusum (Pers.) P. Beauv – Life-form: H caesp. – Chor.: St. Med. – Site: 10.
Briza maxima L. – Life-form: Thscap. – Chor.: Paleo-Sub-trop. – Site: 9.
Bromus madritensis L. – Life-form: Thscap. – Chor.: Eu. Med. – Sites: 10, 11, 13, 14, 17.
B. rigidus Roth – Life-form: Thscap. – Chor.: Paleosubtrop. – Site: 16.
B. sterilis L. – Life-form: Thscap. – Chor.: Paleotemp. – Sites: 2, 17, 19.
B. tectorum L. – Life-form: Thscap. – Chor.: Paleotemp. – Sites: 5, 17.
Catapodium marinum (L.) C. E. Hubb. – Life-form: Thscap. – Chor.: Med.-Atl. – Site: 10.
C. rigidum (L.) C. E. Hubb. – Life-form: Thscap. – Chor.: Eu. Med. – Sites: 9, 11, 14.
Cutandia maritima (L.) Barbey – Life-form: Thscap. – Chor.: St. Med. – Sites: 2, 12, 13, 14, 18, 19, 20.
Cynodon dactylon (L.) Pers. – Life-form: Grhiz. – Chor.: Cosmop. – Sites: 2, 15, 17, 20.
Cynosurus echinatus L. – Life-form: Thscap. – Chor.: Eu. Med. – Site: 9.
Dasypyrum villosum (L.) Borbás – Life-form: Thscap. – Chor.: Med.-Turan. – Sites: 3, 11.
Elymus farctus (Viv.) Melderis – Life-form: Grhiz. – Chor.: St. Med. – Sites: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 18, 19, 20.
Holcus lanatus L – Life-form: H caesp. – Chor.: Circumbor. – Site: 11.
Hordeum marinum Huds. – Life-form: Thscap. – Chor.: Med.-Turan. – Site: 6.
H. murinum L. – Life-form: Thscap. – Chor.: Eu. Med. – Sites: 5, 14, 19.
Lagurus ovatus L. – Life-form: Thscap. – Chor.: Eu. Med. – Sites: 1, 6, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20.
Parapholis incurva (L.) C. E. Hubb. – Life-form: Thscap. – Chor.: Med.-Atl. – Site: 11.
Phleum arenarium L. – Life-form: Thscap. – Chor.: Med.-Atl. – Site: 17.

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Phragmites australis (Cav.) Steud. – Life-form: Grhiz. – Chor.: Subcosmop. – Sites: 13, 15.
Polypogon monspeliensis (L.) Desf. – Life-form: Thscap. – Chor.: Paleosubtrop. – Site: 15.
Saccharum ravennae (L.) Murray – Life-form: Hcaesp. – Chor.: Med.-Turan. – Site: 11.
Sporobolus pungens (Schreb.) Kunth – Life-form: Grhiz. – Chor.: Subtrop. – Sites: 1, 2, 3, 4, 5, 6, 11, 12, 13, 14, 19, 20.
Vulpia ciliata Dumort. – Life-form: Thcaesp. – Chor.: Eu. Med. – Site: 9.
V. fasciculata (Forssk.) Samp. – Life-form: Thcaesp. – Chor.: Med.-Atl. – Sites: 2, 3, 19.

Iridaceae
Romulea bulbocodium (L.) Sebast. & Mauri – Life-form: Gbulb. – Chor.: St. Med. – Site: 13.

Juncaceae
Juncus acutus L. – Life-form: H caesp. – Chor.: Eu. Med. – Site: 15.
J. heldreichianus Parl. – Life-form: Hcaesp. – Chor.: E. Med. – Site: 11.
J. maritimus Lam. – Life-form: G rhiz. – Chor.: Subcosmop. – Site: 11.

Liliaceae
Allium ampeloprasum L. – Life-form: G bulb. – Chor.: Eu.Med. – Site: 6.
A. sphaerocephalon L. – Life-form: Paleo-Temp. G bulb. – Chor.: Paleo-Temp. – Site: 13.
Asphodelus ramosus L. – Life-form: Grhiz. – Chor.: St. Med. – Sites: 11, 13.
Urginea maritima (L.) Baker – Life-form: G bulb. – Chor.: St. Med.-Macarones. – Site: 9.

The life-form spectrum in Fig. 2A shows that therophytes are dominant (52 %), followed by hemicryptophytes (19 %). Geophytes are also rather frequent (12 %), while other forms occur in lower percentages.

Regarding their total distribution, the taxa found in the studied areas can be assigned to twelve chorological groups (Fig. 2B). The Mediterranean elements predominate with 63%, including 28% Eury-Mediterranean and 25 % Steno-Mediterranean taxa. Cosmopolitan and East-Mediterranean groups have a lower number of taxa (12 % and 10 %, respectively).

The life-form spectrum reflects the environmental conditions prevailing in western Greece, with long summer aridity (therophyte dominance), while the Mediterranean element conforms to the geographical position and climatic characteristics.

The flora comprises 3 endemic taxa, the Greek endemics *Anchusella variegata* and *Petrorhagia glumacea*, and the Balkan endemic *P. obcordata*.

Vegetation

The vegetation contributes essentially to the stability of dunes; thus, to predict the change of a dune system under possible future climate change, it is necessary to consider the different patterns of plant communities from the coast landwards and the factors that influence them (Corre 1991).

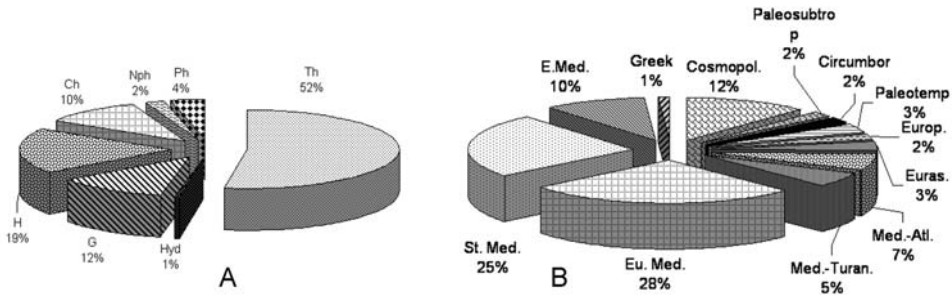


Fig. 2. Life-form spectrum (A) and chorological spectrum (B) of the sand dune flora of western Greece.

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In nine of the twenty sites studied, the annuals *Salsola kali, Cakile maritima, Matthiola tricuspidata* and *Euphorbia peplis* prevail in the foredune front (Natura 2000 code: 1210, 'Annual vegetation of drift lines'). They form an ecotone (class Cakiletea maritimae) between the beach and the adjacent dune ecosystem.

Moving from the sea landwards, where the diversity of the sand dune ecosystem is mainly influenced by wind and soil development, the vegetation belongs mainly to the Agropyrion juncei (association Eryngio-Elymetum farcti), with *Eryngium maritimum, Elymus farctus* and *Sporobolus pungens* prevailing (Natura 2000 code: 2110, 'Embryonic shifting dunes') in eighteen out of twenty sites.

In eight sites shifting (white) dunes with the characteristic *Ammophila arenaria* are found [Natura 2000 code: 2120, 'Shifting dunes along the shoreline with *Ammophila arenaria* (white dunes)']. These formations belong to the alliance Ammophilion arenariae.

Mediterranean fixed beach dunes (Natura 2000 code: 2210, 'Crucianellion maritimae fixed beach dunes') are found in two sites. The species *Crucianella maritima, Pancratium maritimum, Coridothymus capitatus, Elymus farctus* and *Cyperus capitatus* are characteristic for this habitat type and these formations belong to the Crucianellion maritimae alliance.

The habitat type 'Dunes with *Euphorbia terracing*' (Nature 2000 code: 2220), where the species *Euphorbia terracing* and *Silene nicaeensis* dominate, occurs in two sites. This habitat type is classified as the association Euphorbio-Silenetum nicaeensis (Crucianellion maritimae).

Compared to previous data and surveys (Lavrentiades 1964) the extent of sand dune vegetation appears to have decreased during the last 20-30 years, mainly due to direct human impact (development of tourism, trampling, etc.).

To investigate whether the associations are properly developed in the investigated sites, Detrended Correspondence Analysis (DCA) was applied on the relevés of three habitat types: 1210 ('Annual vegetation of drift lines'), 2110 ('Embryonic shifting dunes') and 2120 ('Shifting dunes along the shoreline with *Ammophila arenaria,* white dunes') (Fig. 3).

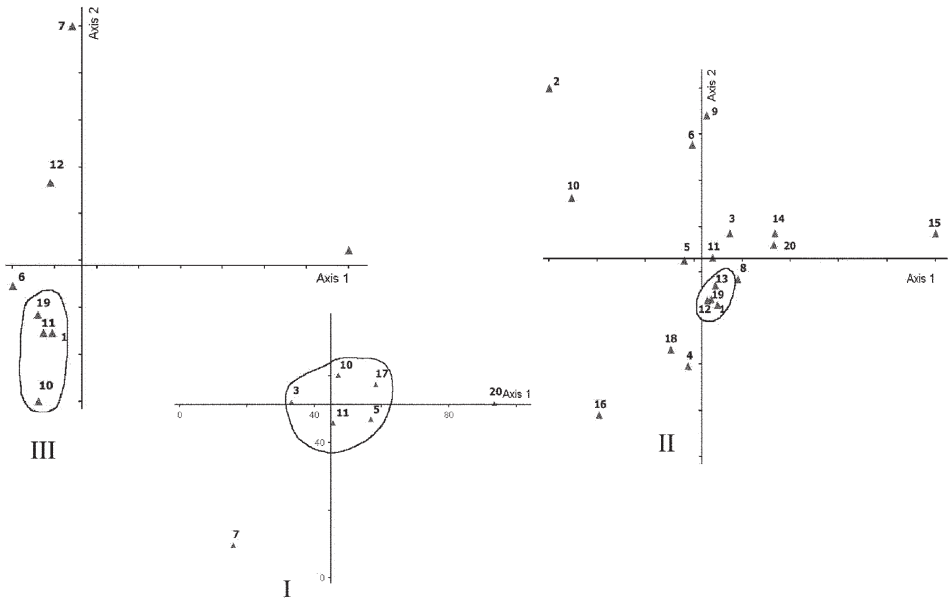


Fig. 3. Ordination diagrams for the three most common coastal sand-dune habitat types: I, 1210; II, 2110; III, 2120. Numbers correspond to the sites of Fig. 1.

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As to habitat type 1210 (Fig. 3I), sites 1, 3, 5, 10, 11 and 17 have a typical Cakiletea maritimae vegetation structure in which *Cakile maritima* and *Salsola kali* dominate. The site 2 vegetation is to be classified in the association Salsolo-Euphorbietum peplis. In sites 7 and 20 the characteristic plants of the class Cakiletea maritimae occur sporadically probably due to a different substrate.

Habitat type 2110 (Fig. 3II) shows on sites 1, 12, 13 and 19 a typical vegetation belonging to the Eryngio-Elymetum farcti (class Ammophiletea) where *Eryngium maritimum*, *Sporobolus pungens* and *Elymus farctus* dominate. Site 15 (Kotichi lagoon) has many ruderal species and, although a Ramsar site, this habitat appears to be quite degraded. The vegetation of site 2 belongs to the Euphorbio paraliae-Agropyretum junceiformis.

Habitat type 2120 (Fig. 3III) on the sites 1, 10, 11, 12, and 19 has a typical Ammophiletum arenariae with *Ammophila arenaria* dominating on well-formed, "white" dunes.

Human impact and conservation action

The sand dunes of western Greece have suffered extensive reduction and serious damage over the last fifty years caused by human activities (mainly tourism). A study of aerial photographs made between 1945, 1986 and 1994 shows the changes in the dune system of the Acheloos and Evinos river deltas. These are mainly due to the dam projects of Kremasta, Kastraki and Stratos, completed between 1965 and 1987, which stopped almost all sedimentary activities along the Acheloos valley and in the delta plain, subsequently disturbing the lagoonal, river-mouth and coastal ecosystems. Alfios also suffered a series of severe alterations, mainly due to the drainage of the Agoulinitsa and Mouria lagoons, to the construction of the Floca dam and to intense sand and gravel exploitation over a length of more than 15 kilometres. Also in the vicinity of many other river mouths (Pamisos, Nedonas, Acherontas rivers) the coastline is retrograding. This confirms Bird's (1986) observations on coastal regression all around the Mediterranean.

The main human activities affecting directly or indirectly the sand dunes of western Greece can be classified as follows:

1. Recreational use such as trampling, free camping and parking, establishment of refreshment stands on the beach, etc.
2. Constructing activities for tourism (e.g. building of hotels or summer houses on the dunes).
3. Waste disposal.
4. Agriculture, grazing, irrigation and drainage projects.
5. River dams, irrigation and canalization projects, all severely disturbing the sedimentary processes which form the coastal dunes.
6. Uncontrolled sand- and gravel exploitation.

Assuming that the global climatic change and the expected sea level rising will severely affect all coastal and dune areas, all measures taken should aim to conserve these invaluable habitats. Human activities should be allowed only in well-defined areas, in accordance with a masterplan for sustainable development of these areas, in accordance with the special local conditions, such as hydrological regime of the rivers, coastal currents, tectonical subsidence or uprising of the area.

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Address of the authors:
S. Spanou, G. Verroios, G. Dimitrellos, A. Tiniakou & T. Georgiadis, Botanical Institute, Division of Plant Biology, Department of Biology, University of Patras, GR-26500 Patras, Greece; e-mail: spnou@mech.upatras.gr, tiniakou@upatras.gr, georgiad@upatras.gr

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