

ERWIN BERGMEIER<sup>1\*</sup>, THOMAS BLOCKEEL<sup>2</sup>, NIELS BÖHLING<sup>3</sup>, CHRISTINA FOURNARAKI<sup>4</sup>, PANAGIOTA GOTSIU<sup>4</sup>, RALF JAHN<sup>5</sup>, RICHARD LANSDOWN<sup>6</sup> & NICHOLAS TURLAND<sup>7</sup>

## An inventory of the vascular plants and bryophytes of Gavdopoula island (S Aegean, Greece) and its phytogeographical significance

### Abstract

Bergmeier E., Blockeel T., Böhling N., Fournaraki C., Gotsiou P., Jahn R., Lansdown R. & Turland N.: An inventory of the vascular plants and bryophytes of Gavdopoula island (S Aegean, Greece) and its phytogeographical significance. – Willdenowia 41: 179–190. – Online ISSN 1868-6397; © 2011 BGBM Berlin-Dahlem. doi:10.3372/wi.41.41121 (available via <http://dx.doi.org/>)

Gavdopoula is an island of 177.5 ha in the S Aegean, near the southeasternmost point of Europe. Based on field excursions in 1998/99 and 2009/10, we provide an annotated floristic catalogue of 186 vascular plant and 13 bryophyte taxa, with a full record of herbarium specimens and field observations, being the first botanical inventory of the island. Species richness in relation to island area is, as shown in a diagram, according to expectations. Among the vascular plants there are six regional ('Cretan area') endemics. The Saharo-Arabian-S Mediterranean phytogeographical element is well represented, with several species confined in Greece or even in Europe to the small islands south of Crete. Of these, *Atriplex mollis* occurs in Europe only on Gavdopoula. The moss *Entosthodon commutatus* has not previously been recorded from the E Mediterranean. The vegetation is controlled chiefly by the dry Mediterranean climate, calcareous shallow soils, sea spray and seasonal grazing. It consists of halo-nitrophytic and *Pistacia lentiscus* scrub, two types of phrygana, small-scale ephemeral pastures with winter-annuals on red-loamy soils, and sea-cliff vegetation. The new combination, *Lysimachia arvensis* var. *caerulea*, is published.

Additional key words: Crete, flora, Gavdos, Mediterranean, phytogeography, islet, species-area relation, vegetation

### Introduction

The islands of the Aegean are diverse in history and habitats as well as in plant and animal species. They are home to widespread organisms as well as to local and regional endemics, small-island specialists and others confined to the larger islands. Phytogeographically, they connect Europe and Asia, most obviously via the island arc of the S Aegean. The central part of the S Aegean island arc is the 'Cretan area'. This phytogeographical term is used here, as in Med-Checklist (Greuter & al. 1984, 1986, 1989; Greu-

ter & Raab-Straube 2008), as comprising Crete and surrounding islands and the Karpathos archipelago. Each Aegean island is distinct in many respects. The flora of the S Aegean islands is particularly remarkable for its affinities to N Africa, and this is nowhere more pronounced in southeastern Mediterranean Europe than on the small offshore islands south of Crete. One of these islets is Gavdopoula, situated in the Libyan Sea about 30 km off the southwestern coast of Crete and 7 km northwest of the southernmost European island, Gavdos.

1 Georg-August-Universität Göttingen, Albrecht-von-Haller-Institut für Pflanzenwissenschaften, Untere Karspüle 2, 37073 Göttingen, Germany; \*e-mail: [erwin.bergmeier@bio.uni-goettingen.de](mailto:erwin.bergmeier@bio.uni-goettingen.de) (author for correspondence).

2 9 Ashfurlong Close, Dore, Sheffield S17 3NN, U.K.; e-mail: [tblockeel@aol.com](mailto:tblockeel@aol.com)

3 Römersteinstr. 12, 73230 Kirchheim/Teck; Germany; e-mail: [nboehling@flora-x.de](mailto:nboehling@flora-x.de), [niels@n-boehling.de](mailto:niels@n-boehling.de)

4 Mediterranean Agronomic Inst. (MAICH), Alysion Agrokipion, P.O.Box 85, 73100 Chania, Crete, Greece; e-mail: [flora@maich.gr](mailto:flora@maich.gr), [yiota@maich.gr](mailto:yiota@maich.gr)

5 Röschenhöhe 8, 09603 Großschirma, Germany; e-mail: [jahnralf@hotmail.com](mailto:jahnralf@hotmail.com)

6 Ardeola Environmental Services, 45 The Bridle, Stroud, Gloucestershire GL5 4SQ, U.K.; e-mail: [rlansdown@ardeola.demon.co.uk](mailto:rlansdown@ardeola.demon.co.uk)

7 Missouri Botanical Garden, P.O. Box 299, Saint Louis, Missouri 63166-0299, U.S.A.; e-mail: [nicholas.turland@mobot.org](mailto:nicholas.turland@mobot.org)

In the frame of quite different projects, C. Fournaraki, P. Gotsiou, E. Bergmeier and N. Böhlring conducted fieldwork on various days in 1998/99, enabling us to make the most of opportunities to survey the plant species of Gavdopoula. Although each of us was granted only a few hours on the island, we believe that our independent yet combined efforts already resulted in a fairly complete inventory. This was proved to be essentially right ten years later when some of us (N. Turland, R. Lansdown and E. Bergmeier with T. Constantinidis, and in 2010 R. Jahn with A. Traxler & al.) took another opportunity to spend a short time on Gavdopoula, and on this occasion also making a collection of bryophytes. Due to the limitations of time and season, however, the bryophyte list presented here is considered preliminary and not intended to be exhaustive.

Until now, there was no botanical inventory for Gavdopoula. In fact, rather surprisingly, to our knowledge this island has not been botanically investigated by others before us. Therefore, the aims of this paper are to bring together our records from Gavdopoula, compile a documentation of the herbarium specimens, provide an annotated list of the vascular plants and bryophytes, and to describe the phytogeographical and ecological significance of the island.

### Geographical background

Stretched from northwest ( $34^{\circ}56'21''\text{N}$ ,  $23^{\circ}59'22''\text{E}$ ) to southeast ( $34^{\circ}55'15''\text{N}$ ,  $24^{\circ}00'46''\text{E}$ ), Gavdopoula is 3 km long and transversely, from southwest to northeast, broadest at 750 m (Fig. 1). The area of the island is 1.775 km<sup>2</sup>, not 2.6 km<sup>2</sup> as claimed by various internet sources. The southwestern coastline is an escarpment standing 30–70 m high, whereas towards the northeast the coast is bouldery or rocky. About 85 % of the island is a low, gently sloping ridge, plateau-like in the southern part, with no abrupt altitudinal difference, between 40 and 100 m. The maximum elevation is 113 m.

Most of the exposed bedrock on the island belongs to the Pindos-Ethia zone (IGME 1993), a carbonate series consisting of hard crystalline limestones and flysch layers of sandstone with calcitic cementing material, the latter according to IGME (1993) confined to the northwest. A calcareous bank of neogene origin is only represented near the eastern and southeastern coastline (IGME 1993). Soils are calcareous lithic leptosols, chiefly eroded to syrosem or, at best, rendzina, with little organic content except for appreciable amounts of humus accumulation under *Pistacia* shrubs. While the soil in the crystalline limestone area is thin and especially in the south poor in nutrients, the Neogene karst pockets contain brown fertile soil. The entire island is more or less influenced by sea spray.

In the absence of meteorological records from Gavdopoula we can only assume that the climate is very similar to that of Gavdos and the southwestern Cretan coast,

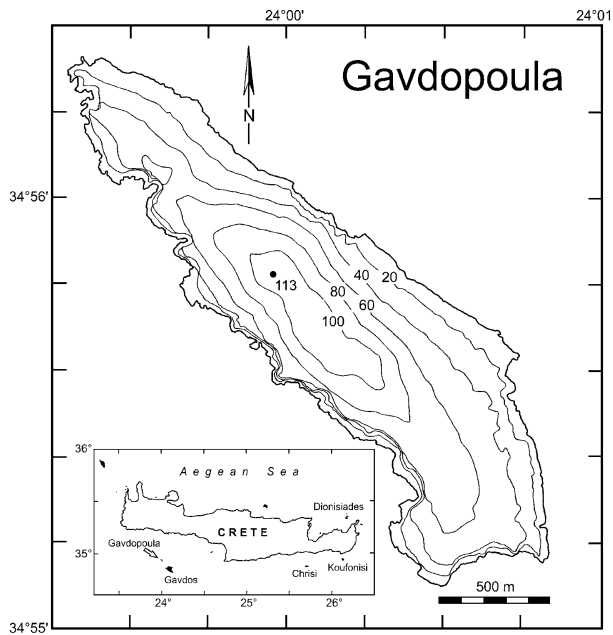


Fig. 1. Contour map of Gavdopoula.

i.e. of a frost-free Mediterranean regime. Rainfall is restricted to winter, probably totalling up to c. 400 mm, which renders Gavdopoula and the other islands off the southern coast of Crete among the driest regions in Mediterranean Europe.

Gavdopoula belongs to the historical province (Eparchia) of Selino and to the prefecture (Nomos) of Chania. Together with Gavdos it forms the Natura 2000 site 'Nisoi Gavdos kai Gavdopoula' (GR 4340013, Islands of Gavdos and Gavdopoula) (Dimopoulos & al. 2005). The island is also protected by the Greek Forest Law.

Remains of a Minoan settlement have been found in Keramos in the south of the island. Gavdopoula may have been inhabited sporadically from Minoan times until the late 19th century. In former times the island had several other names such as Gkotsòpoulo or Antigkòtzo (Kopaka & al. 2001). Gavdopoula is now uninhabited and lacks freshwater except for ephemeral rainwater pools. The most significant human impact is seasonal livestock grazing. Sheep and goats from southwestern Crete (Sfakia) are taken there in late winter and early spring for foraging.

In 1998, Gavdopoula gained public attention as plans to transform the island into a container storage facility became known. This is why two of us (CF and PG) visited the island to help environmental organisations argue against the plans. Fortunately for the biodiversity of Gavdopoula, the project was turned down in 1999.

### Material and methods

We collected on Gavdopoula on the following days:

8.4.1998

C. Fournaraki and P. Gotsiou

- 28.2.1999 N. Böhling  
 28.4.1999 E. Bergmeier  
 15.5.1999 N. Böhling  
 22.10.1999 C. Fournaraki  
 3.4.2009 E. Bergmeier, Th. Constantinidis,  
 R. Lansdown, N. Turland  
 26.4.2010 R. Jahn with A. Traxler & al.

In the catalogue, families, genera and species are in alphabetical order. Records per species are given in chronological order citing the year (1998, 1999, 2009, 2010) and the type of record, field observation (*obs.*) and/or herbarium specimen numbers, together with the collectors' acronyms:

- EB* Erwin Bergmeier  
*F&G* Christina Fournaraki & Panagiota Gotsiou  
*NB* Niels Böhling  
*NT* Nicholas Turland  
*RJ* Ralf Jahn  
*RL* Richard Lansdown

Collections are deposited in EB's private herbarium in Göttingen (GOET, kept separate), those of NB in Berlin (B, with duplicates in his private herbarium, UPA and MAIC), those of F&G in Chania (MAIC), those of RJ in his private herbarium (Großschirma, Germany), those of NT in Patras (UPA) and those of RL will be deposited in Edinburgh (E). Family assignation for vascular plants follows APG III (Angiosperm Phylogeny Group 2009) and Stevens & al. (2001+), nomenclature (author citation) follows the available Med-Checklist volumes (Greuter & al. 1984, 1986, 1989; Greuter & Raab-Straube 2008) or else standard floras.

Bryophyte nomenclature follows Grolle & Long (2000) for liverworts (*Marchantiophyta*) and Hill & al. (2006) for mosses (*Bryophyta*). All bryophytes listed here were collected by Richard Lansdown (RL) and named by Thomas Blockeel.

## Floristic catalogue

### Vascular plants

#### *Polyodiidae*

#### *Pteridaceae*

*Anogramma leptophylla* (L.) Link – 2009: *RL obs.*

#### *Pinidae*

#### *Cupressaceae*

*Juniperus macrocarpa* Sm. – 1999: *EB obs.* (1 plant),  
*F&G 5323*; 2009: *NT obs.*

*Juniperus phoenicea* L. – 1999: *EB obs.* (2 plants); 2009:  
*NT obs.*

#### *Magnoliidae*

#### *Aizoaceae*

*Mesembryanthemum nodiflorum* L. – 1999: *NB obs.*, *EB obs.*

#### *Amaranthaceae* (incl. *Chenopodiaceae*)

*Atriplex halimus* L. – 1998: *F&G 4943*; 1999: *EB 99-8*,  
*NB obs.*; 2009: *EB, NT obs.*; 2010: *RJ obs.*

*Atriplex mollis* Desf. – 1998: *F&G 4934*; 1999: *EB 99-15*,  
*F 5326, NB 9535, 9916*, 2009: *EB 09-8, NT obs.*;  
 2010: *RJ s.n.*

#### *Amaryllidaceae* (incl. *Alliaceae*)

*Allium longanum* Pamp. – 1998: *F&G 4960*; 1999: *NB 9513*  
 (det. D. Tzanoudakis), *EB 99-30*

*Allium rubrovittatum* Boiss. & Heldr. – 1998: *F&G 4924*;  
 1999: *NB 9508/z, 9927* (det. D. Tzanoudakis),  
*EB obs.*; 2009: *EB obs.*; 2010: *RJ obs.*

*Allium subhirsutum* L. – 1998: *F&G 4961*; 1999: *EB 99-23*;  
 2009: *EB obs.*, *NT 1817*; 2010: *RJ obs.*

*Narcissus obsoletus* (Haw.) Steud. (= *N. serotinus* auct.  
 non L.) – 1998: *F&G 4984*; 1999: *F&G 5449* (cult.  
 from coll.). – The nomenclature applied here follows  
 Díaz Lifante & Andrés Camacho (2007).

#### *Anacardiaceae*

*Pistacia lentiscus* L. – 1998: *F&G obs.*; 1999: *EB, NB obs.*;  
 2009: *EB, NT, RL obs.*; 2010: *RJ obs.*

#### *Apiaceae*

*Bupleurum semicompositum* L. – 1998: *F&G 4993*;  
 1999: *EB obs.*, *NB 9914, 9925, 9936, 9964*; 2009:  
*EB, NT obs.*; 2010: *RJ s.n.*

*Crithmum maritimum* L. – 1998: *F&G obs.*; 1999: *EB obs.*

*Daucus guttatus* Sm. – 1998: *F&G 4962*; 1999: *EB obs.*,  
*NB 9934, 9949*; 2010: *RJ s.n.*

*Daucus involucratus* Sm. – 2010: *RJ obs.*

*Lagoecia cuminoides* L. – 1998: *F&G 4986*; 1999: *EB, NB obs.*;  
 2009: *EB, RL obs.*; 2010: *RJ obs.*

*Torilis leptophylla* (L.) Rech.f. – 2009: *EB, NT obs.*

*Torilis nodosa* (L.) Gaertn. – 1998: *F&G 4948*; 2010: *RJ obs.*

#### *Apocynaceae* (incl. *Asclepiadaceae*)

*Periploca angustifolia* Labill. – 1998: *F&G 4918*; 1999:  
*EB obs.*, *NB 9528*; 2009: *EB 09-7, NT obs.*; 2010:  
*RJ obs.*

#### *Araceae*

*Arisarum vulgare* Targ. Tozz. – 1998: *F&G 4923*; 1999:  
*EB, NB obs.*; 2009: *EB, NT, RL obs.*; 2010: *RJ obs.*

#### *Asparagaceae* (incl. *Hyacinthaceae*)

*Asparagus aphyllus* subsp. *orientalis* (Baker) P. H. Davis  
 – 1998: *F&G 4930*; 1999: *F&G 5327, EB obs.*, *NB 9508c*;  
 2009: *EB obs.*, *NT 1825*; 2010: *RJ obs.*

*Asparagus horridus* L. (= *A. stipularis* Forssk.) – 1999: *F 5331*;  
*EB, NB obs.*; 2009: *EB 09-6*

*Bellevalia brevipedicellata* Turrill – 1998: *F&G 4939*;  
 1999: *EB obs.*, *NB 9509/z, 9530, 9947z*; 2009: *NT 1818*

*Charybdis maritima* (L.) Speta (agg.) (= *Urginea maritima* (L.) Baker) – 1998: *F&G 4977*; 1999: *EB, NB obs.*; 2009: *EB, NT obs.*; 2010: *RJ obs.*  
*Muscari spreitzenhoferi* Vierh. – 2009: *EB obs.*  
*Prospero autumnale* (L.) Speta (agg.) (= *Scilla autumnalis* L.) – 1999: *F&G* photo from cult. plant; *NB 9511z, 9934f, 9946z, 9963z*; 2009: *EB, NT, RL obs.*; 2010: *RJ & al.* living coll. (cultivated at Lentas)

### Asteraceae

*Asteriscus aquaticus* (L.) Less. – 1998: *F&G 4988*; 1999: *EB obs.*, *NB 9966*; 2009: *EB obs.*; 2010: *RJ obs.*  
*Atractylis cancellata* L. – 1998: *F&G 4966*; 1999: *EB obs.*, *NB 9536, 9920*; 2009: *NT obs.*; 2010: *RJ s.n.*  
*Bellium minutum* (L.) L. – 1998: *F&G 4973*; 1999: *EB obs.*, *NB 9940*; 2009: *EB, NT, RL obs.*; 2010: *RJ obs.*  
*Carlina graeca* Heldr. & Sartori – 1998: *F&G 4969*; 1999: *EB obs.*; 2010: *RJ obs.*  
*Carlina lanata* L. – 1999: *NB 9967*; 2010: *RJ obs.*  
*Chlamydomphora tridentata* (Delile) Less. – 1999: *EB obs.* (see also Bergmeier & al. 2001)  
*Cichorium pumilum* Jacq. – 1998: *F&G 4953*  
*Cichorium spinosum* L. – 1998: *F&G 4925*; 1999: *EB, NB obs.*; 2009: *EB, NT obs.*; 2010: *RJ obs.*  
*Crepis cretica* Boiss. – 1998: *F&G 4964*; 1999: *EB, NB obs.*; 2009: *EB, RL obs.*, *NT 1832*; 2010: *RJ obs.*  
*Crepis multiflora* Sm. – 1998: *F&G 4963*; 1999: *EB 99-28, NB 9915, 9950, 9951*; 2009: *EB, NT, RL obs.*; 2010: *RJ obs.*  
*Crepis pusilla* (Sommier) Merxm. – 2009: *EB obs.*  
*Crepis tybakiensis* Vierh. – 1999: *EB obs.*  
*Cynara cornigera* Lindl. – 1998: *F&G 4931*; 1999: *EB, NB obs.*; 2009: *EB, NT obs.*; 2010: *RJ obs.*  
*Filago aegaea* subsp. *aristata* Wagenitz – 1999: *EB obs.*; 2010: *RJ obs.*  
*Filago cretensis* Gand. – 2009: *EB, NT obs.*  
*Hedypnois rhagadioloides* (L.) F. W. Schmidt – 1998: *F&G 4954*; 1999: *EB, NB obs.*; 2009: *NT 1833*; 2010: *RJ obs.* – Most records identified to subspecies were referred to subsp. *tubaeformis* (Ten.) Hayek.  
*Hypochaeris achyrophorus* L. – 1998: *F&G 4987*; 1999: *EB obs.*; 2009: *EB, NT obs.*; 2010: *RJ s.n.*  
*Lamyropsis cynaroides* (Lam.) Dittrich – 1999: *EB obs.*  
*Leontodon tuberosus* L. – 1998: *F&G 4983*; 1999: *EB 99-27, NB 9529*; 2009: *EB, NT obs.*; 2010: *RJ obs.*  
*Pallenis spinosa* (L.) Cass. – 1998: *F&G 4967*; 1999: *EB 99-29, NB 9509b, 9944*; 2010: *RJ obs.*  
*Phagnalon rupestre* subsp. *graecum* (Boiss. & Heldr.) Batt. – 1998: *F&G 4909*; 1999: *EB, NB obs.*; 2009: *NT obs.*; 2010: *RJ obs.*  
*Picris pauciflora* Willd. – 1999: *NB 9924*  
*Reichardia picroides* (L.) Roth – 1998: *F&G 4933*; 1999: *EB 99-7, NB obs.*  
*Senecio leucanthemifolius* [subsp. *leucanthemifolius*] var. *pygmaeus* (DC.) Fiori – 1999: *NB 9520* (*S. leucanthemifolius* s.l.); 2009: *EB, RL obs.*, *NT 1839*

*Senecio vulgaris* L. – 1998: *F&G 4979*  
*Sonchus bulbosus* subsp. *microcephalus* (Rech. f.) Kilian & Greuter (= *Aetheorhiza bulbosa* subsp. *microcephala* Rech. f.) – 1999: *EB, NB obs.*; 2009: *NT 1836*; 2010: *RJ obs.*  
*Sonchus oleraceus* L. – 1999: *NB 9943*; 2009 *NT obs.*  
*Taraxacum* sp. – 1999: *NB obs.*  
*Urospermum picroides* (L.) F. W. Schmidt – 1999: *EB obs.*; 2009: *EB obs.*

### Boraginaceae

*Neotostema apulum* (L.) I. M. Johnst. – 1999: *EB obs.*

### Brassicaceae

*Biscutella didyma* L. – 1998: *F&G 4935*; 1999: *NB obs.* (s.l.), *9514* (subsp. *columnae* (Ten.) Nyman); 2009: *EB, NT obs.*  
*Capsella bursa-pastoris* var. *brachycarpa* Heldr. – 1999: *NB 9525*  
*Diplotaxis viminea* (L.) DC. – 1999: *EB obs.*, *NB 9521*; 2009: *EB 09-5, NT 1837*; 2010: *RJ s.n.*  
*Hornungia procumbens* (L.) Hayek (= *Hymenolobus procumbens* (L.) Nutt. ex Torr. & A. Gray) – 2009: *EB obs.*  
*Malcomia chia* (L.) DC. – 1998: *F&G 4975*; 1999: *EB obs.*, *F&G 5329, NB 9500, 9937* (det. O. Georgiou 2000); 2009: *EB, NT obs.*; 2010: *RJ obs.* – With their succulent glossy leaves, large flowers and stout pedicels the observed plants have the appearance of *M. flexuosa* (Sm.) Sm. but, according to O. Georgiou, the collection seen by her represents a coastal ecotype of *M. chia*.

### Campanulaceae

*Campanula erinus* L. – 1998: *F&G 4979*

### Capparaceae

*Capparis orientalis* Veill. – 1998: *F&G obs.*; 1999: *EB 99-3, NB obs.*; 2009: *NT obs.*

### Caryophyllaceae

*Herniaria cinerea* DC. – 1999: *EB 99-11*  
*Paronychia macrosepala* Boiss. – 1998: *F&G 4926*; 1999: *EB obs.*, *NB 9509a*; 2009: *NT obs.*  
*Polycarpon tetraphyllum* (L.) L. – 1999: *EB, NB obs.*; 2009: *EB, NT obs.*; 2010: *RJ obs.*  
*Sagina maritima* G. Don – 1999: *EB obs.*, *NB 9507, 9934c*; 2009: *EB obs.*, *NT 1840*  
*Silene nocturna* L. – 1999: *EB 99-16, F&G 5314, NB 9519*; 2009: *EB obs.*; 2010: *RJ s.n.*  
*Silene sedoides* Poir. (s.str.) – 1998 *F&G 4968*; 1999: *EB obs.*, *NB 9932, 9941*; 2009: *EB obs.*; 2010: *RJ obs.*  
*Spergularia diandra* (Guss.) Heldr. – 1999: *EB obs.*, *NB 9922*  
*Stellaria pallida* (Dumort.) Crép. – 1999: *NB 9924*; *EB 2009 obs.*

**Cistaceae**

*Fumana thymifolia* (L.) Spach ex Webb – 1998: *F&G* 4958; 1999: *EB obs.*, *NB* 9949b (var. *laevis* (Cav.) Grosser); 2009: *NT obs.*; 2010: *RJ obs.*

**Colchicaceae**

*Colchicum cupanii* Guss. (s.str.) – 1999: *NB* 9510z. – The gathered bulbs were cultivated in B and produced rather broad-leaved plants which were tentatively assigned to *C. cousturierii* Greuter. According to Persson (2007: 183), the latter is to be included in *C. cupanii* s.str.

*Colchicum pusillum* Sieber – 1998: *F&G* 4985 (photo from cultivated plant was identified as *C. pusillum* by K. Persson); 1999: *EB obs.*; 2009: *RL obs.*

**Convolvulaceae**

*Convolvulus oleifolius* Desr. – 1998: *F&G* 4957; 1999: *EB* 99-4, *NB* 9534, 9959 (var. *oleifolius*); 2009: *EB*, *NT obs.*

*Cuscuta palaestina* Boiss. – 1998: *F&G* 4927; 1999: *EB obs.*, *NB* 9933; 2009: *EB obs.*, *NT* 1829; 2010: *RJ s.n.*

**Crassulaceae**

*Sedum litoreum* Guss. (s.str.) – 1999: *NB obs.*; 2009: *EB*, *NT*, *RL obs.*; 2010: *RJ obs.*

*Sedum* cf. *rubens* L. – 1998: *F&G* 4982; 1999 *EB obs.*; 2009: *EB*, *RL obs.*

*Umbilicus horizontalis* DC. – 2009: *EB*, *RL obs.*

**Ericaceae**

*Erica manipuliflora* Salisb. – 1999: *EB*, *NB obs.*; 2009: *NT obs.*

**Euphorbiaceae**

*Euphorbia exigua* L. – 1999: *EB obs.*, *NB* 9517; 2009: *EB*, *NT obs.*

*Euphorbia peplus* L. – 1998: *F&G* 4992; 1999: *NB* 9504; 2009: *EB obs.*, *NT* 1838

*Mercurialis annua* L. – 1999: *NB obs.*; 2009: *EB obs.*, *NT* 1820

**Fabaceae**

*Anthyllis hermanniae* L. – 1998: *F&G* 4922; 1999: *EB*, *NB obs.*; 2009: *NT* 1826

*Astragalus hamosus* L. – 2009: *EB obs.*

*Lotus cytisoides* L. – 1998: *F&G* 4942; 1999: *EB* 99-6, *NB* 9503; 2009: *EB*, *NT obs.*; 2010: *RJ obs.*

*Lotus edulis* L. – 1999: *EB obs.*; 2010: *RJ s.n.*

*Medicago coronata* (L.) Bartal. – 1998: *F&G* 4916; 1999: *NB obs.*; 2009: *NT obs.*; 2010: *RJ obs.*

*Medicago littoralis* Loisel. – 1998: *F&G* 4950; 1999: *EB obs.*

*Medicago monspeliaca* (L.) Trautv. (= *Trigonella monspeliaca* L.) – 1998: *F&G* 4917; 1999: *EB obs.*, *NB* 9506; 2009: *EB*, *NT*, *RL obs.*; 2010: *RJ s.n.*

*Medicago orbicularis* (L.) Bartal. – 1998: *F&G* 4915

*Medicago polymorpha* L. – 1999: *EB obs.*

*Medicago truncatula* Gaertn. – 1998: *F&G* 4951; 2010: *RJ obs.*

*Ononis reclinata* L. (s.l., incl. *O. mollis* Savi) – 1998: *F&G* 4965; 1999: *EB obs.*, *NB* 9934d, 9943a, 9965; 2009: *NT obs.*; 2010: *RJ s.n.* (*O. mollis*)

*Ononis verae* Šitj. – 2009: *EB*, *NT*, *RL obs.*

*Scorpiurus muricatus* var. *subvillosus* (L.) Lam. – 1998: *F&G* 4913; 1999: *EB*, *NB obs.*; 2009: *EB obs.*, *NT* 1827; 2010: *RJ s.n.*

*Trifolium campestre* Schreb. – 1998: *F&G* 4940; 1999: *EB obs.*; 2009: *EB obs.*; 2010: *RJ obs.*

*Trifolium infamia-ponertii* Greuter – 1998: *F&G* 4919

*Trifolium scabrum* L. – 1998: *F&G* 4941; 1999: *EB*, *NB obs.*

*Trifolium suffocatum* L. – 2009: *EB obs.*

*Trifolium tomentosum* L. – 2009: *EB obs.*

*Tripodion tetraphyllum* (L.) Fourr. (= *Anthyllis tetraphylla* L.) – 1998: *F&G* 4914; 2009: *EB obs.*

*Vicia cretica* Boiss. & Heldr. – 1999: *NB obs.* (s.str.)

**Frankeniaceae**

*Frankenia corymbosa* Desf. – 1998: *F&G* 4920; 1999: *EB* 99-13, *NB* 9508d, 9935; 2010: *RJ s.n.*

*Frankenia hirsuta* L. – 1999: *EB obs.*, *F&G* 5325; 2009: *EB obs.*, *NT* 1822

**Gentianaceae**

*Blackstonia perfoliata* (L.) Huds. – 1998: *F&G* 4950; 1999: *EB* 99-26; 2010: *RJ obs.* (subsp. *intermedia* (Ten.) Zeltner)

*Centaurium pulchellum* (Sw.) Druce – 1998: *F&G* 4937b; 1999: *NB* 9931

*Centaurium tenuiflorum* (Hoffmanns. & Link) Fritsch – 1998: *F&G* 4937a; 1999: *EB obs.*; 2009: *EB obs.*; 2010: *RJ obs.*

**Geraniaceae**

*Erodium cicutarium* (L.) L'Hér. – 1998: *F&G* 4971; 1999: *EB obs.*, *NB* 9501, 9518, 9526; 2009: *EB*, *NT obs.*; 2010: *RJ s.n.*

*Erodium gruinum* (L.) L'Hér. – 2009: *EB obs.*

*Erodium malacoides* (L.) L'Hér. – 1998: *F&G* 4980; 1999: *EB obs.*; 2009: *EB obs.*, *NT* 1830, *RL obs.*; 2010: *RJ obs.*

*Erodium neuradifolium* Delile – 1999: *NB* 9499, 9523

*Geranium molle* L. (s.str.) – 1998: *F&G* 4981; 1999: *NB* 9527; 2009: *EB*, *NT*, *RL obs.*

*Geranium purpureum* Vill. – 2009: *EB obs.*

*Geranium rotundifolium* L. – 1999: *EB*, *NB obs.*

**Iridaceae**

*Crocus laevigatus* Bory & Chaub. – 1999: *NB* 9945z

*Crocus tournefortii* J. Gay – 1998: *F&G* (photo from cultivated plant); 1999: *NB* 9905. – Other *Crocus* collections from 1999 and 2009 (*NB* 9512z, *NT* 1821) cannot be assigned with certainty to a species.

*Moraea mediterranea* Goldblatt (= *Gynandriris monophylla* Boiss. & Heldr. ex Klatt) – 1999: *EB obs.*, *NB 9930*, *9930z*; 2009: *EB obs.*; 2010: *RJ obs.*

*Romulea linaresii* subsp. *graeca* Bég. – 1999: *NB 9515*, *9928z* (cf.); 2010: *RJ obs.* (cf., in fruit)

### Juncaceae

*Juncus hybridus* Brot. – 1999: *EB 99-10*

### Lamiaceae

*Ajuga iva* (L.) Schreb. – 2010: *RJ obs.*

*Ballota pseudodictamnus* (L.) Benth. – 2010: *RJ obs.*

*Phlomis fruticosa* L. – 1998: *F&G 4906*; 1999: *EB 99-19*, *NB 9952*; 2010: *RJ s.n.*

*Prasium majus* L. – 1998: *F&G 4929*; 1999: *EB*, *NB obs.*; 2009: *EB*, *NT obs.*; 2010: *RJ obs.*

*Sideritis curvidens* Stapf – 1998: *F&G 4907*; 2010: *RJ s.n.*

*Teucrium alpestre* Sm. – 1999: *NB 9532* (cf.); 2009: *EB 09-4*, *NT 1823*

*Teucrium brevifolium* Schreb. – 1999: *EB 99-18*, *NB obs.*; 2009: *EB obs.*, *NT 1824*; 2010: *RJ obs.*

*Teucrium capitatum* L. – 1998: *F&G 4932*; 1999: *EB 99-5*, *NB 9531*, *9926*, *9957*, *9960a*; 2010: *RJ s.n.* (cf.)

*Teucrium divaricatum* Sieber ex Heldr. – 1998: *F&G 4921*; 1999: *EB 99-20*, *NB 9948*, *9955*; 2010: *RJ obs.*

*Teucrium microphyllum* Desf. – 1999: *EB obs.*; 2010: *RJ obs.*

*Thymbra capitata* (L.) Cav. (= *Coridothymus capitatus* (L.) Rchb. f.) – 1998: *F&G 4928*; 1999: *EB*, *NB obs.*; 2009: *EB*, *NT*, *RL obs.*; 2010: *RJ obs.*

### Linaceae

*Linum strictum* subsp. *spicatum* (Pers.) Nyman – 1998: *F&G 4912*; 1999: *EB obs.*

### Malvaceae

*Malva sylvestris* L. – 2009: *NT 1819*

### Oleaceae

*Olea europaea* L. – 1999: *EB obs.* (1 small-leaved plant, var. *sylvestris* (Mill.) Lehr)

### Orobanchaceae

*Orobanche mutelii* F. W. Schultz (= *O. ramosa* subsp. *mutelii* (F. W. Schultz) Cout.) – 2010: *RJ s.n.*

### Plantaginaceae

*Plantago afra* L. – 1998: *F&G 4972*; 1999: *EB obs.*, *NB 9516*; 2009: *EB*, *NT*, *RL obs.*; 2010: *RJ s.n.*

*Plantago bellardii* All. – 1999: *EB obs.*; 2010: *RJ s.n.*

*Plantago lagopus* L. – 1998: *F&G 4911*; 1999: *EB*, *NB obs.*; 2009: *EB*, *NT obs.*; 2010: *RJ obs.*

*Plantago squarrosa* Murray – 2009: *EB obs.*, *NT 1835*

*Plantago weldenii* Rchb. – 1998: *F&G 4908*; 1999: *EB obs.*; 2009: *EB*, *NT obs.*; 2010: *RJ obs.*

### Plumbaginaceae

*Limonium echioides* (L.) Mill. – 1998: *F&G 4944*; 1999: *EB obs.*, *NB 9958* (det. R. Artelari); 2009: *EB obs.*; 2010: *RJ s.n.*

*Limonium graecum* (Poir.) Rech. f. – 1998: *F&G 4955*; 1999: *EB 99-14*, *NB 9528a* (“cf.” by R. Artelari 2000); 2009: *EB*, *NT obs.*; 2010: *RJ obs.* – It is possible that some, if not all, records refer to *L. hyssopifolium*.

*Limonium hyssopifolium* (Girard) Rech.f. – 1999: *NB 9508a* (det. R. Artelari)

*Limonium ocymifolium* (Poir.) Kuntze (= *L. pigadiense* (Rech. f.) Rech. f.) – 1999: *NB 9527a* (det. R. Artelari). – Nomenclature follows Artelari & Georgiou (2003).

*Limonium proliferum* (d’Urv.) Erben & Brullo, ined. – 1999: *F&G 5328* (det. M. Erben). – A paper with the combination used here is currently in prep. by Erben & Brullo (M. Erben in litt.).

### Poaceae

*Anisantha fasciculata* (C. Presl) Nevski (= *Bromus fasciculatus* C. Presl) – 1999: *EB obs.*, *NB 9923*, *9934x* (det. H. Scholz); 2009: *EB*, *NT obs.*; 2010: *RJ obs.*

*Anisantha madritensis* (L.) Nevski subsp. *madritensis* (= *Bromus madritensis* L. subsp. *madritensis*) – 1998: *F&G 4956*; 2009: *EB 09-3*, *NT obs.*

*Anisantha rubens* (L.) Nevski (= *Bromus rubens* L.) – 1999: *EB obs.*, *F&G 5059*, *NB 9934a* (det. H. Scholz); 2009: *EB 09-2*, *NT 1834*

*Avellinia michelii* (Savi) Parl. – 1999: *EB 99-25*

*Avena barbata* Pott ex Link – 1998: *F&G 4949*; 1999: *EB obs.*; 2010: *RJ s.n.* (subsp. *barbata*)

*Bromus intermedius* Guss. – 1998: *F&G 4955*; 1999: *EB*, *NB obs.*; 2010: *RJ s.n.*

*Castellia tuberculosa* (Moris) Bor – 1999: *EB 99-17*, *NB 9961* (det. H. Scholz)

*Catapodium balearicum* (Willk.) H. Scholz – 1999: *EB obs.*, *NB 9968* (det. H. Scholz); 2009: *NT 1831*; 2010: *RJ s.n.*

*Catapodium rigidum* (L.) C. E. Hubb. – 1998: *F&G 4989*; 1999: *EB obs.*; 2009: *EB obs.*; 2010: *RJ s.n.*

*Dactylis glomerata* L. (s.l.) – 1998: *F&G 4946*; 1999: *EB obs.*, *NB 9934b*, *9921*; 2009: *EB obs.*

*Dactylis glomerata* subsp. *hackelii* (Asch. & Graebn.) Cif. & Giacom. – 1999: *NB 9529a*, *9533* (det. H. Scholz)

*Dactylis glomerata* subsp. *hispanica* (Roth) Nyman – 2010: *RJ s.n.*

*Gastridium phleoides* (Nees & Meyen) C. E. Hubb. – 1999: *EB 99-24*; 2010: *RJ s.n.*

*Hyparrhenia hirta* (L.) Stapf – 1999: *NB obs.*; 2009: *NT obs.*

*Lolium rigidum* Gaudin – 2009: *NT 1828*

*Mailella crypsoides* (d’Urv.) Boiss. (= *Phleum crypsoides* (d’Urv.) Hack.) – 1999: *EB obs.*, *F&G 5748*, *NB 9502* (det. H. Scholz); 2009: *EB obs.*

- Melica minuta* L. – 1999: *NB 9960* (det. H. Scholz)  
*Parapholis incurva* L. – 1999: *NB 9963* (det. H. Scholz);  
 2010: *RJ s.n.*  
*Parapholis marginata* Runemark – 1999: *EB 99-9*  
*Piptatherum miliaceum* (L.) Coss. subsp. *miliaceum* –  
 1999: *EB obs.*  
*Poa bulbosa* L. (s.l., incl. *P. pelasgis* H. Scholz) – 1999:  
*NB obs.*  
*Poa infirma* Kunth – 2009: *EB obs.*  
*Psilurus incurvus* (Gouan) Schinz & Thell. – 1999: *EB*,  
*NB obs.*; 2010: *RJ obs.*  
*Rostraria cristata* (L.) Tzvelev – 1998: *F&G 4990*; 1999:  
*EB obs.*, *NB 9938, 9939* (det. H. Scholz); 2009: *EB*,  
*NT obs.*; 2010: *RJ s.n.*  
*Rostraria obtusiflora* (Boiss.) Holub – 1999: *NB 9949a*  
 (det. H. Scholz; see also Böhling & Scholz 2003: 73)  
*Stipa capensis* Thunb. – 1998: *F&G 4991*; 1999: *EB, NB*  
*obs.*; 2010: *RJ obs.*  
*Trachynia distachya* (L.) Link – 1998: *F&G 4948*; 1999:  
*EB obs.*, *NB 9929*; 2010: *RJ s.n.*

#### Posidoniaceae

- Posidonia oceanica* (L.) Delile – 2010: *D. Abed-Navadi*,  
*I. Gallmetzer & A. Haselmair obs.*

#### Primulaceae

- Lysimachia arvensis* (L.) U. Manns & Anderb. (≡ *Ana-*  
*gallis arvensis* L.) – 1998: *F&G 4974*; 1999 *EB, NB*  
*obs.* (s.l.); 2009: *EB, NT, RL obs.*; 2010: *RJ obs.* – All  
 plants seen represent the blue-flowered *Lysimachia*  
*arvensis* var. *caerulea* (L.) Turland & Bergmeier,  
**comb. nov.** (≡ *Anagallis caerulea* L., Amoen. Acad.  
 4: 479. 1759 ≡ *A. arvensis* var. *caerulea* (L.) Gouan).  
*Lysimachia linum-stellatum* L. (= *Asterolinon linum-stel-*  
*latum* (L.) Duby) – 1999: *EB obs.*

#### Ranunculaceae

- Nigella doerfleri* Vierh. – 1998: *F&G 4936*; 1999: *EB*  
*obs.*, *NB 9956*; 2010: *RJ obs.*

#### Rosaceae

- Sarcopoterium spinosum* Spach – 1999: *F&G 5330*

#### Rubiaceae

- Crucianella latifolia* L. – 1998: *F&G 4910*; 1999: *EB*  
*obs.*; 2010: *RJ obs.*  
*Galium aparine* L. – 2009: *EB, RL obs.*  
*Galium murale* (L.) All. – 1998: *F&G 4947*; 1999: *EB*  
*obs.*; 2009: *EB, RL obs.* (cf.)  
*Sherardia arvensis* L. – 1998: *F&G 4978*; 1999: *NB*  
*obs.*; 2009: *EB, NT, RL obs.*; 2010: *RJ obs.*  
*Theligonum cynocrambe* L. – 1999: *EB, NB obs.*; 2009:  
*NT, RL obs.*  
*Valantia hispida* L. – 1998: *F&G 4904*; 1999: *EB, NB*  
*obs.*; 2009: *EB, NT obs.*; 2010: *RJ s.n.*  
*Valantia muralis* L. – 1998: *F&G 4903*; 1999: *EB, NB*  
*obs.*; 2009: *EB, NT, RL obs.*; 2010: *RJ s.n.*

#### Solanaceae

- Lycium schweinfurthii* Dammer – 1998: *F&G 4959*;  
 1999: *EB, NB obs.*; 2009: *EB, NT obs.*  
*Mandragora officinarum* L. (= *M. autumnalis* Bertol.) –  
 1999: *NB obs.*; 2009: *EB, NT obs.*; 2010: *RJ obs.*

#### Urticaceae

- Parietaria cretica* L. – 1998: *F&G 4952*; 1999: *EB obs.*,  
*NB 9942*; 2009: *EB, NT, RL obs.*; 2010: *RJ obs.*

#### Bryophytes

##### Marchantiophyta

##### Fossombroniaceae

- Petalophyllum ralfsii* Nees & Gottsche ex Lehm. – *RL*  
*45/09 p.p.*

##### Lunulariaceae

- Lunularia cruciata* (L.) Lindb. – *RL 45/09 p.p.*

#### Bryophyta

##### Fissidentaceae

- Fissidens incurvus* Starke ex Röhl. – *RL 45/09 p.p.*

##### Funariaceae

- Entosthodon commutatus* Durieu & Mont. – *RL 44/09*  
*p.p.* – This is a rare and little-known species recently  
 elucidated by Brugués & al. (2010) and Brugués &  
 Sérgio (2010). The material from Gavdopoula agrees  
 in all essential details, especially (1) an erect sym-  
 metrical capsule, (2) a well-developed exostome of  
 16 teeth alternating with very small intercalary pro-  
 cesses, and a rudimentary endostome, and (3) unbor-  
 dered, oblong, shortly acuminate leaves.  
*Funariella curviseta* (Schwägr.) Sérgio – *RL 39/09 p.p.*,  
*RL 45/09 p.p.*

##### Pottiaceae

- Aloina aloides* (Koch ex Schultz) Kindb. – *RL 42/09 p.p.*  
*Aloina ambigua* (Bruch & Schimp.) Limpr. – *RL 40/09*  
*p.p.*  
*Didymodon acutus* (Brid.) K. Saito – *RL 39/09 p.p.*, *RL*  
*42/09 p.p.*  
*Microbryum starckeanum* (Hedw.) R. H. Zander (agg.)  
 – *RL 37/09 p.p.*, *RL 44/09 p.p.* – These collections are  
 referred here to *M. starckeanum* s.l., following Ros  
 & al. (1996). The spores are nearly smooth, though  
 often somewhat irregular in outline, and the capsules  
 have a variably developed peristome (which has prob-  
 ably been lost partially in many individuals through  
 aging of the capsules).  
*Tortella flavovirens* (Bruch) Broth. – *RL 37/09 p.p.*, *RL*  
*45/09 p.p.*  
*Tortula pallida* (Lindb.) R. H. Zander – *RL 37/09 p.p.*  
*Tortula vahliana* (Schultz) Mont. – *RL 44/09 p.p.* – The  
 leaves in this collection have hyaline hair-points, in

contrast to the usually shorter greenish-yellow points found in most collections of *T. vahliana*. However the concept of this species in Flora Briofítica Ibérica (Cano 2006) includes plants with hyaline hair-points.

*Trichostomum brachydontium* Bruch – RL 38/09, RL 39/09 p.p., RL 40/09 p.p., RL 41/09, RL 42/09 p.p., RL 43/09, RL 45/09 p.p.

In addition to the taxa listed above, a distinctive diminutive species of *Tortula* of uncertain identity is present in small quantity in RL 45/09. Unidentifiable specimens of senescent *Fossombronia* (RL 40/09 p.p.) and sterile *Bryum* (RL 40/09 p.p.) were also collected.

### Phytogeography

We found 186 vascular plant taxa on the island of Gavdopoula. This is almost exactly what could be predicted from a species-area curve constructed for the islands surrounding Crete (Fig. 2). At least 22 of the species recorded on Gavdopoula are not known to occur on the nearest and much bigger island of Gavdos (Bergmeier & al. 1997). Of these, the shrubby halophytes *Atriplex halimus*, *A. mollis*, *Asparagus horridus* and *Lycium schweinfurthii* are species of halo-nitrophytic scrub, a habitat type that is most prominent on small islands and not well represented on Gavdos.

Aegean small-island species are represented on Gavdopoula by *Asparagus horridus* and *Hornungia procumbens*. It is known that grazing can be detrimental to non-adapted small-island specialists (Bergmeier & Dimopoulos 2003) and can even eradicate islet populations. On Gavdopoula, *A. horridus*, apart from being a fairly well-defended species itself on account of its spinose cladodes, occurs not uncommonly in the shelter of *Pistacia* scrub. *Hornungia* is a small prostrate low-competitive annual which may profit from sea spray.

The S Mediterranean phytogeographical element is well represented on Gavdopoula. Apart from more widespread species, the following are particularly noteworthy as their distribution reaches its northern limit in Crete and the surrounding islands or, at most, in the S Aegean:

*Allium longanum* is known otherwise only from Gavdos (Bergmeier & al. 1997), Antikythira (Tzanoudakis & al. 2006, RJ *s.n.* 1995), Libyan Cyrenaica, the two Cycladean islands of Sirina and Koutzomiti and from north-eastern Crete (Stearn 1977).

*Asparagus horridus*, widespread in coastal N Africa, Mediterranean Spain and along the southeastern Mediterranean, is a small-island species in the Aegean, confined in the Cretan area to islands surrounding Crete and Karpathos (Bergmeier & Dimopoulos 2003).

*Atriplex mollis* is a N African halophyte with its single

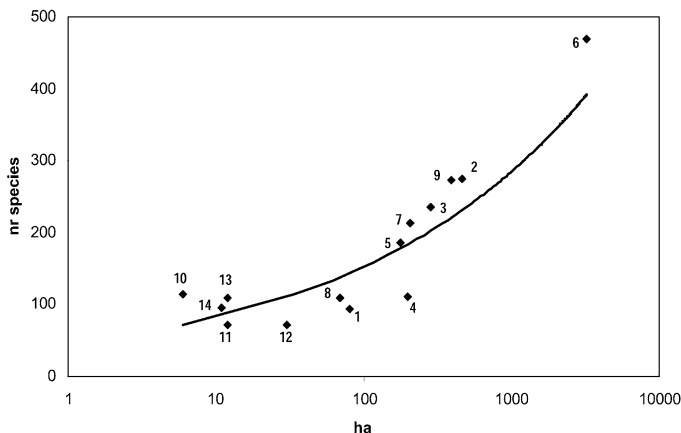


Fig. 2. Species-area relation of the islands surrounding Crete: (1) Agria Gramvousa, (2) Chrisi, (3) Dragonada, (4) Elassa, (5) Gavdopoula, (6) Gavdos, (7) Gianisada, (8) Imeri Gramvousa, (9) Koufonisi, (10) Makrouli, (11) Mikronisi, (12) Paximada, (13) Strongyli, (14) Trachilos, based on data in Bergmeier & al. 1997, Bergmeier & Dimopoulos 2001, Bergmeier & al. 2001, Bergmeier & Dimopoulos 2003, Kallimanis & al. 2009 and this paper. The trend line is potential, the horizontal axis scale is logarithmic.

European occurrence on Gavdopoula, where it is a common coastal shrub (Bergmeier & al. 1999; see also Fig. 3).

*Castellia tuberculosa*, an annual grass of Macaronesian, S Mediterranean and SW Asian general distribution, has been rarely found in the Cretan area. Apart from Gavdopoula (Böhling & Scholz 2003) there are three previous records from eastern Crete: in 1973 on a sandy beach 3 km S of Agios Nikolaos (Greuter & al. 1985: 32), in 1996 near Myrtos W of Ierapetra (Jahn 1996) and E of Ferma on the E side of the valley of Agia Fotia (35°01'33"N, 25°52'34"E), roadside bank, 50 m, 5.5.1994, Jahn *s.n.*

*Chlamydomphora tridentata*, a southeastern Mediterranean annual composite of halophytic habitats, is known in Greece only from Rodos and the islands S of Crete (Bergmeier & al. 2001).

*Erodium neuradifolium*, a S Mediterranean annual extending into the Saharo-Arabian region, is known off the southern coast of Crete otherwise on the island of Koufonisi (Bergmeier & al. 2001). It also occurs scattered in Crete and the Karpathos island group.

*Frankenia corymbosa*, a small shrubby halophyte of chiefly N African distribution, is known in Greece only from Gavdopoula and Koufonisi (Böhling & al. 1999; Bergmeier & al. 2001) and Gavdos, where RJ collected it in 2010 (*s.n.*) at several locations between Potamos beach and Lavrakas beach, opposite to Gavdopoula.

*Periploca angustifolia*, a species of coastal scrub in the S Mediterranean-Saharan region, occurs in Greece only on the islands S of Crete: Chrisi, Gavdos and Gavdopoula (Bergmeier & al. 1997, 2001). On Gavdopoula, it is a common plant.

*Entosthodon commutatus* is a rare species previously known only from the W Mediterranean region (Algeria, Morocco and Spain) and Macaronesia (as *E. krausei*

Besch.). It is new to the Cretan area and to Greece, and the occurrence on Gavdopoula represents a large eastern extension of its range.

Endemics of the Cretan area occurring on Gavdopoula are:

*Bellevalia brevipedicellata* is a narrowly endemic geophyte of southwestern Crete, Gavdos and Gavdopoula (Turland 1995; Bergmeier & al. 1997; Bareka 2010).

*Crepis cretica* is an annual occurring abundantly throughout the Cretan area.

*Crepis tybakiensis* is an annual widespread in the Cretan area including some of the surrounding islands and is locally common in stony phrygana habitats.

*Muscari spreitzenhoferi* is widespread in Crete and the surrounding islands, ranging from sea level to the high mountains (c. 2100 m).

*Ononis verae* is an annual scattered in western and central Crete (Turland & al. 1993; Fielding & Turland 2005) and occurring also on Gavdos (Bergmeier & al. 1997) and Gavdopoula.

*Teucrium alpestre* is a subshrub endemic to Crete with an altitudinal range similar to that of *Muscari spreitzenhoferi*, from sea level to 2200 m. Apart from Gavdopoula, it is not known to occur on the islands surrounding Crete.

## Vegetation

The vegetation of Gavdopoula is shaped by drought, wind, sea spray and grazing and is not particularly diverse. The most extensive type of vegetation is the E Mediterranean phrygana formation, a mosaic of low shrubs and open ground with herbs in between. There are two types of phrygana on Gavdopoula. Both are commonly dominated by *Thymbra capitata* (*Coridothymus capitatus*) and very low windshorn shrubs of *Pistacia lentiscus*. Other common shrubs and subshrubs of the more extensive type of phrygana on crystalline limestones are *Convolvulus oleifolius*, *Periploca angustifolia*, *Teucrium brevifolium* and *T. capitatum*. The other type of phrygana is restricted to extremely karstic limestones almost without soil found in the south of the island. It is characterised by *Anthyllis hermanniae*, *Erica manipuliflora* and *Fumana thymifolia*. Both types of phrygana are known with similar species composition from Gavdos, Chresi and Crete.

The bryophyte flora also shows the influence of prolonged desiccation and wind. Only acrocarpous mosses and three species of liverwort were recorded, the mosses dominated by the *Pottiaceae*, particularly in the flat interior part of Gavdopoula, with other families limited to the coastal cliffs and slopes. The presence and growth form of shrubs appears critical to bryophytes, most plants of which grow in the shade of the larger and denser bushes, as well as occasionally in the shade of the largest rocks. The most frequent species in these habitats are *Aloina*

*aloides* and *Trichostomum brachydontium*, both of which also occur in open rocky areas between shrubs and on bare rock. Moist, shaded habitats also support small populations of a *Fossombronia*, all plants of which were senescent at the time of survey and could therefore not be identified to species.

Where red or brown clayey soil has accumulated between rock outcrops or as alluvium in slight depressions, vascular plant species densities of 20–30 species per m<sup>2</sup> were found. This is sheep-grazed vegetation chiefly composed of annual plants such as *Crepis cretica*, *Geranium molle*, *Lagoecia cuminoides*, *Medicago monspeliaca*, *Plantago lagopus*, *P. weldenii* and *Sherardia arvensis*. These areas also provide the only really suitable habitat for a diverse bryophyte flora in the more open areas of the flat terrain. *Trichostomum brachydontium* is again widespread, with *Aloina aloides* and some *A. ambigua*. Where the thin soil is periodically wet and the clay swollen, additional species such as *Trifolium tomentosum* and, rare on Gavdopoula, *Crepis pusilla*, *Filago cretensis* and *Trifolium suffocatum* occur with a greater diversity of mosses, including *Microbryum starckeanum*, *Tortella flavovirens* and *Tortula pallida*.

Dense patches of *Pistacia lentiscus* scrub of 10–50 m<sup>2</sup> and 1–2 m tall occur chiefly in the east of Gavdopoula immediately where the terrain drops to the coastline and in the southeastern and south-central part, which is in places more sheltered from the prevailing winds. Apart from *Pistacia*, typical species include *Lycium schweinfurthii*, *Periploca angustifolia*, *Prasium majus* and both *Asparagus* species.

Although not as extensive as phrygana, the most striking vegetation type of Gavdopoula is halo-nitrophytic scrub. As such, it is common along the coasts of many of the Aegean islands, particularly the minor ones, but the kind occurring on Gavdopoula is unique in species composition from a European perspective, with the N African species *Atriplex mollis* and *Frankenia corymbosa*, together with the more widespread *A. halimus*, being the dominant and characteristic taxa. Halo-nitrophytic shrub vegetation occurs on and between coastal rocks chiefly but not exclusively along the northern and eastern coasts, also sheltered below cliffs on the southern coast. In the northwestern part, which is particularly exposed to the strong sea-spray-laden winds, *Pistacia lentiscus*-*Atriplex mollis*-*Atriplex halimus* scrub extends considerably inland and occurs from near sea level to about 50 m. As a result of sea spray blown all over the island, a typical feature of small islands is the occurrence of species of halo-nitrophytic scrub far inland in otherwise non-halophytic vegetation: on Gavdopoula *Frankenia corymbosa* may be found in phrygana and *Atriplex mollis* in *Pistacia* scrub.

The large boulders on the eastern cliffs create the only permanently humid microhabitats on the island, as well as supporting the main breeding population of Cory's shearwater (*Calonectris diomedea diomedea*). This combination results in moist clays which are locally kept



Fig. 3. Halo-nitrophytic scrub with *Atriplex mollis* on Gavdopoula in its single European locality, with gull's nest (*Larus michahellis michahellis*). – Photo by N. Turland, April 2009.

clear by trampling by birds and enriched by guano. They support the only pteridophyte recorded, *Anogramma leptophylla*, as well as the most diverse bryophyte flora on the island. The most abundant mosses are similar to those in the wet pans, such as *Tortella flavovirens* and *Microbryum starckeanum*. However, this habitat also supports the only populations of *Entosthodon commutatus*, *Fissidens incurvus*, *Funariella curviseta* and *Tortula vahliana* recorded, as well as two of the three liverwort species recorded: *Lunularia cruciata* and *Petalophyllum ralfsii*.

Finally, in cliff situations along the western coast, a species-poor vegetation with the pendulous shrub *Capparis orientalis* and sometimes with *Crithmum maritimum* can be found. On the western coast, near the southern end of the island, due to intense sea spray, the sharply eroded karstic limestone slopes are free of plants up to several metres above sea level.

During the late winter months until about Easter the islet Gavdopoula becomes a natural enclosure for sheep. This typical Greek-Aegean habit of shepherd-less ‘island transhumance’ has clearly affected the vegetation of Gavdopoula through grazing and browsing but only very few species were found that seem to be allochthonous, originating from the main island of Crete and accidentally transported to Gavdopoula with the sheep. *Phlomis fruticosa*, *Ballota pseudodictamnus*, *Capsella bursa-pastoris*, *Galium aparine* and *Malva sylvestris* may belong to this group of species of more or less recent casual introductions.

We found the potentially tall shrubs (or low trees but for the wind) *Juniperus macrocarpa* and *Olea europaea* on Gavdopoula only as one or two small shrubs at the northwestern or southeastern end, respectively. *J. phoenicea* was also present with only two low shrubs. Clearly, they represent rare established introductions from Gavidos or southwestern Crete where juniper wood- and scrubland is common. There is a small breeding colony of yellow-legged gulls (*Larus michahellis michahellis*) on Gavdopoula (Fig. 3) and olive seeds were found from the gulls’ regurgitated pellets. So the gulls are very likely the source of the single olive shrub on Gavdopoula, and perhaps of the junipers too.

### Acknowledgements

We are grateful to R. Artelari and M. Erben (*Limonium*), O. Georgiou (*Malcolmia*), K. Persson (*Colchicum*), H. Scholz (*Poaceae*) and D. Tzanoudakis (*Allium*), who identified or confirmed herbarium specimens. We gratefully acknowledge the National Geographic Society for supporting the visit to Gavdopoula made in 2009 by E. Bergmeier, T. Constantinidis, R. Lansdown and N. Turland during the research project ‘Human recreation versus plant diversity on maritime sands in Crete’ (NGS grant no. 8573-08). The Gavdopoula research of E. Bergmeier

in 1999 was funded by the Greek Ministry of Environment, Regional Planning and Public Works (YPEXODE), in the framework of the Greek Natura 2000 Habitat Types Mapping and Documentation Project. The Deutsche Forschungsgemeinschaft supported the fieldwork of N. Böhling within the scope of a research project on ‘Indicator values of the vascular plants in the Southern Aegean’, implemented at the Botanic Garden and Botanical Museum Berlin-Dahlem (DFG grant GR 676/7). A. Traxler (Biological Research Station ‘Zora’ in Lentas, Crete) funded the research of R. Jahn and organised the excursion to Gavdopoula in 2010. The marine biologists D. Abed-Navandi, I. Gallmetzer and A. Haselmair reported the occurrence of *Posidonia oceanica*. R. Jahn thanks also the other nine participants of the excursion for their generous support. Thanks are also due to B. Raufeisen, Göttingen, for preparing the map.

### References

- Angiosperm Phylogeny Group 2009: An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG III. – *Bot. J. Linn. Soc.* **161**: 105–121.
- Artelari R. & Georgiou O. 2003: Biosystematic study of the genus *Limonium* (*Plumbaginaceae*) in the Aegean area, Greece III. *Limonium* on the islands Kithira and Antikithira and the surrounding islets. – *Nordic J. Bot.* **22**: 483–501.
- Bareka P. 2010 [“2009”]: *Bellevalia brevipedicellata* Turill. – Pp. 146–147 in: Phitos D., Constantinidis T. & Kamari G. (ed.), *The Red Data Book of rare and threatened plants of Greece 1*. – Patras: Hellenic Botanical Society.
- Bergmeier E., Böhling N., Fournaraki C. & Gotsiou P. 1999: *Atriplex mollis* Desf. [in: Greuter W. & Raus T. (ed.), *Med-Checklist Notulae*, 18]. – *Willdenowia* **29**: 52–53.
- Bergmeier E. & Dimopoulos P. 2001: Chances and limits of floristic island inventories – the Dionysades group (South Aegean, Greece) re-visited. – *Phyton* (Horn) **41**: 277–293.
- Bergmeier E. & Dimopoulos P. 2003: The vegetation of islets in the Aegean and the relation between the occurrence of islet specialists, island size, and grazing. – *Phytocoenologia* **33**: 447–474
- Bergmeier E., Jahn R. & Jagel A. 1997: Flora and vegetation of Gavidos (Greece), the southernmost European island I. Vascular flora and chorological relations. – *Candollea* **52**: 305–358.
- Bergmeier E., Kyriotakis Z., Jahn R., Böhling N., Dimopoulos P., Raus T. & Tzanoudakis D. 2001: Flora and phytogeographical significance of the islands Chrisi, Koufonisi and nearby islets (South Aegean, Greece). – *Willdenowia* **31**: 329–356.
- Böhling N., Bergmeier E., Fournaraki C. & Gotsiou P. 1999: *Frankenia corymbosa* Desf. [in: Greuter W. &

- Raus T. (ed.), Med-Checklist Notulae, 18]. – Willdenowia **29**: 55.
- Böhling N. & Scholz H. 2003: The *Gramineae* (*Poaceae*) flora of the southern Aegean islands (Greece). Checklist, new records, internal distribution. – Ber. Inst. Landschafts- Pflanzenökologie Univ. Hohenheim, Beih. **16**: 1–88.
- Brugués M., Ros R. M., Sáez L. & Cano M. J. 2010: *Entosthodon commutatus* Durieu et Mont. (*Funariaceae*, *Bryopsida*), new to Europe and Morocco. – Cryptog. Bryol. **31**: 271–276.
- Brugués M. & Sérgio C. 2010: On the identity of some *Entosthodon* species endemic to Macaronesia or the North of Africa. – Cryptog. Bryol. **31**: 277–280.
- Cano M. J. 2006: *Tortula* Hedw. – Pp. 146–176 in: Guerra J., Cano M. J. & Ros R. M., Flora briofítica ibérica 3. *Pottiales: Pottiaceae. Encalyptales: Encalyptaceae*. – Murcia: Universidad de Murcia & Sociedad Española de Briología.
- Díaz Lifante Z. & Andrés Camacho C. 2007: Morphological variation of *Narcissus serotinus* L. s.l. (*Amaryllidaceae*) in the Iberian Peninsula. – Bot. J. Linn. Soc. **154**: 237–257.
- Dimopoulos P., Bergmeier E., Theodoropoulos K., Fischer P. & Tsiapoulou M. 2005: Monitoring guide for habitat types and plant species in the Natura 2000 sites of Greece with management institutions. – University of Ioannina and Hellenic Ministry of the Environment, Physical Planning & Public Works. Agrinio, Greece. [170 pp., in Greek].
- Fielding J. & Turland N. 2005: Flowers of Crete. – Kew: Royal Botanic Gardens.
- Greuter W., Burdet H. M. & Long G. (ed.) 1984, 1986, 1989: Med-Checklist **1**, **3**, **4**. – Genève: Conservatoire et Jardin botaniques, Ville de Genève; Berlin: Botanischer Garten & Botanisches Museum Berlin-Dahlem.
- Greuter W., Matthäs U. & Risse H. 1985: Additions to the flora of Crete, 1973–83 (1984), III. – Willdenowia **15**: 23–60.
- Greuter W. & Raab-Straube E. von (ed.) 2008: Med-Checklist. A critical inventory of vascular plants of the circum-Mediterranean countries **2**. – Palermo: OPTIMA Secretariat; Genève: Med-Checklist Trust of OPTIMA; Berlin: Euro+Med Plantbase Secretariat.
- Grolle R. & Long D. G. 2000: An annotated check-list of the *Hepaticae* and *Anthocerotae* of Europe and Macaronesia. – J. Bryol. **22**: 103–140.
- Hill M. O., Bell N., Bruggeman-Nannenga M. A., Brugués M., Cano M. J., Enroth J., Flatberg K. I., Frahm J.-P., Gallego M. T., Garilleti R., Guerra J., Hedenäs L., Holyoak D. T., Hyvönen J., Ignatov M. S., Lara F., Mazimpaka V., Muñoz J. & Söderström L. 2006: An annotated checklist of the mosses of Europe and Macaronesia. – J. Bryol. **28**: 198–267
- IGME (Institute of Geology and Mineral Exploration (ed.) 1993: Geological map of Greece 1: 50 000. Gávdos island. – Athen: Institute of Geology and Mineral Exploration.
- Jahn R. (ed.) 1996: Kreta. Botanische Exkursion für Fortgeschrittene, 14.–27. April 1996. – Regensburg: 49 pp.; mimeographed.
- Kallimanis, A. S., Bergmeier E., Panitsa M., Georghiou K., Delipetrou P. & Dimopoulos P. 2010: Biogeographical determinants for total and endemic species richness in a continental archipelago. – Biodiversity Conservation **19**: 1225–1235.
- Kopaka K., Nikolakis G., Tsantiroopoulos A. & Kossyva A. 2001: Sympliroseis sto toponymiko tis Gavdou kai tis Gavdopoulas. Ta kritika toponymia [Additions to the locality names of Gavdos and Gavdopoula. The locality names of Crete]. – Proceedings of the Greek Scientific Conference of the Historical and Laographic Society of Rethymno, Rethymno, Crete 1998: 283–333.
- Persson K. 2007: Nomenclatural synopsis of the genus *Colchicum* (*Colchicaceae*), with some new species and combinations. – Bot. Jahrb. Syst. **127**: 165–242.
- Ros R. M., Guerra J., Carrion J. S., Cano M. J. 1996: A new point of view on the taxonomy of *Pottia starckiana* agg. (*Musci, Pottiaceae*). – Pl. Syst. Evol. **199**: 153–165.
- Stearn W. T. 1977: *Allium longanum*, a species new for the south-eastern Aegean region. – Ann. Mus. Goulandris **3**: 39–44.
- Stevens P. F. 2001+ [continuously updated]: Angiosperm Phylogeny Website. – Published at <http://www.mobot.org/MOBOT/research/APweb/> [accessed 18 July–19 August 2010].
- Turland N. J. 1995: *Bellevalia brevipedicellata* Turrill. – Pp. 84–85 in: Phitos D., Strid A., Snogerup S. & Greuter W. (ed.), The Red Data Book of rare and threatened plants of Greece. – S. loc.: WWF.
- Turland N. J., Chilton L. & Press J. R. 1993: Flora of the Cretan area. Annotated checklist & atlas. – London.
- Tzanoudakis D., Panitsa M., Trigas P. & Iatrou G. 2006: Floristic and phytosociological investigation of the island Antikythera and nearby islets (SW Aegean area, Greece). – Willdenowia **36**: 285–301.