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

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Abstract

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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; Greuter & 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.
In the frame of quite different projects, C. Fournaraki, P. Gotsiou, E. Bergmeier and N. Böhling 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°56'21"N, 23°59'22"E) to southeast (34°55'15"N, 24°00'46"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 km², not 2.6 km² 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, 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 Gkotzòpoulo 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  
Polypodiales  
Pteridaceae  

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  

Amaranthaceae (incl. Chenopodiaceae)  
Atriplex halimus L. – 1998: F&G 4943; 1999: EB 99-8,  
F 5326, NB 9535, 9916, 2009: EB 09-8, NT obs.;  
2010: RJ s.n.  

Amaryllidaceae (incl. Alliaceae)  
9513 (det. D. Tzanoudakis), EB 99-30  
Allium rubroviittatum Boiss. & Heldr. – 1998: F&G  
4924; 1999: NB 9508/z, 9927 (det. D. Tzanoudakis),  
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.  
from coll.). – The nomenclature applied here follows  

Anacardiaceae  

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

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

Lagoezia cuminoides L. – 1998: F&G 4986; 1999: EB,  
Torilis leptophylla (L.) Rchb.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:  

Asparagaceae (incl. Hyacinthaceae)  
Asparagus aphyllus subsp. orientalis (Baker) P. H. Davis  
9508c; 2009: EB obs., NT 1825; 2010: RJ obs.  
Asparagus horridus L. (= A. stipularis Forssk.) – 1998:  
F 5331; EB, NB obs.; 2009: EB 09-6  
Bellevallia brevipedicellata Turrill – 1998: F&G 4939;  
1999: EB obs., NB 9509/z, 9530, 9947z; 2009: NT  
1101


Prospero autunale (L.) Speta (agg.) (= Scilla autumnalis L.) – 1999: F&G photo from cult. plant; NB 9511z, 9934f, 9946c, 9963z; 2009: EB, NT, RL obs.; 2010: RJ & al. living coll. (cultivated at Lentas)

**Asteraceae**

Asteriscus aquaticus – 1999: EB obs., NB 9922

Asteriscus rhodostegia (Ten.) Hayek. – 1999: EB obs., NB 9922


Chlamydophora tridentata (Delile) Less. – 1999: EB obs. (see also Bergmeier & al. 2001)


Crepis pusilla (Somnier) Mxrm. – 2009: EB obs.


Lampropolis cynaroides (Lam.) Dittrich – 1999: EB obs.


Picris pauciflora Willd. – 1999: NB 9924


Senecio vulgaris L. – 1998: F&G 4979


Taraxacum sp. – 1999: NB obs.


**Boraginaceae**


**Brassicaceae**


Capsella bursa-pastoris var. brachycarpa Heldr. – 1999: NB 9525


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**


**Caryophyllaceae**

Hermiaria cinerea DC. – 1999: EB 99-11


Sagina maritima G. Don – 1999: EB obs., NB 9507, 9934c; 2009: EB obs., NT 1840


Spergularia diandra (Guss.) Heldr. – 1999: EB obs., NB 9922

Stellaria pallida (Dumort.) Crèp. – 1999: NB 9924; EB 2009 obs.
**Cistaceae**

**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. cousturieri 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**

**Crassulaceae**

**Ericaceae**

**Euphorbiaceae**

**Fabaceae**
Medicago orbicularis (L.) Bartal. – 1998: F&G 4915
Trifolium inflamia-ponertii Greuter – 1998: F&G 4919
Vicia cratica Boiss. & Heldr. – 1999: NB obs. (s.str.)

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

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

**Geraniaceae**
Erodium neoradifolium Delile – 1999: NB 9499, 9523
Geranium purpureum Vill. – 2009: EB 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.
Romulea linaresii subsp. graeca Bég. – 1999: NB 9515, 9928z (cf.); 2010; RJ obs. (cf., in fruit)

Juncaceae
Juncus hybrida Brot. – 1999: EB 99-10

Lamiaceae
Ajuga iva (L.) Schreb. – 2010: RJ obs. 
Ballota pseudodictamnus (L.) Benth. – 2010: RJ obs. 
Teucrium alpestre Sm. – 1999: NB 9532 (cf.); 2009: EB 09-4, NT 1823 

Linaceae

Malvaceae
Malva sylvestris L. – 2009: NT 1819

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

Orobanchaceae

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

Plumbaginaceae
Limonium hyssopifolium (Girard) Rech.f. – 1999: NB 9508a (det. R. Artelari) 
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 rubens (L.) Nevski (= Bromus rubens L.) – 1999: EB obs., F&G 5059, NB 9934a (det. H. Scholz); 2009: EB 09-2, NT 1834 
Avellinia micheli (Savi) Parl. – 1999: EB 99-25 
Castellaria tuberculosa (Moris) Bor – 1999: EB 99-17, NB 9961 (det. H. Scholz) 
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. 
Lolium rigidum Gaudin – 2009: NT 1828 

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
Poa bulbosa L. (s.l., incl. P. pelasgis H. Scholz) – 1999:
NB 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)
obs.; 2010: RJ obs.
Trachynia distachya (L.) Link – 1998: F&G 4948; 1999:
EB obs., NB 9929; 2010: RJ s.n.

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

Primulaceae
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-

Ranunculaceae
obs., NB 9956; 2010: RJ obs.

Rosaceae
Sarcopoterium spinosum Spach – 1999: F&G 5330

Rubiaceae
obs.; 2010: RJ obs.
Galium murale (L.) All. – 1998: F&G 4947; 1999: EB
obs.; 2009: EB, RL obs. (cf.)
Thelegonium cynocrambe L. – 1999: EB, NB obs.; 2009:
NT, RL obs.

Solanaceae
Lycium schweinfurthii Dammer – 1998: F&G 4959;
Mandragora officinarum L. (= M. autumnalis Bertol.) – 1999:

Urticaceae
NB 9942; 2009: EB, NT, RL obs.; 2010: RJ obs.

Bryophytes
Marchantiophyta
Fossombroniaceae
Petalophyllum ralssii Nees & Gottsche ex Lehm. – RL

Lunulariaceae

Bryophyta

Fissidentaceae

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 proc-
esses, and a rudimentary endostome, and (3) unbor-
dered, oblong, shortly acuminate leaves.
Funariella curviseta (Schwägr.) Sérgio – RL 39/09 p.p.,

Pottiaceae
Aloina ambigua (Bruch & Schimp.) Limpr. – RL 40/09
Didymodon acutus (Brid.) K. Saito – RL 39/09 p.p., RL
Microbryum starkeeanum (Hedw.) R. H. Zander (agg.) – RL
37/09 p.p., RL 44/09 p.p. – These collections are
referred here to M. starkeeanum 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-
bly been lost partially in many individuals through
aging of the capsules).
Tortella flavivirens (Bruch) Broth. – RL 37/09 p.p., RL
Tortula vahliana (Schultz) Mont. – RL 44/09 p.p. – The
leaves in this collection have hyaline hair-points, in

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.

**Phytokeography**

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), Antikythera (Tzanoudakis & al. 2006, *RI s.n.* 1995), Libyan Cyrenaica, the two Cyclades of Sirina and Koutzomiti and from north-eastern Crete (Steam 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 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 Fota (35°01′33″N, 25°52′34″E), roadside bank, 50 m, 5.5.1994, *Jahn s.n.*

*Chlamydophora 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 neuradiifolium*, 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.

*Periplaca 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 tybakensis_ 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.

_Teuchrium 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_ (Cordothymus 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_, _Peripleea angustifolia_, _Teuchrium 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, Chrisi 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 _Pottiacaeae_, 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 _Fissombrenia_, 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 m² were found. This is sheep-grazed vegetation chiefly composed of annual plants such as _Crepis cretica_, _Geranium molle_, _Lagoecia cummioideae_, _Medicago monspeliaca_, _Plantago lagopus_, _P. weldeni_ 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 starkeanum_, _Tortella flavovirens_ and _Tortula pallida_.

Dense patches of _Pistacia lentiscus_ scrub of 10–50 m² 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-nitrophitic 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 NAfrican species _Atriplex mollis_ and _Frankenia corymbosa_, together with the more widespread _A. halimus_, being the dominant and characteristic taxa. Halo-nitrophitic 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-nitrophitic 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 flavivirens* and *Microbryum starkeanum*. However, this habitat also supports the only populations of *Entosodochon 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. *Philonis 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 Gavdos or southwestern Crete where juniper woodland 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.

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References


Bergmeier E. & Dimopoulos P. 2001: Chances and limits of floristic island inventories – the Dionysades group (South Aegean, Greece) re-visited. – Phytom (Horn) 41: 277–293.


