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PATTERNS OF ENDEMISM ALONG AN ELEVATION GRADIENT IN SIERRA NEVADA (SPAIN) AND LEFKA ORI (CRETE, GREECE)

Modelos de endemicidad a lo largo de un gradiente altitudinal en Sierra Nevada (España) y Lefka Ori (Creta, Grecia)

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ABSTRACT.– Aim: High mountains in the Mediterranean region of Europe are particularly rich in endemic vascular plants. We aimed to compare the altitudinal patterns of vascular plant species richness and the proportion of endemic species in two Mediterranean region: Lefka Ori on the island of Crete (Greece) and Sierra Nevada on the Iberian peninsula.

Location: Sierra Nevada, Granada (Spain); Lefka Ori, Crete (Greece).

Methods: Data from standardised permanent plots settings on summit sites (comprising eight plot sectors, covering the upeermost 10 altitudinal metres) of different elevations were used (GLORIA Multi-Summit approach; www.gloria.ac.at). Species numbers, rates of endemic species, and soils temperature were compared by means of ANCOVA and linear regression.

Results: The two regions, though climatically similar, showed strikingly different patterns: In Sierra Nevada, the proportion of endemic vascular plants (species restricted to Sierra Nevada) showed a stepwise increase from the lowest to

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the highest summit. In contrast, the proportion of endemic species restricted to Crete was not significantly different between the four summits in Lefka Ori. In both regions the observed trends were largely consistent with the altitudinal distribution of the endemic species obtained from standard floras.

Main conclusions: The geographic positions of the two regions, i.e. island versus mainland and the higher elevation of Sierra Nevada are suggested to be the primary causes of the observed differences.

The high degree of endemism in the cold environments of Mediterranean mountains' upper bioclimatic zones indicates a pronounced vulnerability to the impacts of climate change. A continued and intensified species monitoring in the mountains around the Mediterranean basin, therefore, should be considered as a priority research task.

Keywords: Endemism, Vascular plant species richness, Mediterranean mountains, Islands, GLORIA program, Climate warming.

RESUMEN.– Objetivo: Las zonas de alta montaña en la región mediterránea europea son particularmente ricas en plantas vasculares endémicas. Nuestro objetivo es comparar los modelos altitudinales para la riqueza de plantas vasculares y la proporción de endemismos en dos regiones mediterráneas: Lefka Ori en la isla de Creta (Grecia) y Sierra Nevada en la Península Ibérica.

Localización: Sierra Nevada, Granada (España); Lefka Ori, Creta (Grecia).

Método: Los datos proceden de un muestreo estandarizado en varias cimas situadas a diferentes altitudes (GLORIA Multi-Summit approach; www.gloria.ac.at). El número de especies, tasas de endemicidad, y temperatura del suelo se compararon por medio de ANCOVA y regresión lineal.

Resultados: Las dos regiones objeto de análisis, aunque similares climáticamente, muestran patrones llamativamente diferentes: en Sierra Nevada, la proporción de plantas vasculares endémicas (especies restringidas a Sierra Nevada) muestra un incremento gradual desde la cima más baja a la más alta. En contraste, la proporción de endemismos restringidos a Creta no fue significativamente diferente entre las cuatro cimas de Lefka Ori. Las tendencias observadas en ambas regiones fueron en gran parte consistentes con la distribución de las especies endémicas obtenida de las floras para cada región.

Conclusiones principales: La posición geográfica de ambas regiones, por ejemplo. isla frente a continente, y la mayor elevación de Sierra Nevada se sugieren como las principales causas de las diferencias observadas.

El alto grado de endemicidad en los ambientes fríos de las zonas bioclimáticas superiores de las montañas mediterráneas evidencia una marcada vulnerabilidad a los impactos del cambio climático. Por lo tanto, el seguimiento continuado e intensivo de las especies de montaña alrededor de la cuenca mediterránea, debería considerarse como una tarea investigadora prioritaria.

Palabras clave: Endemicidad, Riqueza de plantas vasculares, montañas mediterráneas, islas, proyecto GLORIA, calentamiento climático.

1. Introduction

The degree of endemism of a region's flora is considered as a measure of the uniqueness of the flora which attracts and inspires botanists and amateurs (Van Der Werff and Consiglio, 2004). Mountain areas are often hot spots of plant diversity (Barthlott *et al.*, 1996; Myers *et al.*, 2000) and can host a large number of endemic species. Even though vascular plant species richness generally decreases with altitude, Europe's alpine life zone, covering around 3% of Europe, show a disproportionately high number of species making up approximately 20% of the continents native flora (Väre *et al.*, 2003). This high plant diversity can be attributed to a compression of thermal zones, to high habitat diversity related to rugged topography above the forest line, and to dispersal barriers between mountain ranges supporting divergent speciation. Europe shows a general south-north gradient of mountain endemism, decreasing from the Mediterranean to the temperate and further to the boreal mountains (Favarger, 1972). Mountains of the Mediterranean region remained more isolated and were only partly glaciated during the Pleistocene, (compare Blanca *et al.*, 1998; Pauli *et al.*, 2003; Hughes & Woodward 2008), whereas mountains further north were more extensively or almost fully ice-covered and their margins were more connected to surrounding areas and offered migration pathways. The importance of endemic plants for the mountain vegetation in southern Europe is well documented, e.g. for Crete (Strid, 1993; Dafis *et al.*, 1996; Phitos *et al.*, 1996; Médail and Quézel, 1999; Bergmeier, 2002) or for the Sierra Nevada in southern Spain (Quézel, 1953; Rivas Goday and Mayor López, 1966; Molero Mesa *et al*,. 1996; Médail and Quézel, 1999; Mota *et al.*, 2002).

In the present study we focus on altitudinal gradients of vascular plant species richness and the degree of endemism in two Mediterranean mountain ranges with a different geographic situation: Lefka Ori on the island of Crete and Sierra Nevada on the Iberian Peninsula. By using data from standardized permanent plot settings established on summit sites of different elevations (GLORIA Multi Summit approach; Pauli *et al.*, 2004), we question if the two climatically similar mountain areas show similar patterns of altitudinal species distribution with respect to the proportion of endemic species.

2. Methods

2.1. Study area

The two selected Mediterranean mountain regions (Fig. 1) are part of an international network of permanent plots in alpine ecosystems (GLORIA -

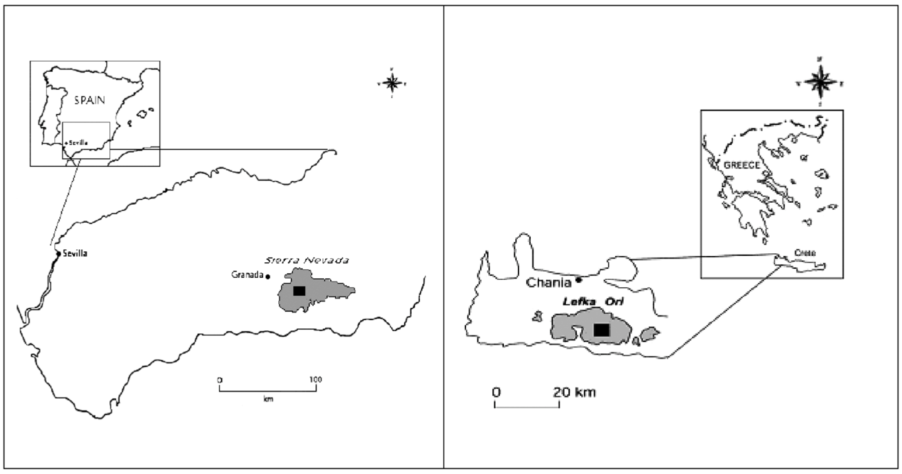

Figure 1. The study areas Sierra Nevada, Spain (left) and the Lefka Ori, Crete (right), rectangles show the position of study summits. Summit sites in Sierra Nevada: Pulpitito (2778 m), Cúpula (2968 m), Pico del Tosal Cartujo (3150 m), Cerro de los Machos (3327 m); in the Lefka Ori: Lowest summit (1964 m); Chorafas (1965 m); South-East Kakovoli (2160 m); Sternes (2339 m).

Figura 1. Las áreas de estudio: Sierra Nevada, España (izquierda) y Lefka Ori, Creta (derecha); los rectángulos muestran la posición de las cimas de estudio. Cimas en Sierra Nevada: Pulpitito (2778 m), Cúpula (2968 m), Pico del Tosal Cartujo (3150 m), Cerro de los Machos (3327 m); en Lefka Ori: Lowest summit (1964 m); Chorafas (1965 m); South-East Kakovoli (2160 m); Sternes (2339 m).

Global Observation Research Initiative in Alpine Environments; www.gloria.ac.at). Plots were setup to assess the impacts of climate change on plant species composition along a gradient from the potential climatic treeline to the uppermost bioclimatic zone of each region. The two regions were selected for this study because of (1) their exceptionally high number of endemic vascular plant species, and (2) for their similar Mediterranean-type climate with predominant winter rainfall and a pronounced dry season in summer.

The Sierra Nevada of southern Spain extends over about 80 km in an E-W direction and reaches its highest point at 3481 m a.s.l. At altitudes above 2500 m mean annual precipitation amounts to around 800 mm (Delgado *et al.*, 2001) and falls almost exclusively as snow (Molero Mesa *et al.*, 1996). The four studied summits were in the western, higher part of the range on siliceous bedrock. The summits ranged from 2778 m in the upper oro-Mediterranean zone to 3327 m in the upper cryoro-Mediterranean zone; for a definition of zones compare Molero Mesa and Pérez-Raya (1987).

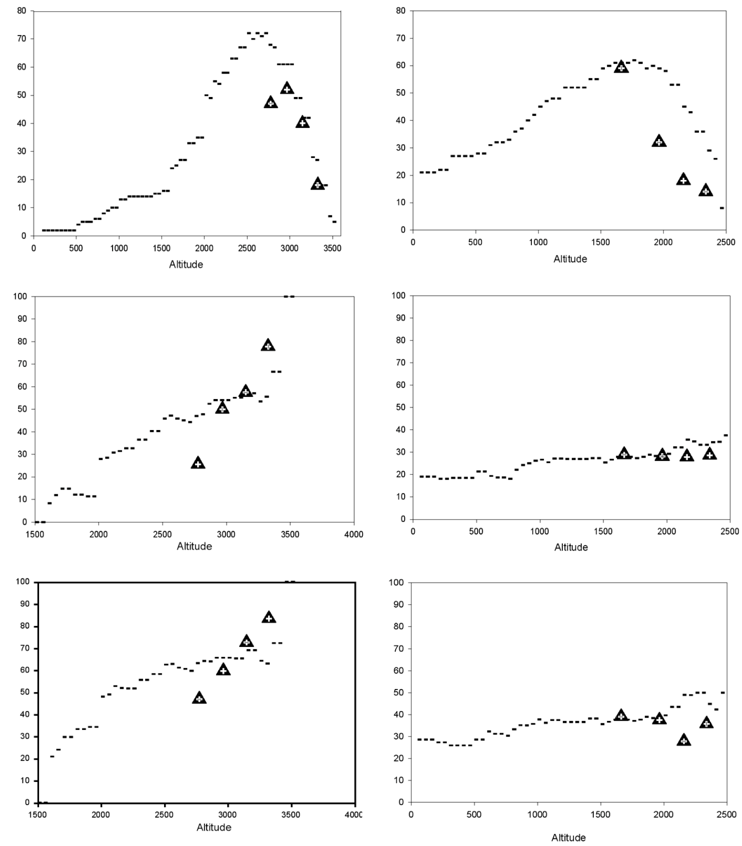

Figure 2. Altitudinal distribution of vascular plant species numbers found in the summit areas of the two study regions; left, Sierra Nevada (Spain); right, Lefka Ori (Crete). a, b, triangles: the number of species found on each summits; horizontal bars: the number out of all species found on the four summits that occur in each 50-m altitudinal band from sea level to the highest peaks (from literature data of vertical species ranges). d,c, triangles: the proportion (percentage) of local endemic species on the four summits; horizontal bars: the percentage share of locally endemic species of all summits species in the 50-m altitudinal bands (from literature data of vertical species ranges); e, f, as before, but for regional endemic species.

Figura 2. Distribución altitudinal del número de especies de plantas vasculares en las áreas cimeras de las dos regiones de estudio; izquierda, Sierra Nevada (España); derecha, Lefka Ori (Creta). a, b, triángulos: número de especies encontradas en cada cima; barras horizontales: número de entre todas las especies encontradas en las cuatro cimas que se da en cada banda altitudinal de 50-m desde el nivel del mar hasta las cimas más altas (procedente de datos bibliográficos sobre los rangos verticales de las especies). c, d, triángulos: proporción (porcentaje) de especies endémicas locales en las cuatro cimas; barras horizontales: porcentaje de especies endémicas locales de todas las cimas en cada banda altitudinal de 50-m (procedente de datos bibliográficos sobre los rangos verticales de las especies); e, f, como la anterior pero para las especies endémicas regionales.

The Lefka Ori region is located in the western part of Crete covering 385 km^2 above 1000 m and reaching 2453 m at Pachnes summit. The massif is the wettest place on the island with 1900-2000 mm mean annual precipitation (Rackham and Moody, 1996). The summits were in the eastern part on carbonatic bedrock (marble and dolomite) and ranged from 1664 m in the oro-Mediterranean zone to 2339 m in the alti-Mediterranean zones.

2.2. Data recording

The sampling design used on the selected summit sites followed the GLORIA Field Manual (http://www.gloria.ac.at; Pauli *et al.* 2004). On each summit, the area from its highest point to the 10-m contour line below the summit was surveyed. This area was subdivided into eight summit area sections (SASs). Four upper SASs extended downward to the 5-m contour line and the four lower SASs from the 5-m to the 10-m contour line. The SASs were orientated towards the cardinal geographical directions, with their boundaries set at NE, SE, SW, and NW. Within each SAS, all vascular plant species were recorded. A miniature temperature data logger (StowAway Tidbit; Onset Corporation, Bourne, Massachusetts) was buried at 10 cm below the soil surface in each upper SAS, approximately 4.5 m below the highest summit point. The temperature series measured at an interval of 1 hour between 2001 and 2002 were used in this study.

2.3. Data analysis

Vascular plants species numbers for each summit were derived from merging the eight SASs, and for each cardinal direction from merging the upper and the lower SASs of each aspect. Species numbers per summit were visually compared with the overall altitudinal distribution (obtained from standard floras) of the species found on the summits (Fig. 3). The relationship of percentage local endemics (le) and regional endemics (lese) on summits of different altitude was analysed by Analysis of Covariance (ANCOVA), using data of the four aspects on each summit (Fig.4 a,b,c,d). Linear regression was used to analyse the relation between yearly mean temperature and percentage of local and regional endemics (Fig.5 a,b,c,d).

A species was considered here as locally endemic when its overall distribution was restricted to Sierra Nevada or to the Island of Crete respectively; and regionally endemic when its overall distribution was restricted to the Baetic range of southern Spain or to the Aegean region, respectively (Annexe 1).

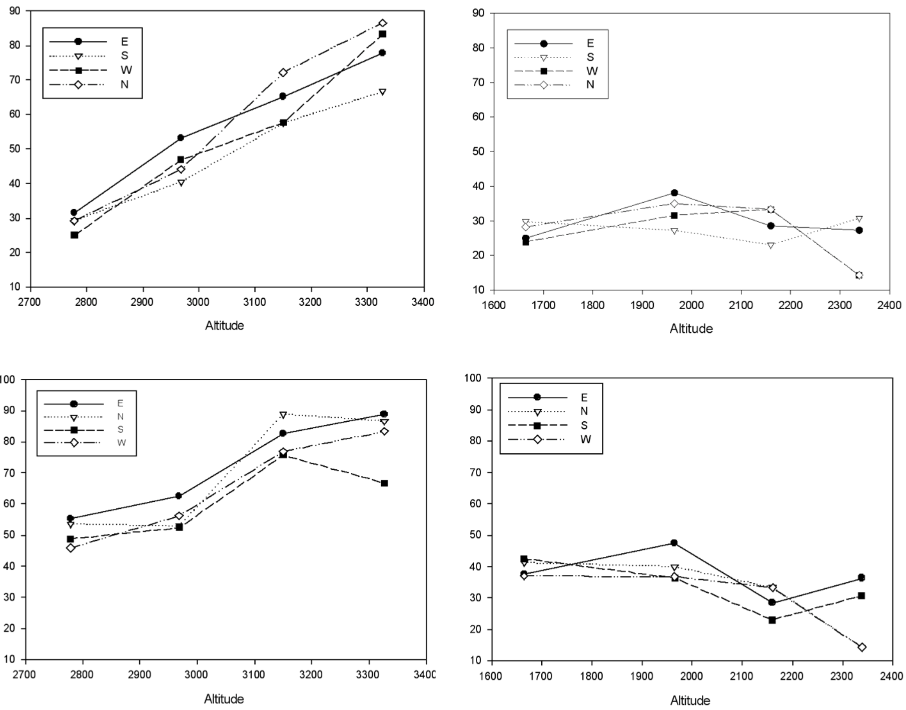

Figure 3. Proportion (percentage) of local and regional endemic vascular plants in the four cardinal directions on the study summits; (a, c) Sierra Nevada, (b, d) Lefka Ori.

Figura 3. Espectro taxonómico de las familias más relevantes en los cuadrados de muestreo.

Figura 3. Proporción (porcentaje) de plantas vasculares endémicas locales y regionales en las cuatro orientaciones de las cimas de estudio; (a, c) Sierra Nevada, (b, d) Lefka Ori.

The information about the distribution and altitudinal ranges of the species were extracted from several bibliographic references. In the case of Sierra Nevada, the literature sources were Flora Iberica (Castroviejo *et al.*, 1986-1997) and Molero Mesa and Pérez-Raya (1987) in cases not yet treated in Flora Iberica. For Lefka Ori, sources were Jahn and Schönfelder (1995) and Strid and Tan (1991). Altitudinal species ranges in metres above sea level, indicated in the above standard floras and check lists, were used. The nomenclature of taxon names followed Flora Europaea (Tutin *et al.*, 1964 - 1980).

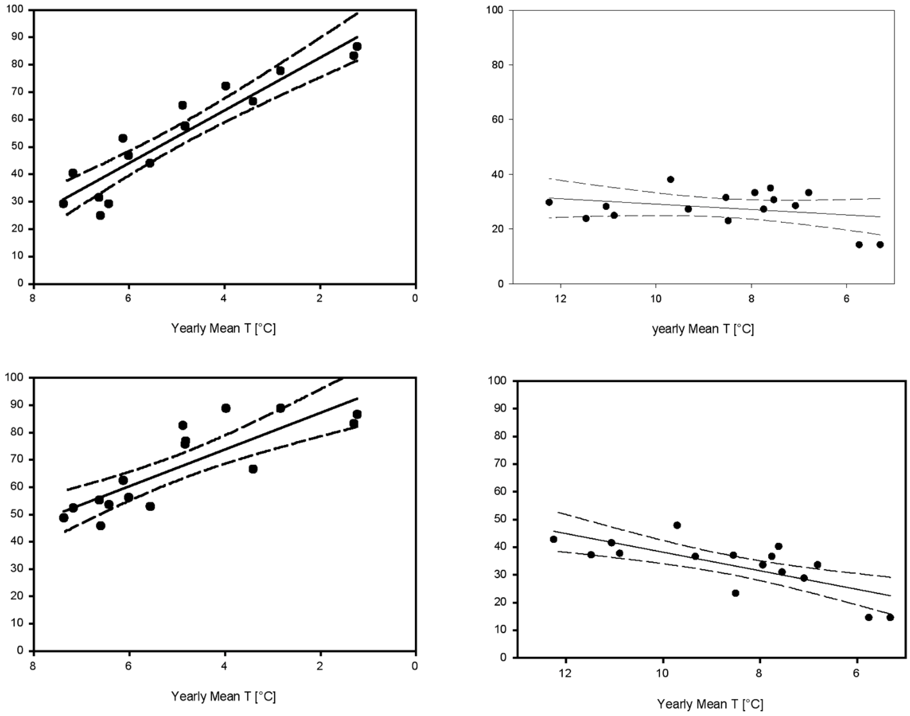

Figure 4. Percentage of local and regional endemics against yearly mean soil temperature. a, c Sierra Nevada, b, d Lefka Ori. Broken lines indicate the 95% confidence intervals.

Figura 4. Porcentaje de endemismos locales y regionales frente a temperatura media anual del suelo. a, c Sierra Nevada, b, d Lefka Ori. Las líneas discontinuas indican los intervalos del 95% de confianza.

3. Results

Total vascular plant species richness on the study summits was decreasing with increasing elevation in both regions, but with the exception of the second-lowest peak in Sierra Nevada, showing slightly higher species numbers than the lowest one. The altitudinal distribution (obtained from literature sources) of the species found on the summits in Sierra Nevada ranged from almost sea level to the maximum altitude for around 3500 m a.s.l., but shows a pronounced peak between 2500 and 3000 m a.s.l. (Fig. 2a). A similar pattern, however, with a less pronounced peak between 1500 and 2000 m a.s.l. resulted from the Lefka Ori data (Fig. 2b).

The proportion of locally endemic species along the full altitudinal gradient (vertical ranges obtained from literature sources) shows a distinct increase with elevation in Sierra Nevada from no endemic species at 1500 m to 100% endemics at 3500 m (Fig. 2c), whereas only a weak altitudinal trend was found for Lefka Ori, ranging from 20% endemics between 0 and 500m to and 35-40% endemics above around 2200 m (Fig. 2d). The patterns for regional endemics were similar to the local endemics, apart from the second highest peak in Lefka Ori (Fig. 2e, f).

The proportion of local endemic as well as of regional endemic vascular plant species in Sierra Nevada showed a significant increase from the lowest to the highest site (Fig. 3a, c; Table 1, p <0.001). This was not the case in Lefka

Table 1. Summary of the results from ANCOVA and linear regression. TRC: target region. LEO: Lefka Ori. SNE: Sierra Nevada. Le: local endemics. Lese: regional endemics (these generally include also the local endemics). Perc_le: percentage of local endemics. Perc_lese: percentage of regional endemics (these generally include also the local endemics). Sualt: altitude of summit. yM: yearly mean soil temperature.

Tabla 1. Resumen de los resultados de ANCOVA y regresión lineal. TRC: target region. LEO: Lefka Ori. SNE: Sierra Nevada. Le: endemismos locales. Lese: endemismos regionales (éstos, por lo general, también incluyen a los endemismos locales). Perc_le: porcentaje de endemismos locales. Perc_lese: porcentaje de endemismos regionales (éstos, por lo general, también incluyen a los endemismos locales). Sualt: altitud de la cima. Y M: temperatura media anual del suelo.

TRC	Endemics	Model design	Analysis	Source	df	SS	MS	F	P	R2 adjusted
SNE	le	perc_le=Intercept+SUALT+Aspect+Aspect*SUALT	ANCOVA	Corrected Model	7	5929.074	847.011	63.210	0.000	0.967
				Intercept	1	3582.557	3582.557	267.357	0.000	
				SUALT	1	5549.154	5549.154	414.120	0.000	
				Aspect	3	139.969	46.656	3.482	0.070	
				Aspect* SUALT	3	156.452	52.151	3.892	0.055	
				Error	8	107.199	13.400			
SNE	lese	perc_lese=Intercept+SUALT+Aspect+Aspect*SUALT	ANCOVA	Corrected Model	7	3146.973	449.568	6.852	0.007	0.732
				Intercept	1	1159.644	1159.644	17.676	0.003	
				SUALT	1	2720.221	2720.221	41.462	0.000	
				Aspect	3	91.255	30.418	0.464	0.716	
				Aspect* SUALT	3	108.412	36.137	0.551	0.662	
				Error	8	524.858	65.607			
LEO	le	perc_le=Intercept+SUALT+Aspect+Aspect*SUALT	ANCOVA	Corrected Model	7	119.532	17.076	0.254	0.956	0.182(unadjusted)
				Intercept	1	399.036	399.036	5.929	0.041	
				SUALT	1	41.738	41.738	0.620	0.454	
				Aspect	3	41.321	13.774	0.205	0.890	
				Aspect* SUALT	3	46.473	15.491	0.230	0.873	
				Error	8	538.414	67.302			
LEO	lese	perc_lese=Intercept+SUALT+Aspect+Aspect*SUALT	ANCOVA	Corrected Model	7	817.979	116.854	1.868	0.200	0.288
				Intercept	1	1647.755	1647.755	26.347	0.001	
				SUALT	1	599.396	599.396	9.584	0.015	
				Aspect	3	85.265	28.422	0.454	0.721	
				Aspect* SUALT	3	108.250	36.083	0.577	0.646	
				Error	8	500.321	62.540			
SNE	le	perc_le=Intercept+yM	Linear Regression	Regression	1	5254.412	5254.412	94.085	0.000	0.861
				Residual	14	781.862	55.847			
SNE	lese	perc_lese=Intercept+yM	Linear Regression	Regression	1	2553.121	2553.121	31.951	0.000	0.674
				Residual	14	1118.710	79.908			
LEO	le	perc_le=Intercept+yM	Linear Regression	Regression	1	58.533	58.533	1.367	0.262	0.024
				Residual	14	599.414	42.815			
LEO	lese	perc_lese=Intercept+yM	Linear Regression	Regression	1	705.234	705.234	16.105	0.001	0.535
				Residual	14	613.066	43.790			

Ori. Here the percentage of local endemics did not significantly change from the lowest to the highest site (Fig. 3b; Table 1, $p = 0.45$), and slightly decrease with elevation in the case of regional endemics (Fig. 3d; Table 1, $p = 0.015$). No significant differences in the percentage of local and regional endemics in relation to slope exposures were found (Fig. 3; Table 1).

In Sierra Nevada, the percentage of both local and regional endemic species was related to yearly mean soil temperature, showing an increase of the proportion of endemics with decreasing temperature (Fig. 4a, c; Table 1, $p < 0.001$). In Lefka Ori , local endemics did not show this relation, and the proportion of regional endemics was negatively related to soil temperature, corresponding to their proportional decreases with altitude (Fig. 4b, d; Table 1).

4. Discussion

Although both Sierra Nevada and Lefka Ori are located in the southern European Mediterranean zone, we observed distinct differences regarding the altitudinal patterns of endemic vascular plant species: the proportion of endemic species (local and regional) was increasing with elevation in Sierra Nevada, whereas it remained rather constant along the altitudinal gradient in Lefka Ori.

The difference in the geographic position, island versus mainland, and the high elevation of Sierra Nevada are suggested to be the primary reasons for the strikingly different patterns. In Sierra Nevada, being by far the highest mountain range in the southern Iberian peninsula, historic (Pleistocene) as well as present orographic isolation appear to have supported endemism, whereas in Lefka Ori, being 1000 m lower than Sierra Nevada, dispersal barriers caused by the geographical distance to mainland Greece seem to be the predominant factor.

Of the factors not related to geographical distance, low temperature is considered to be the main cause contributing to orographic isolation in alpine environments (Chapin and Körner, 1994; Price and Barry, 1997; Körner, 2003; Pauli *et al.*, 2003). Most of the endemic species recorded in Sierra Nevada are cryophilic plants restricted to low temperature environments (Molero Mesa *et al.*, 1996). Blanca *et al.*, (2002) report a share of 30-40% in the upper Sierra Nevada, but it can even reach 80% at some sites. Endemics were considered to be of fundamental importance for the zonal vegetation of the upper elevation levels, where they accounted for up to about 90% of vegetation cover on high summits (Pauli *et al.*, 2003). In Lefka Ori, the shorter vertical distance and, hence, the less pronounced thermal gradient, should lead to a reduced potential of temperature-related ecological niches and altitudinally distinct distribution patterns. Further, as endemism here is principally favoured by the island position, orographic thermal isolation is of subordinate relevance for the proportion of endemics within a particular elevation zone. Low temperature per se, therefore, cannot be taken as a principal indicator for endemism, but in combination with orographic isolation and the Pleistocene history (i.e. not full glaciated mountains would favour endemism). Whereas the proportion of the endemics of the entire island of Crete did not much vary among the summits, a previous GLORIA study, comparing very narrowly distributed endemics (restricted to the Lefka Ori), however showed an altitudinal increase in endemics percentages, with 3% on the lower, 6% on the second highest and 9% on the highest summit (Kazakis *et al.*, 2007). Values for the Lefka Ori given by Strid (1996), of 26.6% Cretan endemics and 10% single mountain endemics (i.e. restricted to Lefka Ori) above 1500 m a.s.l. are well in the magnitude found on the summit sites.

Besides altitude, varying substrate conditions in the Sierra Nevada massif –siliceous in the core part including the summits analysed in this study, calcareous in parts of the margins– may further enhance habitat separation (compare Kruckeberg and Rabinowitz, 1985; Médail and Verlaque, 1997).

Finally, as Bergmeier suggests (1995, 2002), the floristic composition of the vegetation in the Lefka Ori is influenced by constant land use impact over several thousand years. This may be a further reason explaining the less pronounced altitudinal differences of endemic percentages among the summit sites.

Traditional practices of pastoral farming, but, appear to be relevant in both regions (compare Mc Neill, J. R. 1992). Alterations of natural vegetation through human activities, however, were much more pronounced at lower elevations (compare Nogués-Bravo *et al.*, 2008), but little is known about the actual impact of land-use practices on the species distribution in Mediterranean high mountain areas.

The generally large proportion of endemics in our two Mediterranean study regions, and their accumulation at the highest altitudes in the case of Sierra Nevada, appears to be a common feature of high mountain vegetation around the Mediterranean basin. Similarly, high rates of endemism are known form the Moroccan Atlas mountains (Faverger, 1972), and above-average proportions of endemics in the highest vegetation zones were reported form the Central Apennines (Stanisci *et al.*, 2005) as well as from the highly fragmented and patchily distributed subnival environments of the mountains of Iran (Noroozi *et al.*, 2011).

This situation –a primarily endemic vegetation being concentrated in the uppermost bioclimatic zones– gives rise to the concern that the high mountain flora of the wider Mediterranean region is highly vulnerable to impacts of climate warming. Warming-induced biodiversity losses are to be expected, particularly, if temperature increases are paired with decreasing precipitation as was projected for the south of Europe during the upcoming decades (Christensen *et al.,* 2007). A Europe-wide study showed that an increase of more thermophilous species in alpine vegetation across the continent is already discernible (Gottfried *et al.*, 2012); our sites in Sierra Nevada and Lefka Ori were part of this study. An accelerating "thermophilisation" of alpine vegetation will threaten cryophilic species through colonisation of high-elevation habitats by usually more widespread species of lower altitudes. A recent paper provided evidence that species numbers were declining on the southern European summits within less than a decade (Pauli *et al.*, 2012, in press). This deserves fostering comparative monitoring activities in Mediterranean mountain regions.

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Annexe 1. Checklist of local (le) and regional (se) endemics in Lefka Ori and Sierra Nevada.

Anexo 1. Lista de endemismos locales (le) y regionales (se) en Lefka Ori y Sierra Nevada.

Lefka Ori	
Alyssum fragillimum (Bald.) Rech.f.	le
Alyssum sphacioticum Boiss. & Heldr.	le
Arabis cretica Boiss. & Heldr.	le
Asperula idaea Hal csy	le
Bufonia stricta (Sm.) Gurke subsp. *stricta*	se
Carlina corymbosa subsp. *curetum* (Heldr. ex Hal csy) Rech.f.	le
Centaurea idaea Boiss. & Heldr.	le
Centaurea raphanina Sibth. & Sm. subsp. *raphanina*	se
Crepis sibthorpiana Boiss. & Heldr.	le
Cuscuta atrans Feinbrun	le
Dactylis glomerata L. subsp. *rigida* (Boiss and Heldr.) Hayek	se
Draba cretica Boiss. & Heldr.	le
Erysimum mutabile Boiss. & Heldr.	le
Herniaria parnassica subsp. *cretica* Chaudhri	le
Lactuca viminea subsp. *alpestris* (Gand.) Fer kov	le
Melica rectiflora Boiss. & Heldr.	se
Muscari spreitzenhoferi (Heldr.) Vierh.	le
Pimpinella tragium subsp. *depressa* (DC.) Tutin	le
Satureja spinosa L.	se
Scutellaria hirta Sibth. & Sm.	le
Sedum tristriatum Boiss.	se
Sideritis syriaca L. subsp. *syriaca*	le
Teucrium alpestre Sibth. & Sm. subsp. *alpestre*	le
Verbascum spinosum L.	le
Sierra Nevada	
Alyssum purpureum Lag. & Rodr.	le
Andryala agardhii Haens. ex DC.	se
Arenaria tetraquetra subsp. *amabilis* (Bory) H.Lindb.	le
Artemisia granatensis Boiss.	le
Biscutella glacialis (Boiss. & Reut.) Jord.	le
Campanula willkommii Witasek	le
Carduus carlinoides subsp. *hispanicus* (Kazmi) Franco	le
*Chaenorhinum glareos*um (Boiss.) Willk.	le
Cirsium acaule subsp. *gregarium* (Boiss. ex DC.) H.Werner	se
Coincya monensis subsp. *nevadensis* (Willk.) Leadlay	le
Crepis oporinoides Boiss. ex Froel.	se
Dactylis glomerata subsp. *juncinella* (Bory) Stebbins & Zohary	le
Draba hispanica Boiss. subsp. *laderoi* Rivas Martínez, M.E. García & Penas	le
Erigeron frigidus Boiss. ex DC.	le

Erigeron major (Boiss.) Vierh.	se
Erysimum nevadense Reut. subsp. *nevadense*	se
Euphrasia willkommii Freyn	se
Festuca clementei Boiss.	le
Festuca pseudeskia Boiss.	le
Galium rosellum (Boiss.) Boiss. & Reut.	se
Genista baetica Spach	le
Herniaria boissieri J.Gay	le
Holcus caespitosus Boiss.	le
Iberis carnosa Willd. subsp. *embergeri* (Serve) Moreno	le
Jasione crispa subsp. *amethystina* (Lag. & Rodr.) Tutin	le
Lactuca perennis L. subsp. *granatensis* Charpin & Fernández. Casas	se
Leontodon boryi Boiss. ex DC.	se
Lepidium hirtum subsp. *stylatum* (Lag. & Rodr.) Thell.	le
Leucanthemopsis radicans (Cav.) Heywood	le
Linaria aeruginea (Gouan) Cav. subsp. *nevadensis* (Boiss.) Rivas Martínez, Asensi, Molero Mesa & F. Valle	le
Lotus corniculatus L. subsp. *glacialis* (Boiss.) Valdés	le
Nepeta amethystina Poiret. subsp. *laciniata* (Willk.) Ubera & Valdés	se
Pimpinella procumbens (Boiss.) H.Wolff	le
Plantago nivalis Boiss.	le
Plantago radicata Hoffmm. & Link subsp. *granatensis* (Willk.) Rivas Martínez, Asensi, Molero Mesa & F. Valle	le
Poa minor Gaudin subsp. *nevadensis* Nannfeldt	le
Reseda complicata Bory	le
Saxifraga nevadensis Boiss.	le
Sempervivum nevadense Wale	le
Senecio boissieri DC.	se
Senecio pyrenaicus Loefl. subsp. *granatensis* (Boiss. ex DC) Rivas Martínez	se
Sideritis glacialis Boiss.	le
Teucrium lerrouxii Sennen	se
Thymus serpylloides Bory subsp. *serpylloides*	le
Trisetum glaciale (Bory) Boiss.	le
Viola crassiuscula Bory	le
Vitaliana primuliflora subsp. *assoana* M.La¡nz	le

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