

Ecology and Population Structure of Two Heathland Species, Endemic in Southern Portugal. *Centaurea crocata* and *Centaurea fraylensis* (Asteraceae)

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Abstract. Distribution, sociology and population structure of *Centaurea crocata* and *C. fraylensis* were studied in the Serra de Monchique, the mountainous hinterland of the Algarve. The Serra is the main area of distribution of *Centaurea crocata* and the exclusive area of distribution of *C. fraylensis*. Field data were collected from April to July 1998. 51 phytosociological relevés were made in all kinds of habitats where *Centaureae* occurred. To analyse their population structure, vegetative morphometric parameters (plant height, rosette diameter, root collar diameter) were measured on 434 individuals of *C. crocata* and 296 of *C. fraylensis*. All studies were restricted to non-destructive observations.

The species are restricted to the more humid western and northern parts of the Serra. *C. crocata* shows a wider ecological range than *C. fraylensis* with respect to the number of populations (38; 15), altitude (290-840m; 300-500m a.s.l.), substrate (schists and syenite; only schists) and total distribution. Both species are constant character species of the *Quercus-Stauracanthetum*, a vegetation type which originated on wind exposed mountain ridges with shallow soils in the mesomediterranean belt. The main strategy of the *Centaurea*-species is that of a siter; they can resprout from the napiform root after damage or burning. The generative reproduction strategy is supported by vegetative propagation. If vital populations are nearby, they are able to colonise roadside verges, forest pathways, firebreaks and terraced slopes with *Eucalyptus* plantations. There, they are associates of [*Ericion umbellatae*]-basal communities. The pioneer character of *C. crocata* is more distinct than that of *C. fraylensis*. The enormous variability of all the measured vegetative parameters does not allow one to draw conclusions about the age structure of the populations studied or to look for correlations between population structure and habitat. Both species must be considered as potentially endangered by the current land-use changes in the Serra. Finally, some deficits in the knowledge of their reproductive biology and further research topics are mentioned and the needs for conservation efforts are strengthened.

Key words: Serra de Monchique; *Ericion umbellatae*; plant sociology; population biology; reproduction; conservation biology; endangered plants

Sumário. Estudou-se a distribuição, sociologia e dimensão das populações de *Centaurea crocata* e *C. fraylensis* na Serra de Monchique, zona montanhosa interior do Algarve. Esta é a principal

área de distribuição destas espécies. Foram colhidos dados de campo entre Abril e Julho de 1998. Efectuaram-se 51 inventários fitossociológicos em todos os tipos de habitat onde estas espécies ocorrem. Para analisar a estrutura das populações, mediram-se parâmetros morfométricos vegetativos (altura da planta, diâmetro da roseta, diâmetro do colo da raiz), respectivamente, em 434 e 296 indivíduos. Todo o estudo se restringiu a observações sem colheita.

As espécies estudadas distribuem-se apenas pelas encostas Norte e Oeste da serra, mais húmidas. A *C. crocata* apresenta uma amplitude ecológica maior do que a *C. fraylensis*, no que respeita ao número de populações (38; 19), altitude (290-840 m. s. m.; 300-500 m. s. m.), substrato (xistos e sienitos; apenas xistos) e distribuição total. Ambas as espécies são características de *Quercus-Stauracanthetum*, um tipo de vegetação original das cadeias montanhosas expostas ao vento, em solos delgados, na cintura mesomediterrânica. Estas espécies de *Centaurea* têm, antes de mais, uma estratégia de *sitters*, pois rebentam de toija, após fogo, a partir da sua raiz napiforme. A sua estratégia reprodutiva de regeneração assenta na propagação vegetativa. Se existirem populações vitais nas proximidades, estas espécies conseguem colonizar bermas de estrada, caminhos florestais, aceiros e plantações de *Eucalyptus* em socolcos. Surgem aí associadas a comunidades basais de *Ericion umbellatae*. O carácter pioneiro da *C. crocata* é mais óbvio do que o da *C. fraylensis*. A grande variabilidade dos vários parâmetros vegetativos medidos não permite retirar conclusões acerca da estrutura etária das populações estudadas, nem estabelecer correlações entre a estrutura das populações e o habitat. Ambas as espécies devem ser consideradas potencialmente ameaçadas pelas actuais alterações do uso do solo que se observam na serra. Finalmente, são apontadas algumas lacunas no conhecimento da biologia reprodutiva destas espécies, assim como tópicos para investigação futura e reforço das medidas de conservação das mesmas.

Palavras-chave: Serra de Monchique; *Ericion umbellatae*; fitossociologia; biologia populacional; reprodução; conservação; plantas ameaçadas

Résumé. Une étude de la distribution, sociologie et dimension des populations de *Centaurea crocata* e *C. fraylensis* a été réalisée dans la "Serra de Monchique", zone montagneuse de l'Algarve intérieur. Cette zone est la principale aire de distribution de ces espèces. Des résultats ont été recueillis sur le terrain entre les mois d'avril et juillet 1998. 51 inventaires phytosociologiques ont été effectués dans tous les types d'habitats où ces espèces sont présentes. Afin d'analyser la structure des populations, les paramètres morphométriques végétatifs (hauteur de la plante, diamètre de la rosette, diamètre du col de la racine) ont été mesurés sur respectivement 434 et 296 individus. Toute l'étude se limite à des observations sans cueillette.

Les espèces étudiées sont seulement distribuées sur les versants humides Nord et Ouest du massif. La *C. crocata* présente une amplitude écologique supérieure à celle de *C. fraylensis*, en ce qui concerne le nombre de populations (38; 19), l'altitude (290-840 m.s.m.; 300-500 m.s.m.), le substrat (schistes et syénites; schistes seulement) et la distribution totale. Les deux espèces sont caractéristiques du *Quercus-Stauracanthetum*, type de végétation originaire des chaînes montagneuses exposées au vent, sur des sols minces et appartenant à la ceinture mésoméditerranéenne. Ces espèces de *Centaurea* ont, avant tout, une stratégie de "sitters", vu que suite à un feu elles reprennent de souche de leur racine napiforme. Leur stratégie de régénération repose sur la propagation végétative. Si des populations vitales existent à proximité, ces espèces arrivent à coloniser les bermes, les chemins forestiers, les chemins coupe-feux et les plantations d'*Eucalyptus* en terrasses. Elles y apparaissent associées à des communautés de bases de *Ericion umbellatae*. Le caractère pionnier des *C. crocata* est plus évident que celui des *C. fraylensis*. La grande variabilité des divers paramètres végétatifs mesurés ne permettent pas de tirer quelconque conclusion sur la structure d'âge des populations étudiées, ni d'établir des corrélations entre la structure des populations et l'habitat.

Les deux espèces doivent être considérées comme potentiellement menacées par les actuelles utilisations du sol que l'on peut observer dans le massif. Finalement, certaines lacunes sont indiquées au niveau de la connaissance de la biologie reproductive de ces espèces, de même que des topiques pour une future recherche et d'un renfort des mesures de conservation de ces mêmes espèces.

Mots-clés: Serra de Monchique; *Ericion umbellatae*; Phyto-sociologie; biologie des populations; reproduction; conservation; plantes menacées.

Introduction

The genus *Centaurea* includes in total about 800 species (WAGENITZ and HELLWIG, 1996), with the Mediterranean area and SW Asia as centres of diversity. Section *Acrocentron* with 98 taxa has an East (Balkan Peninsula) and a Southwest (Iberian Peninsula) Mediterranean centre of diversification, the latter being considered as secondary by GARCIA JACAS and SUSANNA (1992). The taxa of this section are mostly hemicryptophytes and occur in open shrubland communities in mountain ranges. Many of them are stenochoric and the section exhibits a geographical and edaphical vicariance pattern. Many taxa are restricted either to acidophilous heathland or to basiphilous garrigue and phrygana vegetation. One member of the section *Acrocentron* is *Centaurea crocata* J. do Amaral Franco 1984, a taxon which probably evolved as a fertile hybrid from the Westbetic-Algarvian *Centaurea prolongi* and a parent of section *Chamaecyanus* by neopolyploidisation (GARCIA JACAS and SUSANNA, 1992). This saffron-coloured flowering *Centaurea* is endemic in south-western Portugal (see Figure 1); its distribution ranges from the Serra de Monchique westwards to the littoral and north-westwards to the lower Alentejo near Odemira and is always linked to acid soils. The study of herbarium collections by GARCIA JACAS and SUSANNA (1994) made obvious that all the citations of

Centaurea prolongi from Portugal must be referred to *Centaurea crocata* except the specimens from the calcareous part (Barrocal) of the Eastern Algarve. The same is true for all the citations of "*Centaurea prolongi*" in geobotanical publications from the Serra de Monchique and its surroundings, for example in BRAUN-BLANQUET *et al.* (1964) and in MALATO BÉLIZ (1982).

Current knowledge about the ecological requirements of *Centaurea crocata* is quite limited. FRANCO (1984) mentions xerophilic shrublands as habitat. From the notations on herbarium sheets and from field observations, GARCIA JACAS and SUSANNA (1994) state a tendency to disturbed places (roadside banks and ditches, ploughed areas) and rocky outcrops. In the phytosociological literature, *Centaurea crocata* is mentioned for the Serra de Monchique as a "companion" species in *Cisto-Ericetum australis*-heathland by BRAUN-BLANQUET *et al.* (1964) and in *Quercus lusitanicae-Stauracanthetum boivinii*-heathland and *Phillyreo-Arbutetum*-maquis by MALATO BÉLIZ (1982). From the paper of SENG and DEIL (1999), which deals with forest vegetation in the Serra de Monchique, one can see that *Centaurea crocata* occurs with high frequency in those *Eucalyptus globulus*-forestations which have been planted in *Ericion umbellatae*-communities. A few records refer to cork-oak forests (*Sanguisorbo-Quercetum suberis* and *Myrto-Quercetum suberis*) and to *Arbutus*-maquis.

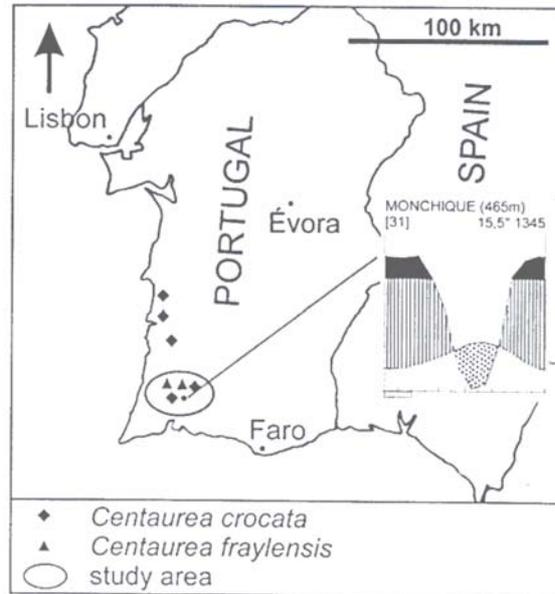


Figure 1 – Location of the study area and distribution of *Centaurea crocata* and *C. fraylensis* (after FRANCO, 1984, GARCIA JACAS & SUSANNA, 1994 and own data)

Another *Centaurea*, endemic exclusively in the Serra de Monchique, is *Centaurea fraylensis* Sch. Bip. ex Nym. 1879 from the section *Centaurea* (see Figure 1). This species is a red-violet flowering, prostrate hemicryptophyte. No ecological or plant sociological data are available in the literature. Preliminary observations showed that *Centaurea fraylensis*, like *C. crocata*, is often linked to open *Erica umbellata*-heathland.

During the last few decades, these heathland communities have been under severe land-use changes. Some major trends are the decline or even in some areas the total abandonment of traditional shifting cultivation practises, a decreasing grazing impact, the afforestation with allochton taxa like *Eucalyptus* and *Pinus* and the change of fire frequency and intensity. The most important change is the destruction of

heathlands by terracing and by *Eucalyptus* plantations. MALATO BÉLIZ complained in 1982 about the "eucalyptomania" in the Serra de Monchique. Since then, *Eucalyptus*-forestations have expanded still further. In some valleys, they cover 20 to 30% of the whole land surface (KROHMER and DEIL, 1999). To evaluate the risk if and how these landscape transformations will affect the populations of the two endemic *Centaurea* species, the following questions have to be answered:

1 - What is the current distribution of *Centaurea crocata* and *C. fraylensis* in their main/exclusive area of distribution in the Serra de Monchique?

2 - What are the ecological requirements of the two species and to which plant communities are they associated?

3 - Are they as "stenochoric" elements at the same time "stenoecious", restricted to their primary habitats and behaving as sitters? Or are they able to invade and persist in man-made habitats and expand their areal under human impact?

A first step to answer these questions is to map their current distribution, to have a closer look upon their ecological niches and their coenological character. Secondly, their life cycle and population structure should be studied in different situations. We studied both species in natural (cork-oak woodland, primary heathland), semi-natural (secondary heathland) and man-made habitats (roadside verges, fire prevention strips, etc.). Efficient conservation strategies for rare plant species must be based upon a knowledge of their demography (HOLDEREGGER, 1996). This is why we collected data about population size, demographic structure, and reproductive behaviour. These data should allow us to evaluate how the present land use changes might affect the populations of these species in the future.

The study area

Field studies were carried out in the Serra de Monchique, a mountainous region of mid altitude (902 m a.s.l. at Foia) in the Algarve hinterland (District of Faro, Portugal). It has a Mediterranean climate with Atlantic character (see climatic graph in Figure 1). Westerly winds, high humidity and frequent clouds in the summit areas reduce the severity of summer drought. The central parts of the Serra de Monchique consist of a syenite intrusion, surrounded by palaeozoic schists and graywakes. The weathering of the coarse-grained syenite results in cambisols with a sandy texture

and a high water holding capacity ("solos litólicos de sienitos" according to the classification of CARDOSO, 1965), whereas on the schists stony leptosols with low nutrient content developed (KOPP *et al.*, 1989).

The climax community in the thermomediterranean part of the Serra de Monchique is an open woodland (*Myrto-Quercetum suberis*), followed in the mesomediterranean, humid to hyperhumid parts, by dense oak forests (*Sanguisorbo-Quercetum suberis typicum* and *quercetosum canariensis*) (MALATO BÉLIZ, 1982, RIVAS-MARTÍNEZ *et al.*, 1990, SENG and DEIL, 1999). The *Phillyreo-Arbutetum unedonis* as the first degradation step of *Quercus suber*-forests is widespread and still used to gain fruits from the strawberry tree for liquor production ("medronho"). Further degradation results in heathland communities. They have expanded under human impact (fire, grazing, cutting) from a few original sites (mountain ridges heavily exposed to wind, rocky outcrops with superficial soils, hyperhumid sites with stagnant water and pseudogley) and cover currently vast areas. The heathlands show a clear bioclimatic zoning. The altitudinal series is *Genisto hirsutae-Cistetum ladaniferi*, *Cisto ladaniferi-Ulicetum argentei*, *Quercus lusitanicae-Stauracanthetum boivini*, *Erico australis-Cistetum populifolii* to *Cisto salvifolii-Ulicetum minoris*. This is congruent with a transition from *Cisto-Lavanduletea* in the Thermomediterranean to *Calluno-Ulicetea* in the Mesomediterranean. On syenite outcrops at mid altitude, the succession starts with *Halimio calycini-Ericetum australis rosmarinetosum* ined. with *Sileno melliferae-Ranunculetum bupleuroides* ined., goes on to *Stauracantho-Drosophylletum* and ends up with the *Osyrio*

quadripartitae-Juniperetum turbinatae (DEIL *et al.*, in prep.).

Phytogeographically, the study area belongs to the western part (Monchiquense sector) of the Tingitano-Onubense-Algarviense province (GALÁN DE MERA and VICENTE ORELLANA, 1996). Outstanding elements of this province are the character and differential species of the heathland suballiance *Stauracanthion boivinii* (*Ericion umbellatae, Calluno-Ulicetea*), distributed in the mountainous arc from the Serra de Monchique in Southern Portugal via the Sierras de Algeciras (SW Spain) to the Western Rif Mountains (Morocco). These heathlands are remarkable by their degree of endemism and species richness (OJEDA *et al.*, 1995, GALÁN DE MERA and VICENTE ORELLANA, 1996). *Centaurea crocata* and *C. fraylensis* contribute to the Monchiquense endemism.

Methods

Field data were collected between April and July 1998. In the Serra de Monchique, the local distribution of both *Centaurea* species was mapped (Figure 2). 51 phytosociological relevés were made in all habitats (primary and secondary) where the *Centaureae* occurred. To see whether the species exhibit an apophytic character, even impoverished stands at roadside verges and on forest tracks were examined. Structural transects of several meters length with exact position and size of the *Centaureae* and their neighbouring specimens were studied in order to describe the spatial patterns in selected habitats.

To analyse the population structure, vegetative morphometric parameters, which can be interpreted as age-stages or vitality characters (BARKHAM, 1980;

HOLDEREGGER, 1997), were measured. These parameters are plant height, rosette diameter, root collar diameter, number of leaves per rosette and maximal leaf length per specimen. We wanted to see whether these parameters differ according to habitat and associated species. In total, 434 individuals (*Centaurea crocata*) and 296 individuals (*C. fraylensis*) in eight and five different populations were examined. All studies were restricted to non-destructive observations, subterranean parts having been investigated only in a very few specimens. To get an insight into the generative reproduction strategy, the following data were collected in six populations: Number of buds, flowers, achenes per capitulum.

Classification and nomenclature of the plant communities is according to the Zurich-Montpellier school (BRAUN-BLANQUET, 1964; DIERSCHKE, 1994). Cover-abundance values in phytosociological relevés are according to BRAUN-BLANQUET (1964). Impoverished stands are typified following the concept of basal communities sensu KOPECKY and HEJNY (1974). Nomenclature of plant species follows VALDÉS *et al.* (1987).

Results

Local distribution and number of populations: In the Serra de Monchique *Centaurea crocata* is known to exist in 38 locations (Table 1, Figure 2) (further populations, which are not part of this study, occur in coastal regions of the Alentejo). *Centaurea fraylensis*, a species restricted to the Serra de Monchique, was discovered in 15 localities. The two species are co-habitants in nine locations. Both species are restricted to the more humid western and northern parts of the

Serra (Figure 2), they have not been observed in the lower, drier parts of the Serra do Espinhaço de Cão (ESPIRITO SANTO 1989), nor in the south-eastern part of the Serra de Monchique. For *Centaurea crocata*, the altitude of the localities on schists ranges from 290 m to 500 m a.s.l., i.e. from the thermo- to the mesomediterranean bioclimate level (Figure 3). Six populations on syenite near the Foia summit are situated

between 720 and 840 m a.s.l.. The populations of *Centaurea fraylensis* are restricted to schists, the altitude ranges from 300 to 500 m a.s.l.. For both species, the occurrence on mountain ridges and on slopes in western aspect are predominant. *Centaurea crocata* shows a wider ecological range than *C. fraylensis* with respect to the number of populations, altitude, substrate and total distribution.

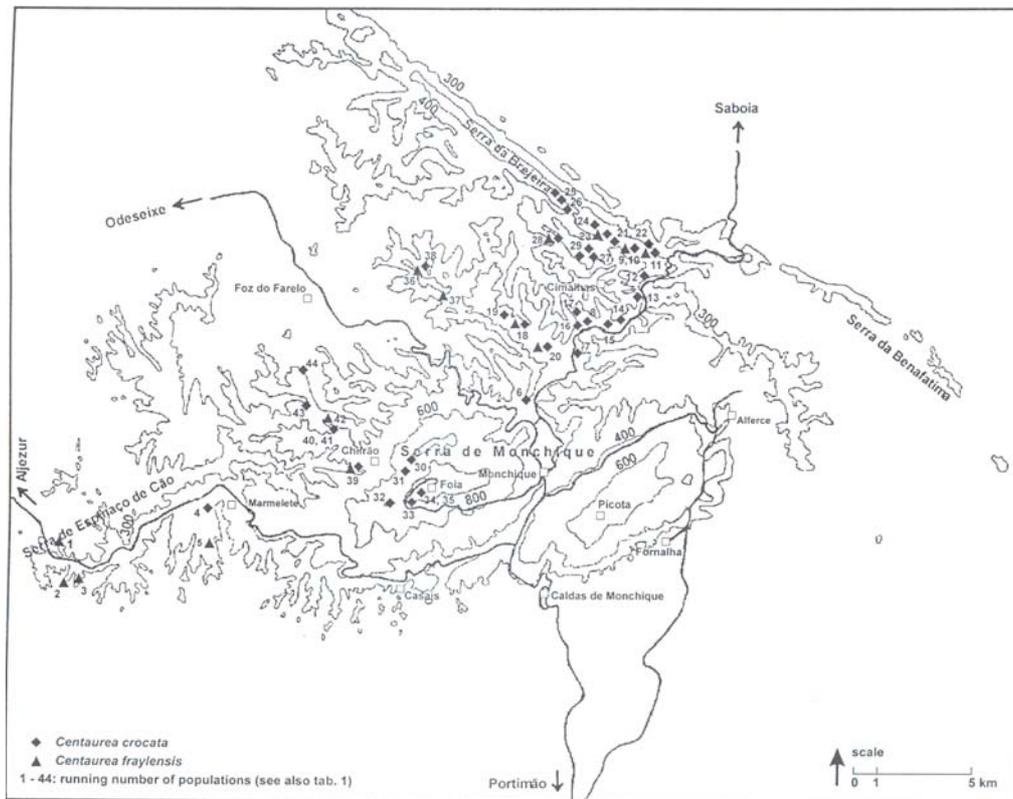


Figure 2 – Distribution of *Centaurea crocata* and *C. fraylensis* in the Serra de Monchique (the syenite area is marked with grey)

Table 1- Environmental conditions and flowering rate of the populations according to habitat and associated species

popu- lation	<i>Centaurea</i>		altitude [m a.s.l.]	aspect	sub- strate	flowering rate [%]													
	<i>crocata</i>	<i>fraylensis</i>				<i>Centaurea crocata</i>			<i>Centaurea fraylensis</i>										
						t.p.	habitats			t.p.	habitats								
							A	B	C		A	B	C	D					
1		x	320-325	W	schists														
2		x	310	W	schists					-									
3		x	315-340	E, NW	schists					25	30	-	38						
4	x		390	NW, SW	schists		33	0											
5		x	370	NW, SW	schists						-	-							
6	x		430	SW, W	schists	17													
7	x		460	SW, W	schists		29	52											
8	x		470	SE	schists	-													
9	x		480-500	NE, SW, N	schists		40	33	71										
10	x	x	460	N	schists	-				24									
11	x	x	470	SW, SE	schists		10	37			50	38							
12	x		430	SSE	schists	-													
13	x		430	E	schists	-													
14	x		430	W	schists	9													
15	x		460-480	S	schists	-													
16	x		460	SSW	schists	20													
17	x		450	W	schists	-													
18	x	x	470-475	NW, SE, SW	schists		33	38	10		45	48	30						
19	x		480	S, SW, SE	schists	-													
20	x	x	495	SW	schists	-				-									
21	x	x	470	S, SE	schists	-				-									
22	x		460	S	schists	-				-									
23	x	x	430	S	schists		-	-			-	-							
24	x		460	S, W	schists	-													
25	x		430	SE, E	schists	-													
26	x		430	SW	schists	-													
27	x		480	N, NE	schists	-													
28	x	x	465	W, NW, N	schists	-				-									
29	x		470	W	schists	-													
30	x		760	W, NW	syenite	-													
31	x		720	S, SE	syenite	-													
32	x		790	NW	syenite	-													
33	x		815	S	syenite	-													
34	x		820	SW	syenite	-													
35	x		840	S, SW	syenite	-													
36		x	410	SW	schists					-									
37		x	420	W	schists					-									
38	x	x	400	NW	schists	-				-									
39	x	x	460	NE, E	schists	-				-									
40	x		400	NE, N	schists	-													
41	x		410	E	schists	-													
42	x		350	NWN	schists	-													
43	x		330	NW	schists	-													
44	x		290	E	schists	-													

t.p.: total population;

-: data about flowering rate not available

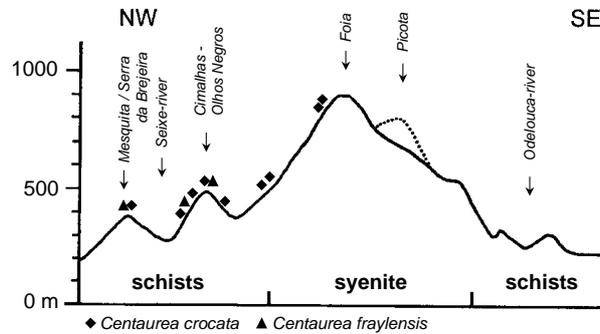


Figure 3 – Altitudinal arrangement of both species along a schematic profile through the Serra

Sociology of the *Centaurea*-species:

The type relevé of the *Quercus lusitanica*-*Stauracanthetum boivinii* selected by RIVAS-MARTÍNEZ *et al.* (1990) from MALATO BÉLIZ (1982), includes *Centaurea crocata* (as "*C. prolongi*") as a companion. From table 2 presented here and from a synoptic view of the heathland communities in the Serra de Monchique (DEIL *et al.*, in prep) it becomes quite evident that both *Centaureae* have their highest frequency and abundance in open *Erica umbellata*-*Stauracanthus boivinii*-heathlands. They are good character species of the *Quercus-Stauracanthetum* (Table 2, columns 1-23), an association which is endemic in the Monchiquense sector (GALÁN DE MERA and VICENTE ORELLANA 1996). This community is concentrated in the humid western and north-western schistous parts of the Serra and occurs exclusively on wind exposed mountain ridges with stony soils and with a shallow or even completely missing humus layer. From these sites, which seem to be original heath habitats, the heathlands have expanded under human impact to *Phillyreo-Arbutetum*-climax sites and to originally open *Quercus suber*-woodland

sites. Currently, the traditional land-use (burning and pasturing) is abandoned and high-growing shrubs are invading these secondary *Erica umbellata*-heathlands.

To a large extent, the heathlands have been transformed into *Eucalyptus globulus*- and *Pinus pinaster*-plantations within the last few decades (MALATO BÉLIZ, 1982, KROHMER and DEIL, 1999). In the ground layer of these forests, the floristic composition resembles to that of non-reforested sites (Table 2, columns 24-30). *Centaurea crocata* and *C. fraylensis* still occur there. The plant cover however is much more open and the sites are often terraced before planting. This vegetation type was called "matas artificiais" by MALATO BÉLIZ (1982). It is identical with type 10 (*Eucalyptus*-afforestations in *Quercus lusitanica*-heathland) in SENG and DEIL (1999). Both *Centaurea*-species seem to be able to recolonize these terraces or to survive under a planted open *Eucalyptus*- or *Pinus*-canopy. In these heathland fragments, which can be named according to the nomenclature of KOPECKY and HEJNY (1974) [*Stauracanthetion*]-basal community, constant and typical members of the *Quercus-Stauracan-*

thetum are missing or very rare: in the shrub layer *Erica umbellata*, *Lavandula luisieri*, *Cistus ladanifer*, *C. populifolius*, *Lithodora prostrata*, *Thymelaea villosa* and *Thymus villosus*, in the herb layer *Ornithogalum broteroi*, *Epipactis helleborine* and *Carex depressa*. Both *Centaurea*-species can even expand to sites with high disturbance like roadside ditches, forest pathways and timber storage areas if a population is nearby (Figure 4, Table 2, columns 25, 26, 30). These stands can be still more impoverished and in this case be typified as [*Ericion umbellatae*]-basal community (Table 2, columns 34-36). In higher altitudes and at northern slopes, *Quercus-Stauracanthetum* is replaced by *Erico australis-Cistetum populifolii*. The *Erica australis*-heathland grows taller and more densely than the *Erica umbellata*-dominated heathland. Six populations of *Centaurea crocata* were discovered in this association near the summit of Foia (Table 2, columns 31-33). These are the only populations of this species on syenite. *Centaurea crocata* is associated there with *Ulex minor*, *Cistus crispus* and *Cistus psilosepalus* and with species indicating grazing pressure (*Cynara algarbiensis* among others). The *Pteridium aquilinum-fazies* of this association is however avoided by *Centaurea crocata*.

In other plant communities and habitats, *Centaurea crocata* and *C. fraylensis* occur only sporadically and in small populations. Some individuals were observed in the heathland community *Cisto-Ericetum australis* (Table 2, columns 38-43), in the rock community *Sileno melliferae-Ranunculetum bupleuroidis* (Table 2, columns 44-47) and in open cork-oak forests (*Myrto-Quercetum suberis*, Table 2, column 48-51).

We can conclude from the phytosociological data that *Centaurea crocata* and *C. fraylensis* are good character species of intact *Quercus-Stauracanthetum*-communities. *Erica umbellata*-heathland is the primary habitat of both species. Starting from this heathland, they are able to colonize neighbouring man-made habitats (forest roads, roadside verges, fire breaks, terraces, *Eucalyptus*-plantations, etc.). Both species show a kind of apophytic character and some pioneer features. Whether the occurrence in habitats with different disturbance regimes is reflected in the population characters and to what extent the species are endangered or favoured by changing land-use will be discussed now.

Plant size variability and population structure: The graphs in Figure 5 show the correlation between height classes, rosette size and flowering rate in all measured specimens (434 individuals of *C. crocata*, 296 of *C. fraylensis*) from different populations. Both species, within and between the populations, show a remarkable variability in all these parameters. For example in *C. fraylensis*, the rosette diameter ranges from 5 to 45 cm and the leaf number per rosette from 1 to 40. In both species, rosette diameter > 4 cm is the minimum size for flowering. In all populations, a considerable number of rosettes remains vegetative. The average rosette diameter within populations ranges from 9 to 14 cm (*C. crocata*) and from 11 to 22 cm (*C. fraylensis*). There are no clear correlations between rosette diameter and habitat or between leaf number and habitat, but significant correlations between rosette diameter and flowering rate and the leaf number and flowering rate (Figure 6, A-D).

Appendix table 2:

Additional species with low constancy:

Adenocarpus complicatus anisochilus 33:2, 37:1; *Agrostis castellana* 6:+, 37:+; *Aira cupaniana* 40:+; cf. *Allium scorzonerifolium* 48:1; *Anarrhinum bellidifolium* 38:1; *Anthyllis gerardii* 33:x; *Anthyllis lotoides* 43:1; *Avena barbata lusitanica* 47:1; *Bellis sylvestris* 10:+, 13:+; *Briza maxima* 33:2, 44:+; *Calamintha sylvatica ascendens* 37:+; *Cetraria aculeata* 16:+; *Chamaerops humilis* 26:1; *Cladonia spec.* 20:1; *Coleostephus myconis* 22:+; *Conopodium thalictrifolium* 40:+, 42:+; *Coronilla dura* 33:1, 43:x; *Cytinus hypocistis* 10:+, 43: +; *Cytisus striatus* 14:+, 32:x; *Daucus carota* 37:+, 39:+; *Dipcadi serotinum* s.str. 47:+; *Distichoselinum tenuifolium* 51:1; cf. *Elaeoselinum asclepium* 26:1; *Erica ciliaris* 20:1; *Fritillaria lusitanica* 16:+; *Gladiolus communis* 33:+; *Holcus grandiflorus* 34:+; *Holcus mollis* 43:+; *Hypericum perfoliatum* 24:x; *Hypericum perforatum* 25:+; *Hypochaeris glabra* 40:+, 46: +; *Hypochaeris radicata* 16:+; *Lathyrus angulatus* 43:+; *Limodorum abortivum* 32:x; *Lotus parviflorus* 43:+; *Lotus subbiflorus castellanus* 39:x; *Micropyrum tenellum* (incl. *patens*) 46:1; *Ornithopus pinnatus* 43:+; *Orobanche cf. gracilis* 33:x; *Phagnalon saxatile* 23:+, 43:+; *Picris composita lusitanica* 23:+, 38:+; *Pistacia lentiscus* 26:+; *Plantago lanceolata* 37:1; *Pleurozium* sp. 17:2; *Polytrichum piliferum* 46:+; *Rhacomitrium heterostichum* 46:+; *Rubus ulmifolius* 23:+; *Scandix pecten-veneris* 23:2; *Sedum sediforme* 46:+; *Senecio liooidus* 14:+; *Senecio vulgaris* 43:+; *Serapias cordigera* 38:+; *Sherardia arvensis* 23:+; *Thesium divaricatum* 25:1; *Tuberaria macrosepala* 43:+, 46:1; *Ulex argenteus* 10:+; *Vicia angustifolia* 44:+, 45:x; *Vicia pubescens* 10:+ ; *Vulpia geniculata* 29:+; *Vulpia myuros* s.str. 43:+

localities, date of relevés:

- 1: Olhos Negros, 18.05.1998
2, 15: Olhos Negros south of Joana Mendes, 13.5.1996
3, 21: Serra da Brejeira, 13.5.1996
4: Chilhão, 23.06.1998
5: Corchas, 16.06.1998
6, 18, 19: Cimalhas, 25.4.1995
7: Serra de Brejeira near Mesquita, 04.06.1998
8: Serra de Espinhaço de Cão west of Marmelete, 27.04.1998
9: Cimalhas, 05.05.1998
10: Cimalhas, 16.06.1998
11: Serra da Benafatima near Taipas, 11.06.1998
12: Serra de Espinhaço de Cão west of Marmelete, 24.04.1998
13, 14: Malhães, 13.5.1996
16, 17: Cimalhas, 13.5.1996
20: west of Chilhão, 9.6.1995
22: Odeceixe valley, 13.5.1996
23: Serra do Espinhaço de Cão near Marmelete, 1.4.1995
24, 25: Mesquita (Serra de Brejeira), 04.05.1998
26, 29: Padescas, 17.04.1998
27: Serra de Espinhaço de Cão west of Marmelete, 28.04.1998
28: Cimalhas, 23.04.1998
30: Mesquita (Serra de Brejeira), 01.05.1998
31: west of Foia summit, 08.06.1998
32, 33: west of Foia summit, 09.06.1998
34: Eira do Bufo, 21.04.1998
35: Cerro Redondo, 04.06.1998
36: Mesquita (Serra de Brejeira), 23.04.1998
37, 39, 41: Serra de Espinhaço de Cão west of Marmelete between Porto do Lobo and Abitureira, 1.4.1995
38: Barranco do Besteirinho, 24.4.1995
40, 42: Malhães (Serra da Brejeira), 13.5.1996
43: Odelouca valley near Madeiras, 25.3.1996
44, 45: Serra da Brejeira near Mesquita, 13.5.1996
46: Cerro da Malhada Velha, Picota, 19.3.1996
47: Picota summit, 18.4.1996
48: Casais, 18.04.1998
49: between Casais and Marmelete, 26.05.1998
50: Fornalha, 22.04.1998
51: north of Monchique, 06.05.1998

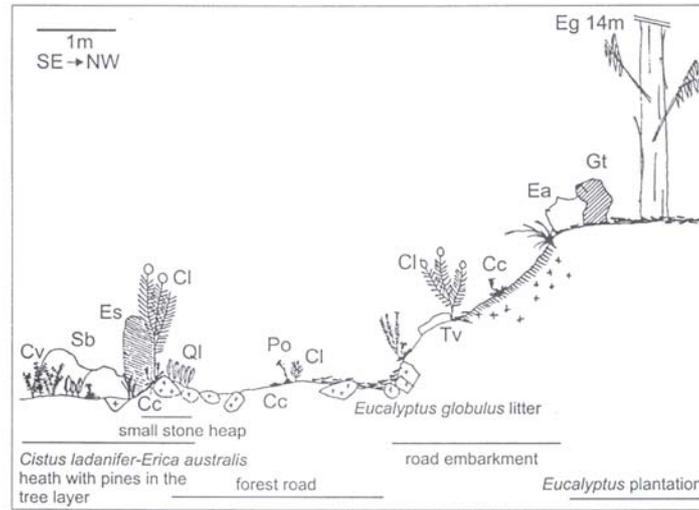


Figure 4 - *Centaurea crocata* in man-made habitats. Structure and floristic composition in a habitat series forest road - road embankment - *Eucalyptus*-plantation.

(Abbreviations: Cv: *Calluna vulgaris*, Cc: *Centaurea crocata*, Cl: *Cistus ladanifer*, Ea: *Erica australis*, Eg: *Eucalyptus globulus*, Es: *Erica scoparia*, Gt: *Genista tridentata*, Ls: *Lavandula stoechas*, Po: *Pulicaria odora*, Ql: *Quercus lusitanica*, Sb: *Stauracanthus boivinii*, Tv: *Thymus villosus*)

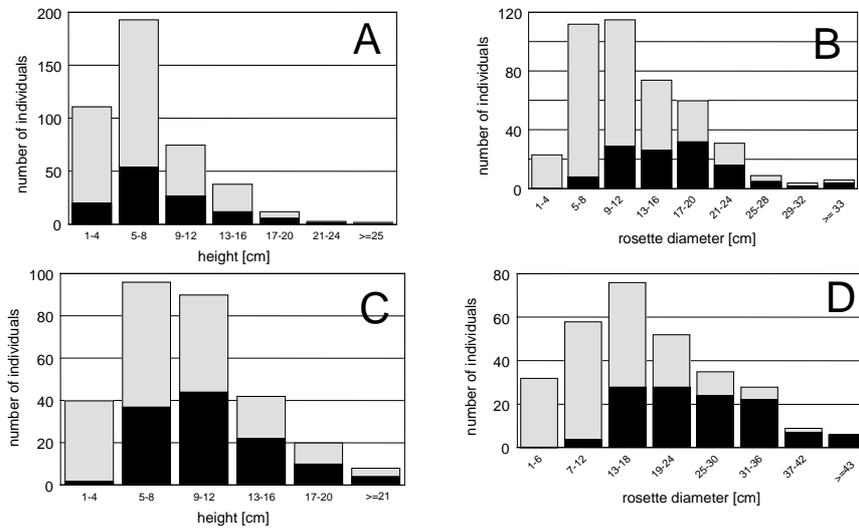


Figure 5 - Plant size (height, rosette diameter) with those which were flowering in black in *Centaurea crocata* (A, B) and *C. fraylensis* (C, D) populations (total number of measured individuals: *C. crocata* 434, *C. fraylensis* 296)

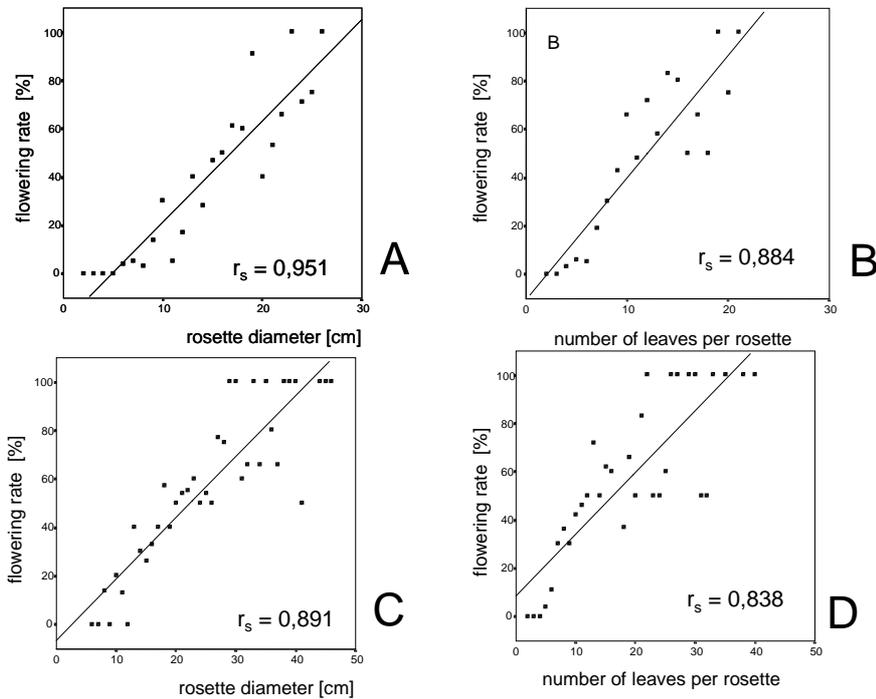


Figure 6 - Correlation between vegetative parameters (rosette diameter, number of leaves/rosette) and flowering rate in *C. crocata* (A, B) and *C. fraylensis* (C, D) populations ($p < 0,01$, Spearman's correlation coefficient r_s) (number of measured specimens: 25 (A), 20 (B), 39 (C), 33 (D))

To see how the density of the plant canopy and the co-occurring species affect the morphology of the *Centaureae*, the data were analysed according to populations in different communities. Although plant height of both species varies considerably within the populations, individuals from heathlands are significantly taller than those from open areas like road embankments, etc. ($P < 0.001$, Mann-Whitney U-test). The same can be stated for maximum leaf length.

Correlations between the measured vegetative parameters were calculated for the total population as well as for separate populations. In *Centaurea*

crocata, all vegetative parameters are significantly correlated, in *C. fraylensis*, only the parameters rosette diameter and number of leaves are significantly correlated to each other in all populations.

The knowledge about the reproductive phase of the life cycle of both species is quite preliminary. We made some observations about the flowering rate and seed production. In 1998, *Centaurea crocata* started flowering at the end of April, fructification began in June whereas fructification of *Centaurea fraylensis* started two weeks later. For some populations, which occur in close neighbourhood in different habitats, the flowering rate was recorded

during flowering peak. There are no clear correlations between flowering rate and plant community (Table 1).

Centaurea crocata produces about 50 (mean value, $n = 4353$), *Centaurea fraylensis* about 27 (mean value, $n = 844$) achenes per capitulum. There is a considerable reduction of the reproductive organs by pasturing animals who browse the flowering heads of *Centaurea crocata*. The heads of *Centaurea fraylensis* are often attacked by the larvae of *Curculionidae* who are predators of the fruits. In both species, fruit setting does not differ significantly according to the habitats and is not correlated with the sampled vegetative parameters.

The generative reproduction strategy is combined with vegetative propagation. The plants can resprout from the napiform root when the aboveground parts have been damaged by browsing or destroyed by fire. Both species develop long subterranean creeping roots (up to 40cm long with eight daughter rosettes) which send secondary roots to the surface. It is unknown whether the *Centaureae* are only able to fill gaps in the plant canopy by this clonal growth strategy without rising the number of individuals or whether self-cloning results in more individuals and in short-range dispersal.

Discussion

Centaurea crocata and *C. fraylensis* can be described as "rare" relative to distribution, habitat specification and population size (RABINOWITZ *et al.*, 1986), they are stenochoric as well as stenoecious. Comparing both species, there is a congruence concerning local distribution, total area and sociological range. In all these characters, *Centaurea*

crocata has a broader range. *C. fraylensis* is a narrow endemic in the strictest sense (KRUCKEBERG and RABINOWITZ, 1985).

From the available plant sociological data we can conclude that both species are nearly exclusively associated to low-growing acidophilous *Erica umbellata*-heathland. They are good character species of the *Quercus-Stauracanthetum*, a vegetation type which is original on wind exposed mountain ridges with shallow soils in the mesomediterranean belt. Episodical fire is an intrinsic factor of this ecosystem. The community can expand to less shallow soils, favoured by a higher, man-made fire-frequency and by clearing of the forests.

The main strategy of the *Centaurea*-species is that of a sitter and they exhibit a kind of guerilla strategy by clonal growth. They can resprout after burning. Like in *Taraxacum serotinum* (MOLNAR and BOKROS, 1996), the resprouting capacity from napiform roots in the two *Centaureae* can be interpreted as an adaptation to disturbance. Apart from their sitter character, *Centaurea crocata* and (less evident) *C. fraylensis* have also a certain pioneer character. They can recolonize roadside verges, fire breaks and terrace slopes after disturbance if vital populations are nearby.

Centaurea crocata ($2n = 40$) belongs to the group of neopolyploid taxa within section *Acrocentron* with basic chromosome number 10, which shows a greater ecological plasticity and colonizing capacity than the palaeopolyploidic group with basic chromosome number 11. The latter are mostly chasmophytes and survived in small relictic areas (GARCIA JACAS and SUSANNA, 1992).

Unlike with other species like *Drosophyllum lusitanicum* (MÜLLER and DEIL, 2001), *Crepis tectorum*

(ANDERSSON, 1989) and *Saxifraga mutata* (HOLDEREGGER, 1996, 1997), where vegetative parameters like plant height, rosette diameter, lignification of the basal shoot, etc. can be used as differentiating qualities of adult versus juvenile plants and as indirect parameters for life-phases respectively age-stages (BARKHAM, 1980), this approach has not been successful in our study with the *Centaureae*. The enormous variability of all measured vegetative parameters in *Centaurea crocata* and in *C. fraylensis* did not allow us to draw conclusions about the age structure of the studied populations nor to look for correlations between population structure and habitat. In a gardening experiment, the correlation between age and root collar diameter should be investigated in a planted population as a way to get an insight into the age structure of the field populations.

Conclusions

Centaurea crocata and *Centaurea fraylensis* can be considered as potentially endangered species. They occur in isolated populations, often in small individual numbers and they have not even the minimal protection status. In the Serra de Monchique, there does not exist a single nature reserve at the moment. Apart from the extremely rare *Rhododendron*-ravines, the most interesting places in the Serra from the botanical point of view are some mountain ridges in the schistous part of the Serra with *Quercus-Stauracanthetum* and its endemics *Centaurea crocata* and *C. fraylensis* and some rocky outcrops in the central syenite area. All these sites should be protected from *Eucalyptus*-plantations, from changes of the

hydrological system and from the direct destruction by terracing and by syenite exploitation.

The current land-use trends can affect the populations in different and contradicting ways. A diminishing grazing pressure of heathland might reduce the germination niches, but favour the life span and the vegetative regeneration. The abandonment of the traditional pasture use and the burning management of secondary *Ericion umbellatae*-heathland will allow the regrowth of dense *Erica australis*-heathland and of the tall-growing *Phillyreo-Arbutetum*-maquis. This will reduce the area of the *Quercus-Stauracanthetum* to its original sites. It is unknown whether *Centaurea crocata* and *C. fraylensis* can persist under *Eucalyptus globulus* or *Pinus pinaster* and to which extent they can tolerate the shadowing and the litter production by these trees. In the Serra de Monchique, such plantations have often been established at the *Quercus-Stauracanthetum*-sites in the last few decades.

Currently, data about the dispersal strategy and efficiency of *Centaurea crocata* and *C. fraylensis* are totally missing. We do not even know which dispersal agents are effective. Myrmecochory, which was documented for the stenochoric cliff-species *Centaurea corymbosa* (COLAS *et al.*, 1997), may be possible also for the *Centaureae* studied here. With additional data about the dispersal strategy and efficiency it might be possible to determine to which extent their geographical distribution is limited by a restricted colonizing capacity (KRUCKEBERG and RABINOWITZ, 1985) or by their specific ecological requirements. We also do not know whether the species perform a transient

or permanent seed bank. Furthermore, our knowledge about the generative reproduction is scanty. Data about germination rate and seedling survival are totally missing. A long-term biomonitoring program should be implemented in the different ecological and sociological situations where *Centaurea crocata* and *C. fraylensis* do occur.

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