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Temporihygrophilous *Quercus broteroi* forests in southern Portugal: Analysis and conservation

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Abstract

This article deals with a phytosociological survey of marcescent Portuguese oak (*Quercus broteroi*) forests in southern Portugal, and presents the results of an analysis of 56 relevés, combining Braun–Blanquet's methodology with hierarchical cluster analysis (Ward's Hierarchical Clustering, based on Bray–Curtis distance). From these results, a new temporihygrophilous Portuguese oak forest association is described. Largely thermomediterranean, upper dry to subhumid, *Ulici welwitschiani–Quercetum broteroi* occurs on limestone soils within the Coastal Lusitan-Andalusian Province. Its high conservation value – mainly due to its rarity and floristic structure – supports this forest's integration in Habitat 9240 (Annex B-I from Council Directive 92/43/EEC) in order to ensure its preservation. Based on the results, new biogeographic borders for the Ribatagan-Sadensean Sector are proposed.

Keywords: *Biodiversity conservation, hierarchical cluster analysis, phytosociology,* Quercus broteroi *woodlands, Vale do Guizo formation*

Introduction

As mature stages representative of the Holarctic kingdom, deciduous marcescent forests appear as characteristic formations in typically Sub-Mediterranean ecotones, marking the transition between Temperate bioclimates and those genuinely Mediterranean (Rivas-Martínez 2005a).

Several studies have investigated marcescent groves in the Mediterranean basin region, including Blasi and Di Pietro (1998), Allegrezza et al. (2002), Blasi et al. (2004), Di Pietro and Tondi (2005), Allegrezza et al. (2006), Biondi et al. (2006), Di Pietro et al. (2010) and Biondi et al. (2010) on the Italian Peninsula; Georgiadis et al. (1990) on the Greek Peninsula; Kaya and Raynal (2001), Ketenoglu et al. (2010) and Kavgaci et al. (2010) on the Anatolian Peninsula; Gavilán et al. (1998), Cano et al. (2001), del Río & Penas (2006), Pinto-Gomes et al. (2007); and Del Río et al. (2007) on the Iberian Peninsula.

Also in the Middle East, these marcescent formations are important study cases as revealed by Basiri (2010), Papini et al. (2011) and Shiran et al. (2011).

Flora Ibérica (Castroviejo et al. 1990) recognizes two subspecies of *Quercus faginea*: *Q. faginea* subsp. *faginea* Lam. and *Q. faginea* subsp. *broteroi* (Cout.) A. Camus. However, disregarding Flora Ibérica, Rivas Martínez and Saénz Laín raised the latter to an independent species as *Quercus broteroi* (Cout.) Rivas Mart. & C. Sáenz. This is the main taxonomical reference used in this study.

Following Ceballos and Ruiz de La Torre (2001), *Q. faginea* is characteristic of continental climates and is present in a wide range of temperatures, from

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a minimum of −25°C to a maximum of 45°C (Ayanz 1986 in Correia & Oliveira 2003). Autochthonous in the Iberian Peninsula and North Africa (Morocco, Tunisia and Algeria), *Q. faginea* occurs in almost all Spanish provinces, except in the northwest and on the Balearic Islands (Ceballos & Ruiz de la Torre 2001). In Portugal, large tracts of *Q. broteroi* are found in the Arrábida, Sintra, Montejunto and Aire e Candeeiros mountains, as well as in the vicinity of Tomar, Pombal and Leiria (Capelo & Catry 2007).

Study area

The climate of southern Portugal is Mediterranean. Summers are very hot and dry, while winters are fresh. Annual precipitation levels are around 500–800 mm, with a maximum occurring between October and May with 400–700 mm rainfall (Ribeiro et al. 1988). Geomorphologically, the entire region lies completely within the Hesperic Massif, an area composed of sedimentary, igneous and metamorphic consolidated pre-Mesozoic rocks, and where the influence of the Hercynian orogeny is particularly evident (Feio 1952). The area is part of Alentejo's peneplain unity, the largest geomorphological unity in Portuguese territory, and is dominated by Old Massif rocks, as well as other less well-represented formations (Feio 1952).

The contact zone between the ancient massif structures of the *Ossa Morena* and *Sul Portugesa* Zones and the Tertiary Tagus-Sado Cenozoic basin is the location of most of the temporihygrophilous groves of Portuguese oak (Carvalho et al. 1983). The constitutional and genetic similarity of the various basin sectors means that the basin has a typical morphological identity across its entire extent. The Miocene formations extend throughout the basin and are dominated by marine deposits (Alcácer do Sal and Esbarrondadoiro formations). Those of continental origin (Vale do Guizo and Marateca formations) are spread mainly around the periphery (Fernandes & da Silva 1998).

Materials and methods

A total of 56 relevés corresponding to different formations of *Q. broteroi* were analysed in this study. Eleven of these were obtained directly via field surveys, conducted from February 2006 to May 2010 and following the phytosociological approach (Braun-Blanquet 1979; Géhu & Rivas-Martínez 1981 modernized by Rivas-Martínez 2005b; Géhu 2006; Biondi 2011; Pott 2011). This methodology enables the analysis of both the floral composition, as well as their biophysical characterization. The remaining relevés (45) were collected from a number of earlier studies (Braun-Blanquet et al. 1956; Rivas-Goday 1959; Galán De Mera in Pérez Latorre et al.1999; Pinto-Gomes & Paiva-Ferreira 2005).

The determination of taxa was carried out following the proposals of Coutinho (1939), Franco (1971–1984), Castroviejo (1986–2010), and Franco and Rocha Afonso (1994–2003). The taxonomic determination of *Quercus coccifera* subsp. *rivasmartinezii* followed that of Capelo and Costa (2005). Syntaxonomical nomenclature followed Rivas-Martínez et al. (2002).

The Community Analysis Package 2004 programme (version 4.1.3; Seaby & Henderson 2007) was used to carry out hierarchical cluster analysis.

Biogeographical and bioclimatic information follows Rivas-Martínez (2005a, 2007, 2010). The bioclimatic characterization of the studied formations was based on the bioclimatic maps developed by Monteiro-Henriques (2010), and was carried out by the overlap of relevé locations since they represent the most up-to-date information for the Portuguese mainland.

Results and discussion

The dendrogram of relevé classification (Figure 1) shows two main clusters (A and B), with an approximate truncation level of 4.4. It is also possible to distinguish four main cluster groups at a truncation level of 3.3 (A1, A2, B1, B2).

The relevé cluster group A corresponds to the typically thermomediterranean associations described by Galán De Mera et al. in Pérez Latorre (1999) (*Oleo sylvestris–Quercetum broteroi*, *Os–Qb*) and Pinto-Gomes and Paiva-Ferreira (2005) (*Quercetum alpestris–broteroi*, *Q-ab*). These two associations have a high similarity, as shown by the presence of one relevé (B14) from the *Os–Qb* group within the *Q-ab* cluster. Analysis of the synoptic table (Table I) reveals that the two associations are floristically differentiated by the species present in *Os–Qb* and absent from *Q-ab*, such as *Rosa sempervirens*, *Ulex scabra* and *Calicotome villosa*.

Cluster B includes relevés of two mesomediterranean associations: the *Pistacio terebinthi–Quercetum broteroi* () group, which corresponds to the silicicolous association of Rivas-Goday (1959), and the *Arisaro–Quercetum broteroi* (*Ac–Qb*) group of Braun-Blanquet et al. (1956) corresponding to climatophilous groves from the Portuguese Divisory and Arrabidense territories. Relative to the *Ac–Qb* group, the presence of one relevé (C4) in the *Q-ab* group is due to a very poor inventory, with few characteristic species and an almost entire absence of companions promoting the group shift. A new group, *Uw–Qb*, is also identified corresponding to the new association proposed here: *Ulici welwitschiani–Quercetum broteroi*.

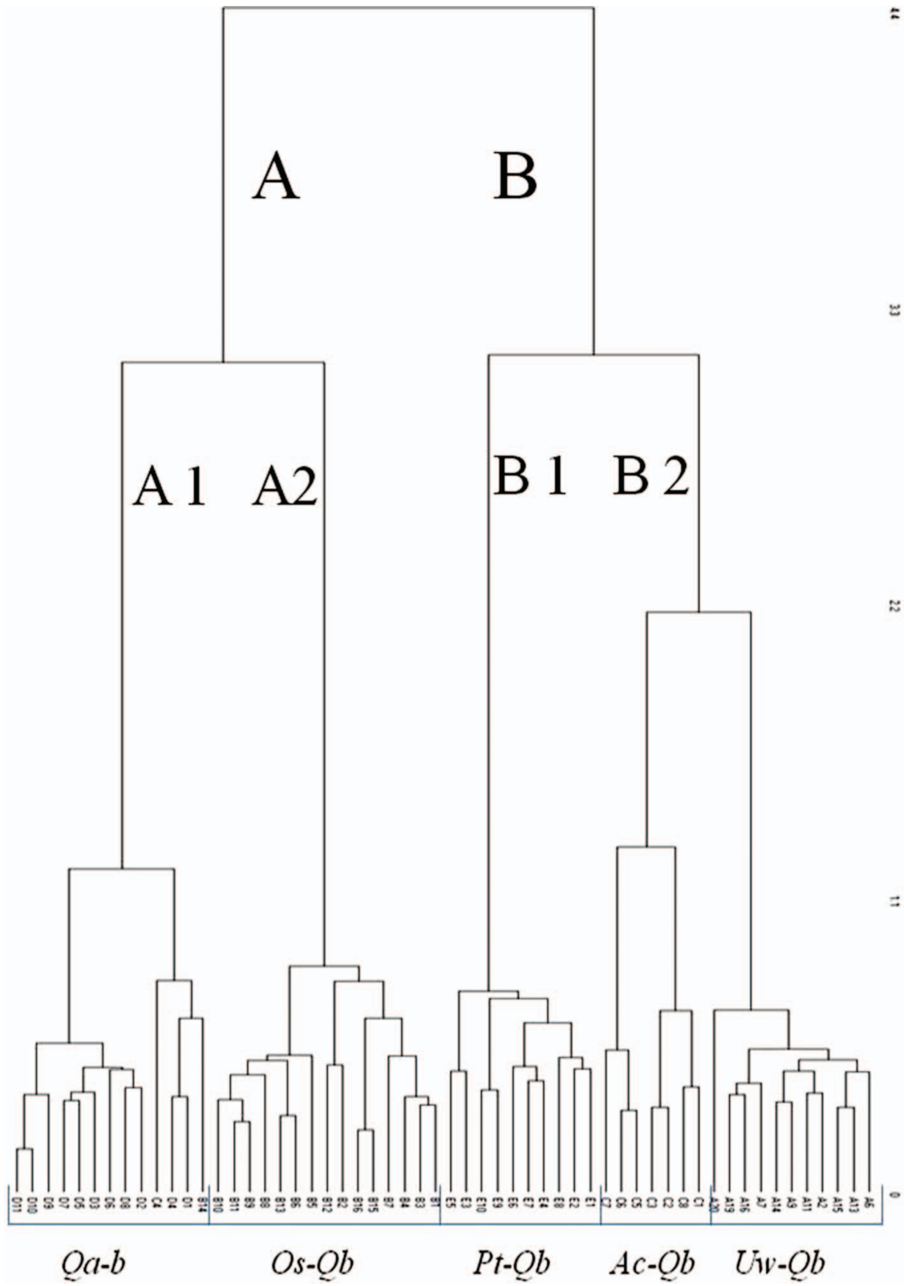

Figure 1. Ward's hierarchical clustering, based on Bray–Curtis distance: *Uw–Qb*, *Ulici welwitschiani–Quercetum broteroi*; *Ac–Qb*, *Arisaro–Quercetum broteroi*; *Pt–Qb*, *Pistacio terebinthi–Quercetum broteroi*; *Os–Qb*, *Oleo sylvestris–Quercetum broteroi*; *Q-ab*, *Quercetum alpestris–broteroi*.

As shown in Table I, the groups defined in the dendrogram are determined by the presence/absence of certain taxa. For instance, *Ac–Qb* is characterized by taxa, such as *Genista tournefortii*, *Ulex airensis*, *Erica scoparia*, *Ilex aquifolium* and *Ulex minor*, which are absent from *Pt–Qb* and *Uw–Qb*. The strong presence of *Pistacia terebinthus* and *Teucrium fruticans*, as well as *Vincetoxicum nigrum*, also differentiates *Pt–Qb* from *Ac–Qb* and *Uw–Qb*.

The new association proposed here is also characterized by the presence of *Q. faginea* subsp. *broteroi* and differs significantly floristically from both *Pt–Qb* and *Ac–Qb*. These differences are reflected in the presence of species, such as *Ulex australis* subsp. *welwitschianus*, *Dactylis hispanica* subsp. *lusitanica*, *Pyrus bourgaeana*, *Scirpoides holoschoenus*, *Carex riparia*, *Oenanthe croccata* and *Salix atrocinerea*, as well as companions (referred to in Table I) absent from the remaining associations.

Uw–Qb is easily differentiated from *Pt–Qb* mainly in lithological terms, since it is a silicicolous association, but also by thermotype, since *Pt–Qb* is present only in the mesomediterranean stage.

Regardless of its floristic affinities with *Ac–Qb* (both included in Cluster B2), *Uw–Qb* is distinct because it grows mostly within a dryer ombrotype

Table I. Synoptic table of thermo-mesomediterranean Portuguese oak formations.

Association characteristics and differentials	**A**	**E**	**C**	**D**	**B**
Number of relevés	**11**	10	8	11	16
Ulex australis subsp. *welwitschianus*	**V**	·	·	·	·
Dactylis hispanica subsp. *Lusitanica*	**V**	·	·	·	·
Pyrus bourgaeana	**IV**	·	·	·	·
Scirpoides holoschoenus	**III**	·	·	·	·
Carex riparia	**III**	·	·	·	·
Oenanthe croccata	**III**	·	·	·	·
Salix atrocinerea	**II**	·	·	·	·
Pistacia terebinthus	•	V	·	II	I
Teucrium fruticans	•	V	·	·	III
Vincetoxicum nigrum	•	III	·	·	·
Genista tournefortii	•	·	III	·	·
Ulex airensis	•	·	II	·	·
Erica scoparia	•	·	I	·	·
Ilex aquifolium	•	·	I	·	·
Ulex minor	•	·	I	·	·
Quercus faginea subsp. *alpestris*	•	·	·	V	·
Genista algarbiensis	•	·	·	V	·
Ulex argenteus	•	·	·	IV	·
Lithodora lusitanica	•	·	·	III	·
Cephalaria leucantha	•	·	·	II	·
Ulex scabra	•	·	·	·	IV
Rosa sempervirens	•	·	·	·	III
Calicotome villosa	•	·	·	·	I
Alliance, Order and Class characteristics					
Quercus broteroi	**V**	V	V	V	V
Ruscus aculeatus	**V**	III	V	III	III
Rubia peregrina	**V**	V	IV	V	III
Arbutus unedo	**V**	III	III	V	IV
Quercus rotundifolia	**IV**	III	II	III	I
Crataegus monogyna subsp. *brevispina*	**V**	III	III	+	V
Daphne gnidium	**V**	IV	III	IV	V
Olea europaea subsp. *sylvestris*	**V**	I	I	III	IV
Lonicera implexa	**III**	IV	I	IV	III
Arisarum simorrhinum	**I**	I	IV	IV	I
Rhamnus alaternus	**V**	·	IV	II	II
Smilax aspera subsp. *altissima*	**V**	IV	IV	IV	·
Phillyrea latifolia subsp. *media*	**II**	IV	III	II	·
Asparagus acutifolius	**IV**	IV	·	IV	III
Viburnum tinus	•	II	III	V	III
Anemone palmata	•	III	I	II	+
Hyacinthoides hispanica	**+**	·	II	V	·
Asparagus aphyllus	**III**	·	II	·	I
Sanguisorba hybrida	**III**	·	II	·	+
Arum italicum subsp. *neglectum*	**V**	III	I	·	·
Asplenium onopteris	**I**	+	IV	·	·
Paeonia broteroi	**+**	IV	I	·	·
Quercus suber	**IV**	III	·	·	+
Quercus x marianica	**+**	·	·	IV	I
Carex halleriana	•	III	I	V	·
Lonicera etrusca	•	+	I	I	·
Smilax aspera	•	·	II	II	V
Carex distachya	**III**		+		
Teucrium scorodonia	**II**	·	II	·	·
Quercus coccifera subsp. *rivasmartinezii*	**+**	·	II	·	·
Hedera maderensis subsp. *iberica*	**+**	·	III	·	·
Bupleurum paniculatum	**+**	·	·	+	·
Phillyrea latifolia	•	·	·	IV	IV
Clematis flammula	•	·	·	IV	III
Laurus nobilis	**+**	·	·	·	·

(*continued*)

Table I. (*Continued*).

Association characteristics and differentials	**A**	**E**	**C**	**D**	**B**
Ruscus hypophyllum	•	·	·	·	+
Pipthatherum paradoxum	•	·	·	·	I
Eryngium tricuspidatum	•	·	·	·	+
***Pistacio-Rhamnetalia* and lower units characteristics**					
Pistacia lentiscus	**V**	II	I	IV	V
Phillyrea angustifolia	**III**	II	I	IV	I
Quercus coccifera	**II**	III	III	IV	III
Myrtus communis	**IV**	·	III	IV	I
Osyris alba	**II**	III	·	I	IV
Rhamnus oleoides	•	I	I	II	III
Juniperus turbinata	•	·	I	II	I
Jasminum fruticans	•	I	I	+	·
Chamaerops humilis	•	·	·	IV	II
Ceratonia siliqua	•	·	·	I	IV
Aristolochia baetica	•	·	·	I	II
Osyris quadripartita	**I**	·	·	·	·
Euphorbia characias	**+**	·	·	·	·
Ephedra fragilis	**+**	·	·	·	·
Quercus lusitanica	**+**				
Coronilla glauca	•	·	·	·	I
Coronilla juncea	•	·	·	·	+
***Rhamno-Prunetea spinosae* and lower unit characteristics**					
Tamus communis	**IV**	III	V	III	III
Rubus ulmifolius	**V**	II	IV	·	II
Lonicera periclymenum subsp. *hispanica*	**IV**	III	·	·	·
Rosa pouzinii	**III**	·	·	·	·
Rosa canina	**I**	·	·	·	·
Clematis vitalba	**+**	·	·	·	·
Companions					
Salvia sclareoides	**+**	+	I	II	·
Aristolochia paucinervis	**III**	IV	III	·	I
Calamintha baetica	**II**	V	IV	·	+
Cheirolophus sempervirens	**II**	·	III	+	·
Agrimonia eupatoria	**II**	·	II	·	+
Iris foetidissima	**II**	·	I	·	II
Agrostis castellana	**III**	II	I	·	·
Origanum virens	**II**	IV	II	·	·
Scrophularia scorodonia	**I**	IV	III	·	·
Allium roseum	**+**	I	I	·	·
Cistus psilosepalus	**+**	I	II	·	·
Eleaeoselinum foetidum	**+**	III	·	·	+
Melica minuta	•	III	II	II	·
Erica arborea	**II**	·	III	·	·
Stachys germanica subsp. *lusitanica*	**II**	·	I	·	·
Fraxinus angustifolia	**II**	·	I	·	·
Brachypodium sylvaticum	**II**	·	IV	·	·
Digitalis purpurea	**+**	·	II	·	·
Prunella vulgaris	**+**	·	III	·	·
Pteridium aquilinum	**+**	·	II	·	·
Epipactis lusitanica	•	·	II	III	·
Cephalanthera longifolia	•	·	I	III	·
Satureja ascendens	•	·	I	+	·
Dactylis hispanica	•	·	III	·	+
Phlomis purpurea	•	·	·	II	IV
Scilla peruviana	•	·	·	V	I
Brachypodium phoenicoides	**IV**	·	·	·	·
Campanula rapunculus	**IV**	·	·	·	·
Thapsia villosa	**II**	·	·	·	·
Cynodon dactylon	**II**	·	·	·	·
Juncus inflexus	**I**	·	·	·	·
Mentha suaveolens	**I**	·	·	·	·

(*continued*)

Table I. (*Continued*).

Association characteristics and differentials	A	E	C	D	B
Holcus lanatus	I	·	·	·	·
Vitis vinifera subsp. *sylvestris*	I	·	·	·	·
Arrhenatherum album	I	·	·	·	·
Genista triacanthos	I	·	·	·	·
Equisetum telmateia	I	·	·	·	·
Phalaris coerulescens	I	·	·	·	·
Thapsia transtagana	I	·	·	·	·
Brachypodium retusum	•	·	·	·	+

A – *Ulici welwitschiani–Quercetum broteroi* (11 rel); B – *Oleo sylvestris-Quercetum broteroi* Galán, A.V. Pérez & Cabezudo in A.V. Pérez, Galán, P. Navas, D. Navas, Y. Gil & Cabezudo 1999 (16 rel); C – *Arisaro–Quercetum broteroi* Br.–Bl., P. Silva & Rozeira 1956 corr. Rivas-Martínez 1975 (8 rel); D – *Quercetum alpestris–broteroi* Pinto Gomes & Paiva Ferreira 2005 (11 rel); E – *Pistacio terebinthi-Quercetum broteroi* Rivas Goday in Rivas Goday, Borja, Esteve, Galiano, Rigual & Rivas-Martínez 1960 (10 rel). Other taxa: *Centaurea africana* +; *Avenella stricta* +; *Cytisus baeticus* +; *Sanguisorba minor* +; *Juncus rugosus* +; *Asphodelus fistolosus* +; *Eryngium dilatatum* +; *Clinopodium arundanum* +; *Clinopodium arundanum* +; *Solanum dulcamara* +; *Achillea ageratum* +; *Oenanthe pimpinelloides* +; *Carduncellus caeruleus* +; *Oenanthe pimpinelloides* +; *Dorycnopsis gerardi* +; *Populus alba* +; *Salix neotricha* +; *Arundo donax* +; *Bryonia dioica* +; *Hypericum tomentosum* +; *Ornithogalum narbonense* +; *Centaurea pullata* +; *Phragmites australis* +; *Cistus populifolius* +; *Campanula primulifolia* +; *Calystegia sepium* +; *Picris spinifera* +; *Silene latifolia* +; *Smyrnium olusatrum* +; *Narcissus calcicola* +; *Elaeoselinum gummiferum* + (A); *Antirrhinum linkianum* I; *Carex divulsa* I; *Luzula forsteri* I; *Lathyrus latifolius* I (C); *Dorycnium hirsutum* I; *Cistus albidus* I; *Ranunculus ficaria* I; *Brachypodium gaditanum* I; *Genista linifolia* I; *Brachypodium retusum* I (E).

(upper dry to subhumid, Figure 2), as shown by the absence of species, such as *I. aquifolium*, *Viburnum tinus* and other subserial community species, including *G. tournefortii*, *U. minor* and *U. airensis*, which occur mainly in upper subhumid or humid ombrotypes.

These facts have led to the proposal of the new association *Ulici welwitschiani–Quercetum broteroi ass. nova hoc loco* (Table II, *holotypus*, rel. 7), which corresponds to the thermomediterranean upper dry-to-subhumid temporihygrophilous Portuguese oak forests. The temporihygrophilous concept applied for this association follows the one published by Rivas-Martínez (2005b) and recently updated by Rivas-Martínez and Sánchez-Mata (2011). It refers to a mesophytic and mesohygrophytic situation with exceptional water supply, due to the torrential topography, above waterlogged soils, remaining wet for only part of the year (wet season) and with well-drained or aired horizons during summer or dry periods.

Although *Uw–Qb* is typically thermomediterranean (Figure 2), which apparently contradicts the results of cluster B (Figure 1), its temporihygrophilous character reinforces its proximity to the mesomediterranean associations, mainly in terms of the decrease in yearly average temperature (*T*) within these groves.

Complementing the bioclimatic filiation, the two ombrothermic diagrams presented in Figure 3, obtained from the nearest meteorological stations to the relevé spots, show the domain of the upper dry ombrotype and upper thermomediterranean thermotype (also revealed in Figure 2). The northern and less oceanic territories reflect the transition to the low mesomediterranean thermotype (Figures 2 and 3), despite the unvarying presence of thermomediterranean elements.

This temporihygrophilous character is confirmed by the constant presence of *Rhamno-Prunetea* elements, as well as species from *Phragmito-Magnocaricetea*, *Molinio-Arrhenatheretea*, *Querco-Fagetea* and *Salici-Populetea*, which highlights the presence of edaphic compensation in this forest association (Table II). In these terms, we can highlight a group of species, such as *Fraxinus angustifolia*, *Brachypodium sylvaticum*, *C. riparia*, *O. croccata*, *S. holoschoenus* and *S. atrocinerea*, representative of the temporihigrophylous character that this association possesses, mainly due to catenal contact with riparian wet deciduous woodlands and corresponding regressive stages. In this group of characteristic hygrophilous species, *D. hispanica* subsp. *lusitanica* and *U. australis* subsp. *welwitschianus*, both with great territorial value, should also be pointed out.

The new *Q. broteroi* grove association is largely composed of three distinct layers, with the tree layer clearly dominated by *Q. broteroi* (Portuguese oak), as well as various small trees, such as *Arbutus unedo*, *Pistacia lentiscus*, *Myrtus communis*, *Erica arborea* and *P. bourgaeana*. *Rubus ulmifolius*, *Crataegus monogyna* subsp. *brevispina* and *Rosa* spp. are the most common shrubs, together with hygrophilous climbing taxa, such as *Lonicera periclymenum* subsp. *hispanica*, *Clematis vitalba*, *Vitis vinifera* subsp. *sylvestris* and *Hedera maderensis* subsp. *iberica*. The herb layer includes various species (e.g. *C. riparia*, *Brachypodium phoenicoides* and *B. sylvaticum*), climbing taxa (e.g. *Asparagus aphyllus*, *Asparagus acutifolius*, *Rubia peregrina* and *Smilax aspera* subsp. *altissima*), as well as nemoral herbs, including *Magydaris panacifolia*.

Thanks to its vast distribution area, these floristic characteristics give to this new forest association great originality and singularity, while its dynamics and synecological properties differentiate it from the other *Q. broteroi* woodlands within the same bioclimatic stage.

Although it is typically calcicolous, as evidenced by the presence of species, such as *Bupleurum paniculatum*, *Iris foetidissima*, *Stachys germanica* subsp. *lusitanica*, *Cheirolophus sempervirens*, *Allium roseum*, *Asphodelus fistolosus* and *Eryngium dilatatum*, the

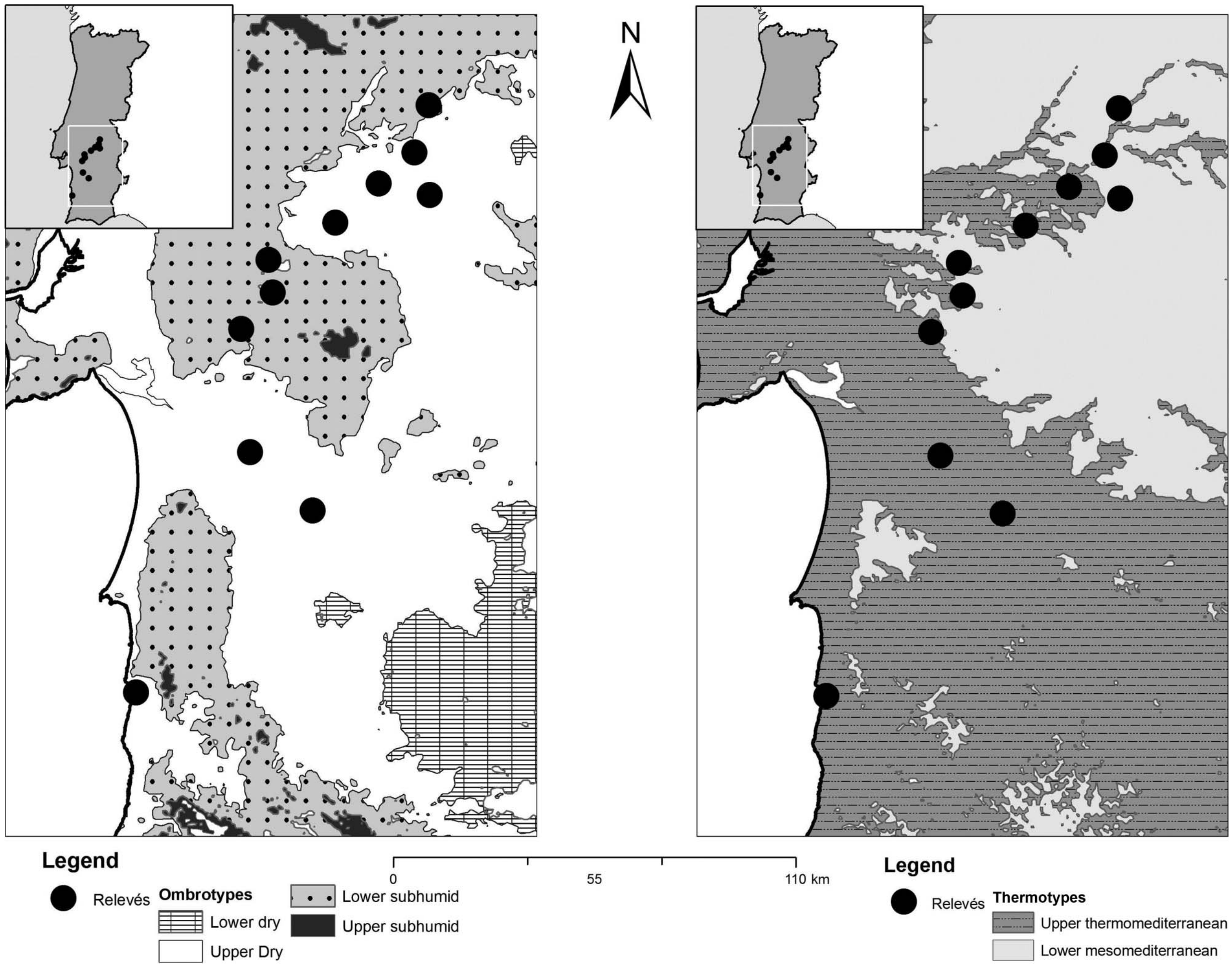

Figure 2. Ombrotypes and thermotypes in the study area (following Monteiro-Henriques 2010) and relevé locations.

continuous presence of acidophilous species (e.g. *U. australis* subsp. *welwitschianus*, *D. hispanica* subsp. *lusitanica*, *Agrostis castellana*, *Avenella stricta*) is noteworthy. Their presence is due to limestone decarbonation, to the temporihygrophilous character, and to the territorial contact with psammophilous soils from the Ribatagan-Sadensean sector. Its predominantly thermomediterranean distribution is emphasized by the presence of species, such as *Quercus lusitanica*, *Thapsia transtagana*, *Osyris quadripartita* and *Asparagus aphyllus*. In the characteristic species group, the consistent presence of oceanic and occidentally distributed taxa, such as *E. arborea*, *Ephedra fragilis*, *Q. coccifera* subsp. *rivasmartinezii* and *Centaurea africana*, must also be highlighted (Table II).

These temporihygrophilous groves were always observed to occur on limestones, and in transitional territories between the Ribatagano and Alentejano Districts. Following research on the edaphological aspects of the formation, the geological and pedological affinities became apparent, as they always occur in the same edaphic situation, i.e. adjacent to torrential streams running through calcareous deposits of the Vale do Guizo formation, characterized by coarse basal deposits with carbonate cement (Teixeira & Gonçalves 1979), as well as at Vila Nova de Milfontes, always in the Tagus-Sado Cenozoic basin.

In terms of serial considerations, this new association has, as fringe and first regressive stage, a *Rhamno-Prunetea* shrubland dominated by *R. ulmifolius*, *C. monogyna* and *Rosa* spp., followed by perennial grasslands dominated by *B. phoenicoides*. The association is also accompanied by exoserial complexes, such as hygrophilous phorb communities dominated by *O. croccata*, *Oenenthe pimpinelloides* and *Scrophularia scorodonia*. The new *Q. broteroi* formation should also be included in the main *catena* of the Coastal Lusitan-Andalusian Province as a temporihygrophilous series in the Miocenic limestones, with geoserial neighbour series comprising *Aro italici–Oleo sylvestris* S. wild olive woodlands situated on calcareous soils with marls or marly limestones and with vertic properties. The *Rhamno fontqueri–Querco*

Table II. *Ulici welwitschiani–Quercetum broteroi* ass nova hoc loco (*Querco rotundifoliae–Oleion sylvestris*, *Quercetalia ilicis*, *Quercetea ilicis*).

Number	15	11	16	19	2	6	9	14	13	7	20	
Exposure	S-SE	SW-W	W	S	SW	NW	S-SE	N	NW	N	N	
Area (sq. m)	400	400	300	400	600	300	500	300	600	400	400	
Slope (%)	10	30	20	10	10	20	7	10	20	20	25	
Cover (%)	100	100	100	95	95	100	95	95	100	95	100	
Average height (m)	18	17	15	12	12	12	8	10	15	12	18	
Altitude (m)	190	125	165	260	105	100	25	110	100	36	25	
Ordinal number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	
Association characteristics or differentials												Presences
Quercus broteroi	4	4	4	4	4	4	5	4	4	4	4	V
Dactylis hispanica subsp. *lusitanica* (Ass. charact)	1	1	1	1	1	1	1	2	1	1	1	V
Ulex australis subsp. *welwitschianus* (Ass. charact)	1	1	+	1	1	1	2	1	1	1	+	V
Arum italicum subsp. *neglectum*	1	2	2	1	2	–	1	1	2	+	2	V
Pyrus bourgaeana (Ass.diff.)	2	1	–	+	+	+	1	1	1	+	–	V
Carex riparia (Ass.diff.)	1	1	–	–	–	+	+	1	1	+	–	IV
Oenanthe croccata (Ass.diff.)	–	1	+	–	1	+	+	+	+	+	–	IV
Scirpoides holoschoenus (Ass.diff.)	+	–	–	+	–	+	+	–	+	–	+	III
Salix atrocinerea (Ass.diff.)	–	–	–	+	–	–	+	–	+	+	–	II
Alliance and Order characteristics												
Ruscus aculeatus	3	2	2	3	2	1	2	1	2	3	3	V
Smilax aspera subsp. *altissima*	3	3	3	3	3	3	2	2	3	3	2	V
Quercus suber	+	+	–	+	–	+	+	+	+	+	+	V
Quercus rotundifolia	–	+	+	+	+	+	+	+	–	+	–	IV
Carex dystachia	–	1	1	–	–	–	+	1	–	+	1	III
Teucrium scorodonia	–	–	–	1	–	–	–	–	–	+	1	II
Bupleurum paniculatum	–	–	–	–	–	1	–	–	1	–	–	I
Asplenium onopteris	–	–	–	–	–	–	–	–	–	+	2	I
Quercus coccifera subsp. *rivasmartinezii*	–	–	–	–	–	–	–	–	–	–	1	+
Class characteristics												
Rubia peregrina	2	1	1	1	1	1	2	1	1	2	1	V
Daphne gnidium	1	1	+	+	+	1	+	+	+	1	–	V
Olea europaea subsp. *sylvestris*	–	+	2	+	1	+	+	1	+	+	1	V
Rhamnus alaternus	–	1	2	2	2	+	2	1	2	1	1	V
Asparagus acutifolius	–	2	1	1	1	+	2	2	2	2	–	V
Lonicera implexa	–	–	–	1	1	–	+	+	–	+	–	III
Phyllirea latifolia subsp. *media*	–	–	2	–	–	–	–	–	2	+	1	II
Arisarum simorrhinum	–	–	–	–	1	–	–	1	–	–	1	II
Other *Quercetea ilicis* lower unit characteristics												
Pistacia lentiscus	2	1	2	2	2	–	2	1	1	2	1	V
Arbutus unedo	2	1	–	1	2	1	1	+	2	2	1	V
Phyllirea angustifolia	+	+	–	–	+	–	+	+	+	1	–	IV
Myrtus communis	–	1	1	–	2	+	1	–	–	1	1	IV
Asparagus aphyllus	1	–	–	–	–	+	1	–	+	+	1	III
Sanguisorba hybrida	–	1	–	–	+	+	+	+	–	–	–	III
Quercus coccifera	–	+	–	+	–	–	–	–	+	+	+	III
Osyris alba	1	–	1	–	–	1	–	–	+	–	–	II
Osyris quadripartita	1	–	–	–	–	–	–	–	–	–	1	I
Paeonia broteroi	–	1	–	–	–	–	–	–	–	–	–	+
Quercus lusitanica	–	+	–	–	–	–	–	–	–	–	–	+
Centaurea africana	–	–	–	–	–	+	–	–	–	–	–	+
Hyacinthoides hispanica	–	–	–	–	–	–	–	–	–	+	–	+
Hedera maderensis subsp. *iberica*	–	–	–	–	–	–	–	–	–	–	3	+
Laurus nobilis	–	–	–	–	–	–	–	–	–	–	3	+
Quercus x marianica	–	–	–	–	–	–	–	–	–	–	2	+
Euphorbia characias	–	–	–	–	–	–	–	–	–	–	+	+
Ephedra fragilis	–	–	–	–	–	–	–	–	–	–	+	+
Rhamno-Prunetea characteristics												
Rubus ulmifolius	3	1	3	2	3	3	2	2	2	2	1	V
Crataegus monogyna subsp. *brevispina*	1	1	1	1	1	2	1	1	1	1	–	V
Lonicera periclymenum subsp. *hispanica*	–	+	–	+	2	2	1	1	1	1	1	V
Tamus communis	–	2	–	–	2	+	1	2	1	+	1	IV
Rosa pouzinii	2	1	–	–	1	–	1	+	3	–	–	III

(*continued*)

Table II. (*Continued*).

Rosa canina	–	–	–	–	–	–	1	+	–	–	–	I
Clematis vitalba	–	–	–	–	–	–	–	+	–	–	–	+
Prunus spinosa	–	–	–	–	–	–	–	–	+	–	–	+
Companions												
Brachypodium phoenicoides	1	2	–	1	1	1	+	1	1	1	–	V
Campanula rapunculus	–	1	1	1	+	1	+	1	1	+	–	V
Agrostis castellana	+	–	–	+	–	–	–	+	+	+	–	III
Fraxinus angustifolia	1	–	–	–	–	1	+	+	+	–	–	III
Calamintha baetica	+	+	–	–	–	–	–	+	+	+	–	III
Agrimonia eupatoria	–	1	–	–	+	+	–	+	+	–	–	III
Aristolochia paucinervis	–	1	–	–	2	+	–	–	1	–	–	II
Cheirolophus sempervirens	–	1	–	–	–	–	1	–	–	1	1	II
Brachypodium sylvaticum	–	–	–	–	–	1	–	–	1	1	1	II
Stachys germanica subsp. *lusitanica*	+	–	–	+	–	–	+	–	–	–	–	II
Origanum virens	+	–	–	1	–	–	–	–	–	+	–	II
Thapsia villosa	–	1	–	–	–	+	–	–	–	+	–	II
Erica arborea	–	1	–	–	–	–	–	–	–	+	2	II
Iris foetidissima	–	–	–	–	–	–	1	1	–	–	2	II
Juncus inflexus	+	+	–	–	–	–	+	–	–	–	–	II
Cynodon dactylon	+	–	–	–	–	–	+	–	+	–	–	II
Mentha suaveolens	–	+	+	–	–	–	–	–	–	–	–	I
Holcus lanatus	–	–	–	–	–	1	–	–	–	+	–	I
Vitis vinifera subsp. *sylvestris*	–	–	1	–	–	–	–	–	–	2	–	I
Retama sphaerocarpa	–	–	+	–	+	–	–	–	–	–	–	I
Arrhenatherum album	–	–	–	–	–	–	+	–	–	+	–	I
Genista triacanthos	–	–	–	–	–	–	+	–	–	+	–	I
Equisetum telmateia	–	–	–	–	–	–	+	–	–	+	–	I
Phalaris coerulescens	–	–	–	–	–	1	–	+	–	–	–	I
Thapsia transtagana	–	–	–	–	–	+	–	+	–	–	–	I
Scrophularia scorodonia	–	–	–	–	–	–	–	+	–	–	+	I

Other taxa: *Cytisus baeticus* 1; *Carex cuprina* +; *Digitalis purpurea* +; *Sanguisorba minor* +; *Juncus rugosus* +; *Allium roseum* +; *Asphodelus fistolosus* + (2); *Eryngium dilatatum* + (4); *Clinopodium arundanum* 1; *Avenella stricta* + (5); *Prunella vulgaris* 1 ; *Salvia sclareoides* + ; *Solanum dulcamara* + ; *Cistus psilosepalus* + ; *Achilea ageratum* +; *Oenanthe pimpinelloides* + (6); *Carduncellus caeruleus* + ; *Dorycnopsis gerardi* + ; *Salix neotricha* + ; *Populus alba* +; *Arundo donax* + (7); *Hypericum tomentosum* + ; *Bryonia dioica* +; *Ornithogalum narbonense* +; *Centaurea pullata* + (8); *Magydaris panacifolia* +; *Phragmites australis* +; *Eleaeoselinum foetidum* +; *Cistus populifolius* + (10); *Campanula primulifolia* +; *Calystegia sepium* +; *Vinca difformis* +; *Picris spinifera* + ; *Silene latifolia* + ; *Smyrnium olusatrum* + ; *Narcissus calcicola* +; *Elaeoselinum gummiferum* +; *Pteridium aquilinum* + (11).

Locations: 1 – Casa Branca; 2 – Herdade do Freixo do Meio; 3 – Avis; 4 – Valongo; 5 – Cabeção; 6 – Cabrela; **7 – Torrão**; 8 – Brotas; 9 – Lavre; 10 – Santa Margarida do Sado; 11 – Vila Nova de Milfontes.

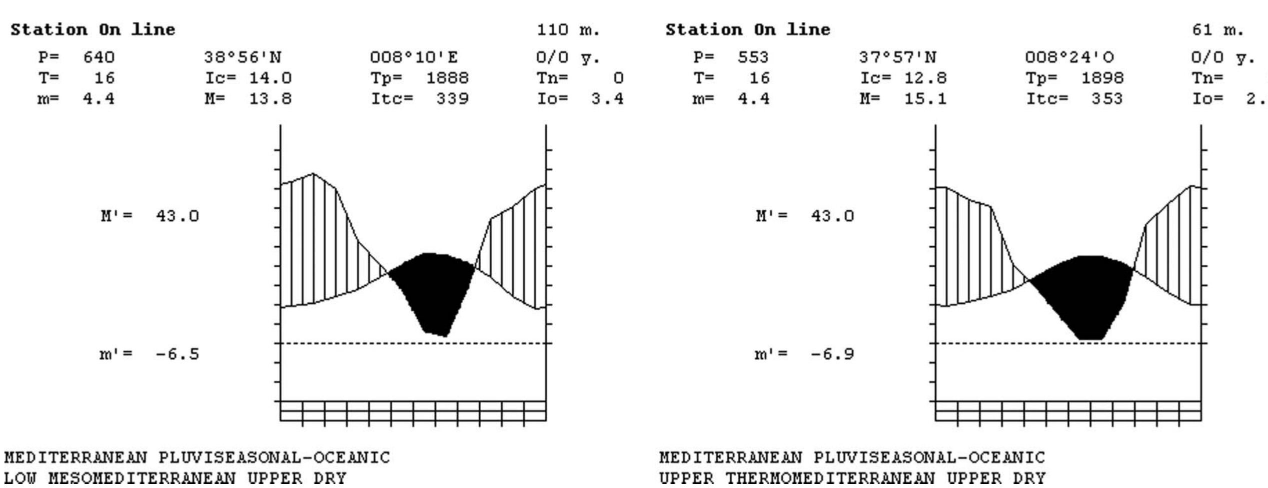

Figure 3. Ombrothermic diagrams.

rotundifoliae S. holm oak woodlands on limestones without vertic properties, and, more rarely, the psammophilous cork oak woodlands of *Aro neglecti–Querco suberis* S. are located above sandy soils. The new formation also makes contact with a number of edapho-hygrophilous series, such as *Ficario*

Figure 4. Biogeography of the study area (Costa et al. 1998), location of relevés and proposal for new biogeographical limits.

ranunculoidis–Fraxino angustifoliae S. and *Salico atrocinereo-australis* S.

A further contribution of this study is the biogeographical placing of the new association within the Coastal Lusitan-Andalusian province (Figure 4), which represents the establishment of new borders between the Sadensean-Dividing Portuguese and Lusitan-Extremadurean Subprovinces (i.e. between the Ribatagan-Sadensean and Marianic-Monchiquensean or Toledan-Taganean Sectors), as well as the border of the Algarvian Sector and Gaditan-Algarvian Subprovince. According to Costa et al. (1998), this border is difficult to pinpoint, but since the new formation occurs on limestones and sandy miocenic and Pleistocenic soils of the Tagus-Sado Cenozoic basin, it belongs to the Coastal Lusitan-Andalusian Province. In this regard, other areas which can be added are the northern and western patches of the Vale do Guizo Formation, the adjacent patches of the Esbarrondadoiro and Marateca Formations, as well as the dunes, sands, sandstones and gravels of the Lower Alentejo Coast. The position of this newly proposed boundary, relative to the Lower Alentejo coast, is reinforced by the presence of specific phytocoenoses: *Junipero navicularis–Quercetum lusitanicae* and *Daphno gnidi–Juniperetum navicularis* scrublands, *Santolinetum impressae* chamaephitic communities, as well as *Euphorbio transtaganae–Celticetum giganteae* and *Herniario unamunoanae–Corynephoretum maritimae* grasslands.

Conclusions

This work represents a new case study contributing to our current knowledge of the natural potential vegetation for the investigated territories. It prompts further more in-depth studies, mainly of upper subhumid and humid ombrotypes and in sharper oceanic territories, since these temporihygrophilous formations likely represent relict traces of surrounding areas of now vanished climatophilous vegetation. Generally speaking, *Uw–Qb* grove formations are extremely degraded since they are located on good agricultural soils and have in their midst cork oak trees that are more highly favoured to the detriment of the Portuguese oak. The poor survival of these grove formations is largely due to their temporihygrophilous nature, with their presence near deeper torrential streams resulting in greater impenetrability to human action. In terms of their conservation value, these grove formations should be seen as high-value islands, since they are reservoirs for the stabilization of spontaneous hybrids and, as such, a detailed taxonomic study of these *Q. broteroi* hybridizations is warranted.

The groves also include Lusitanic endemisms, such as *U. australis* subsp. *welwitschianus* and even *Q. coccifera* subsp. *rivasmartinezii*. *Uw–Qb* groves are also important refuges for species with legal conservation status, such as *Narcissus calcicola* (named on the Council Directive 92/43/CEE Annex II and IV) and *Ruscus aculeatus* (Annex V), as well as other rare species, including *E. fragilis* and *C. africana*. Accordingly, this forest association also incorporates Mediterranean deciduous forests of the 9240 *Q. faginea* and *Quercus canariensis* Iberian woods habitat, according to Annex I of Council Directive 92/43/EEC of 21 May 1992.

In view of their ecological importance, the principal threats currently facing these formations must also be emphasized. The heliophilous fringe of *Rhamno-Prunetea* constitutes a high fire risk, and as such the top priority must be to mechanically control them, maintaining the arboreal and pre-forestal stages. This management scheme would essentially involve promoting the natural regeneration of the species and, consequently, the higher layers and stages of vegetal dynamics.

Syntaxonomical scheme

Quercetea ilicis Br.-Bl. *ex* A. & O. Bolòs 1950

* *Quercetalia ilicis* Br.-Bl. *ex* Molinier 1934 em. Rivas-Martínez 1975

– *Querco rotundifoliae-Oleion sylvestris* Barbéro, Quézel & Rivas-Martínez in Rivas-Martínez, Costa & Izco 1986

1 – *Oleo sylvestris-Quercetum broteroi* Galán, A.V. Pérez & Cabezudo in A.V. Pérez, Galán, P. Navas, D. Navas, Y. Gil & Cabezudo 1999

2 – *Quercetum alpestris-broteroi* Pinto-Gomes & Paiva-Ferreira 2005

3 – ***Ulici welwitschiani-Quercetum broteroi ass. nova hoc loco***

– *Quercion broteroi* Br.-Bl., P. Silva & Rozeira 1956 em. Rivas-Martínez 1975 corr. Ladero 1974

+ *Quercenion broteroi* Rivas-Martínez, Costa & Izco 1986 corr. Rivas-Martínez 1987

1 – *Arisaro-Quercetum broteroi* Br.-Bl., P. Silva & Rozeira 1956 corr. Rivas-Martínez 1975

2 – *Pistacio terebinthi-Quercetum broteroi* Rivas Goday in Rivas Goday, Borja, Esteve, Galiano, Rigual & Rivas-Martínez 1960

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