Vegetatio **82**: 105–112, 1989

Diversity measurements in shrubland communities of Galicia (NW Spain)

M. Basanta[1], E. Díaz Vizcaíno[2], M. Casal[1] & M. Morey[3]
[1] *Departamento de Biología Fundamental (Area de Ecología), Facultad de Biología, Universidad de Santiago de Compostela, Spain;* [2]*Colegio Universitario, 27071 Lugo, Spain;* [3]*Departamento de Biología y Ciencias de la Salud (Area de Ecología), Facultad de Ciencias, Universidad de Palma de Mallorca, Spain*

Accepted 22.2.89

Key words: *Cytisus*, Dominance-diversity, *Erica*, Human influence, Species richness, *Ulex*

Abstract

Diversity was studied in 10 communities, including the understory of native oak woodland, planted woodlands (pine and eucalypt), and shrublands in the strict sense (heathlands, broom shrublands, gorse shrublands).

In each community, species richness, diversity, dominance and evenness were analysed. Differences were observed among communities with regard to species composition, richness in annual herbs, perennial herbs and shrubs, dominant plant families (Ericaceae, Papilionaceae) and diversification of shrub species.

The possible relations between environmental stress and/or human influences on differences in diversity are discussed.

Nomenclature: Tutin, T.G. *et al.* (1964–1980). Flora Europaea, Vol. 1–5. Cambridge University Press, Cambridge.

Introduction

Both drought and oligotrophic conditions, and management practices affect the floristic composition, structural parameters and dynamics of shrubland communities. Such communities in Galicia (NW Spain) develop on acid, nutrient-poor soils, under oceanic climate conditions, with Papilionaceae and Ericaceae shrubs dominating (genera *Ulex*, *Cytisus*, *Genista*, *Erica*, *Calluna*, *Daboecia*). In these respects they resemble the heathlands found in other European Atlantic areas (e.g. Gimingham 1972; Géhu–Franck 1974; Gimingham *et al.* 1979; Rivas Martínez 1979). Also, deforestation, burning, grazing and cutting, are management practices common to several European Atlantic regions: western France, Great Britain, Ireland, the Netherlands and NW Spain (Géhu-Franck 1974; Gimingham *et al.* 1979; Webb 1980; Gimingham *et al.* 1981). They explain to a large extent the persistence of shrubland communities in these areas.

In this paper we present a study of one structural parameter, species diversity, in several types of shrubland subject to different degrees of environmental stress and/or management. Ten types of communities were studied, including the understory of woodlands, both native (*Qercus* *robur*) and planted (with *Pinus* or *Eucalyptus*) and shrublands in the strict sense (heath, broom, and gorse shrublands).

These communities had been previously studied regarding their structure (Basanta 1984; Basanta *et al.* 1988) and their relationship to environmental variables (Díaz Vizcaíno 1985), and some of their general characteristics are listed in Table 1. Each community has been named after the characteristic woody species.

These shrublands have played an important role in traditional agriculture, and they still occupy an area of ca 800 000 ha in Galicia, which is more than 25% of the total region. Furthermore, most of the woodland (ca 1 100 000 ha) has an understory of gorse and heath, except in the case of oak woodland, occupying ca 250 000 ha.

Study area

The study area is the 1770 km^2 basin of the Tambre River, with a length of 111 km one of the main rivers in Galicia, situated northwest of Santiago de Compostela (42 °50′N, 8 °45 ′W).

Soil and climate

The parent material is (mostly Pre-Cambrian) cristalline rocks, mainly granite and metamorphic schist, to a lesser extent gneiss and migmatite and some basic rocks (gabbro, amphibolite) (Parga Pondal 1967). The topography is gentle with hills ranging from 200 to 400 m. The valley has a typical oceanic climate, with mean annual precipitation from 1400 to 1900 mm and mean annual temperature from 10.7 to 13.9 °C (Carballeira *et al.* 1983).

Vegetation and human disturbance

The existing vegetation shows a mosaic distribution due to human influences. The original landscape has been significantly modified by man, so that the climax deciduous oak woodland of *Q. robur*, which occupied large areas in the past (Bellot 1966), has been reduced to small patches. Shrublands and cultivated land are the predominating ecosystems in the study area.

Some factors which have affected the distribution, composition, structure and dynamics of shrub communities are: reforestation with pine and eucalyptus, field abandonment, burning, and sowing and cutting of gorse for fuel, cattle food and organic fertilizer. The intensity of each of these factors has varied with time; at present, burning and reforestation with non-native species are the principal factors responsible for the degradation of the physical and biotic characteristics of the pre-existing ecosystems.

Methods

Sampling

Stratified sampling (cf. Moore *et al.* 1970; Mueller-Dombois & Ellenberg 1974) was carried out, with 184 samples evenly distributed among the existing shrubland types and shrub understory types in woodlands. (Table 1). A quadrat size of 7 × 7 m was used throughout, which is within the minimum area range suggested by various authors for similar vegetation types (Mueller-Dombois & Ellenberg 1974; Westhoff & van der Maarel 1978).

Each sample, includes a list of Pteridophyta and Spermatophyta. Linear cover (Gounot 1969; Greig-Smith 1983) of woody species was recorded along 5 parallel line transects per sample, based on the length intercepted by each woody species, i.e. shrubs and saplings or young individuals of trees in the shrub stratum.

Diversity measures

The concept of diversity includes several aspects (number of species, heterogeneity, equitability), each one of them measured by different indices. (cf. Whittaker 1965; van der Maarel 1988):

1. Species richness:
   S = number of species/sample

Table 1. General features of the different types of shrub vegetation studied. Reciprocal Averaging (both qualitiative and quantitative data) (Basanta 1984) confirmed the discrimination of the 10 communities.

	Type of community	Shrub height (m)	Shrub cover (%)	Effect of environmental stress	Main human disturbance
1. *Cytisus scoparius* shrubland	Broom shrubland	2.3 ± 0.4	98.7 ± 1.5	Negligible	Moderate (sporadic cutting and grazing)
2. *C. striatus* shrubland	Broom shrubland	3.2 ± 0.5	98.9 ± 1.4	Negligible	
3. *Erica australis* shrubland	Heath shrubland	2.1 ± 0.4	100.0 ± 0	Weak (soil texture)	Weak (infrequent cutting)
4. *E. tetralix* shrubland	Heath shrubland	0.7 ± 0.1	95.8 ± 4.2	Severe (waterlogging)	
5. *E. umbellata* shrubland	Heath shrubland	0.6 ± 0.1	71.9 ± 8.2	Severe (shallow soils, aridity)	
6. *Ulex europaeus* shrubland	Gorse shrubland	1.3 ± 0.2	94.2 ± 3.0	Negligible	Intense (sowing, cutting, burning)
7. *U. minor* shrubland	Gorse shrubland	0.6 ± 0.1	94.3 ± 2.4	Weak (soil moisture)	Moderate-intense (cutting)
8. Undergrowth of *Eucalyptus globulus*	Reforestation understory	1.1 ± 0.4	88.6 ± 8.7	Negligible	Very intense (reforestation, burning, cutting)
9. Undergrowth of *Pinus pinaster*	Reforestation understory	1.2 ± 0.5	76.2 ± 11.4	Negligible	
10. Undergrowth of *Quercus robur*	Climax woodland understory	1.4 ± 0.3	62.3 ± 12.0	Negligible	Weak (branch cutting)

Data from Basanta (1984) and Díaz Vizcaíno (1985).

2. Shannon diversity index:

$$H' = -\sum_{i=1}^{S} p_i \log_2 p_i$$

3. Simpson dominance index:

$$\lambda = \sum_{i=1}^{S} p_i^2$$

4. Pielou evenness index:

$$J' = \frac{H'}{H'_{max}}, \text{ with } H'_{max} = \log_2 S .$$

Species richness included the herbaceous and woody species. The remaining indices were obtained from the linear cover data for woody species.

In order to relate species richness to dominance, dominance-diversity curves (Whittaker 1965) were drawn from linear cover data of the woody species, using the mean values of each species in the group of samples from each community.

Results

Species richness

Highest mean values for the total number of species were recorded in the *E. tetralix* and *E. umbellata* communities: 22 species per sample (Table 2). Lowest mean values were found in the *E. globulus*, *E. australis*, *C. striatus* and *C. scoparius* communities (13–15 species per sample). Mean number of shrub species is low (5–6 species) in the *C. striatus*, *C. scoparius* and *E. umbellata* communities. Tree species number is always limited, even in woodlands. As to herbs, the lowest values were found in the *E. australis* and *E. globulus* communities, and the highest values in the *E. tetralix* and *E. umbellata* communities. Annual herbaceous species were more common in the *E. umbellata* community; these are pioneer species, resistant to dry and oligotrophic conditions (e.g., *Aira praecox*, *Andryala integrifolia*, *Senecio lividus*, *Tolpis barbata*, *Tuberaria guttata*); perennial herbs appearing in this community are also resistant to environmental stress (e.g., *Agrostis canina*, *Avenula marginata*, *Sedum brevifolium*). The herbs present in the *E. tetralix* community, however, are mostly perennial species of moist conditions (e.g., *Carum verticillatum*, *Eriophorum angustifolium*, *Schoenus nigricans*, *Serratula tinctoria*).

The proportion of herbaceous species (73.5 and 66.3%) is considerably higher than the proportion of shrub species (26.5 and 33.7%) in the *E. umbellata* and *E. tetralix* communities, whereas the opposite is found in the *E. australis* and *E. globulus* communities, where herbs are sparsely represented (41.3 and 35.3%) and shrubs show the highest values of all (57.7 and 52.4%). The

Table 2. Species richness (mean and standard error) as number of species per sample, and diversity of woody species (mean and standard error).

Community	Total number	Annual herbs	Perennial herbs	Shrubs	Trees	H′	λ	J′	Number of woody species
1. C. scoparius	15.5 ± 2.7	1.9 ± 1.1	7.4 ± 2.2	5.8 ± 1.6	0.4 ± 0.6	0.9 ± 0.2	0.7 ± 0.1	0.4 ± 0.1	6.1 ± 0.8
2. C. striatus	14.7 ± 2.7	1.0 ± 0.4	8.1 ± 1.9	5.0 ± 2.4	0.8 ± 0.9	0.8 ± 0.3	0.8 ± 0.1	0.3 ± 0.1	5.7 ± 1.5
3. E. australis	13.9 ± 2.4	0.4 ± 0.5	5.3 ± 2.0	8.0 ± 1.6	0.1 ± 0.4	1.8 ± 0.3	0.4 ± 0.1	0.6 ± 0.1	8.1 ± 1.8
4. E. tetralix	22.6 ± 4.6	0.2 ± 0.2	14.9 ± 4.1	7.1 ± 1.6	0.5 ± 0.8	2.0 ± 0.2	0.3 ± 0.1	0.7 ± 0.1	7.6 ± 1.3
5. E. umbellata	22.4 ± 3.9	5.0 ± 2.1	11.5 ± 1.4	5.6 ± 1.9	0.5 ± 0.6	1.4 ± 0.1	0.5 ± 0.1	0.6 ± 0.1	5.9 ± 1.1
6. U. europaeus	18.3 ± 2.0	1.4 ± 0.5	9.1 ± 1.4	7.3 ± 1.8	0.5 ± 0.9	1.5 ± 0.2	0.5 ± 0.1	0.5 ± 0.1	7.8 ± 0.6
7. U. minor	19.1 ± 1.7	0.6 ± 0.2	9.4 ± 1.0	8.3 ± 1.9	0.8 ± 1.0	1.9 ± 0.2	0.4 ± 0.1	0.6 ± 0.1	9.1 ± 0.9
8. E. globulus	13.4 ± 2.5	0.5 ± 0.4	4.2 ± 2.2	7.0 ± 1.1	1.6 ± 1.0	1.8 ± 0.5	0.4 ± 0.2	0.6 ± 0.2	8.6 ± 1.1
9. P. pinaster	18.2 ± 3.6	0.5 ± 0.4	8.4 ± 2.3	7.4 ± 1.9	2.0 ± 0.8	1.7 ± 0.4	0.5 ± 0.1	0.5 ± 0.1	9.3 ± 1.4
10. Q. robur	19.5 ± 3.6	0.1 ± 0.2	9.9 ± 2.1	7.8 ± 2.2	1.7 ± 0.8	2.0 ± 0.3	0.3 ± 0.1	0.6 ± 0.1	9.5 ± 1.8

highest percentages for tree species were obviously found in the tree-covered communities (8.9 to 12.3%).

Diversity, dominance and evenness indices

The *C. scoparius* and *C. striatus* communities show the lowest diversity and evenness; they have few woody species, and show the highest values of λ, due to the occurrence of one clearly dominant species. (Table 2). Highest values for H' and J' were found in the *Q. robur* and *E. tetralix* communities with many woody species having equal cover shares. The number of woody species is correlated with the Shannon index except in the *E. tetralix* and *P. pinaster* communities; the latter is rich in woody species, with an evenness index close to 0.5. The *E. tetralix* community has a relatively low number of woody species, but with a very even cover distribution and hence a high evenness (J' = 0.7).

Dominance-diversity curves

The average dominance-diversity curves (Whittaker 1965) for the different communities are shown in Fig. 1. The *E. australis* and *E. tetralix* communities are the only ones with shrub species exceeding 30% of the total cover; in both communities the overlayering of shrub species is very high. The number of species with intermediate to low cover values ($\leq$ 10 m) is rather high (11 to 27 species).

Discussion

The literature on the relationship between diversity and other factors such as ecosystem stability or complexity is extensive and contradictory. The idea that high diversity values are associated with high system stability (e.g., Bazzaz 1975; Naveh & Whittaker 1979) has been questioned in studies where experimental results point to a relationship

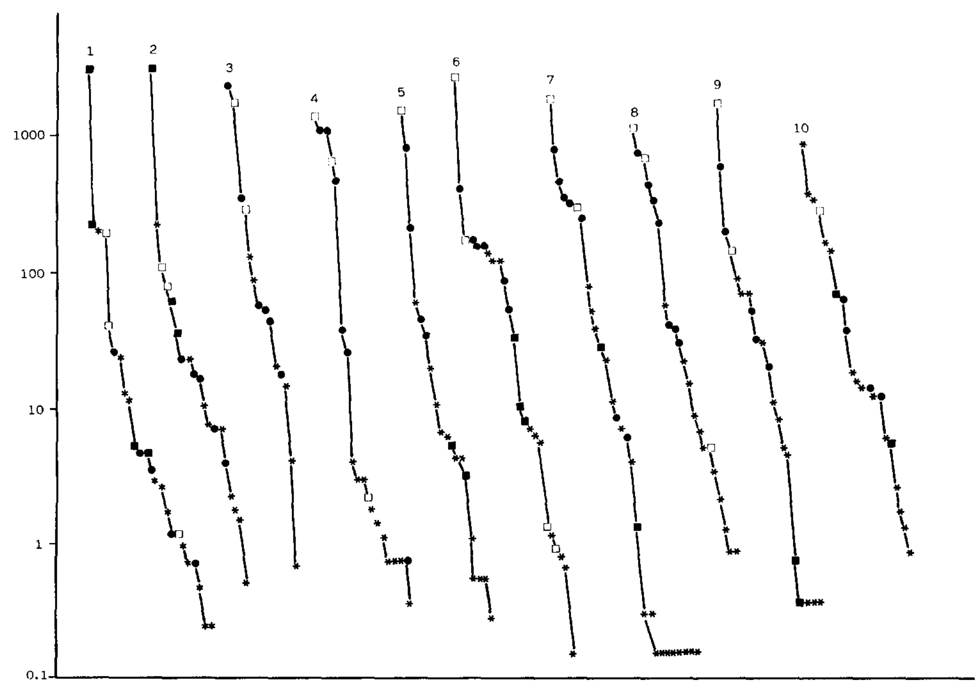

Fig. 1. Dominance-diversity curves for the different communities (see Table 1); dominance expressed as ^{10}log linear cover (cm)

■ *Cytisus-Adenocarpus* } Papilionaceae
□ *Ulex-Genista* } Papilionaceae
• Ericaceae
* Other families

between diversity and reduced stability, or where the results are equivocal (Goodman 1975; Jacobs 1975; Houssard *et al.* 1980).

This lack of agreement may be due to the difficulty of adjusting particular experimental results to theoretical models referring to more general situations, as King & Pimm (1983) point out (see also van der Maarel 1988). Furthermore, the disagreement on what constitutes stability has contributed to the confusion.

Others have attempted to relate diversity to disturbance (Denslow 1980; Miller 1982; Armesto & Pickett 1985; Glitzenstein *et al.* 1986) and here, too, disagreement exists as to the effects of different kinds, intensities and frequencies of management on diversity. It is very difficult to define or quantify the degree of disturbance experienced by a particular ecosystem, since communities are often affected by several kinds of disturbance, each with a characteristic size and frequency (Miller 1982). Also, the particular features of the system, such as vegetation structure, type of dominant species or conditions of the vegetation prior to disturbance, cause different responses to similar disturbances in different communities (Armesto & Pickett 1985; Glitzenstein *et al.* 1986).

In addition to disorganizing processes (as management is in most cases), limiting processes (environmental stress), have an influence on the diversity and organization of an ecosystem (e.g., Fernández Alés *et al.* 1984). Environmental stress may limit dominance and competitive exclusion, leading to increased diversity (e.g., Pianka 1974; del Moral & Fleming 1980). Frequently, both types of processes act together, with different relative intensities, and a permanent interaction between them exists which affects the community's degree of organization at different times.

We now summarize and discuss our results in the light of these issues. The total number of species for all communities studied shows a mean value of 17.9 ± 0.9; the mean value for the number of woody species is 7.6 ± 0.4. Many authors point to the floristic poverty of similar European shrublands, as well as to the broad ecological tolerance of many of their constituent species which allows them to survive under severe environmental conditions (Bannister 1964; Dalda 1978; Gimingham *et al.* 1979; MacCarter & Gaynor 1980; Miles & Young 1980; Williams 1981). Also, management practices and the acidifying effects of some of these species contribute to the low species richness of such communities and to a progressive edaphic impoverishment (Gimingham 1972; Gimingham *et al.* 1979; Miles & Young 1980).

The *E. australis* community and the understory of *E. globulus* woodlands are particular cases, since they have very few herbaceous species but a relatively high diversity of woody species. This seems to support the idea that both species inhibit herb growth (Baker 1966; Bellot 1966; Carballeira & Cuervo 1980; Rigueiro & Silva-Pando 1983).

The *E. umbellata* community, with a high species richness, has comparatively low values for diversity of woody species because it is a pioneer shrubland, with a high proportion of bare rock and a low vegetation cover. The dominant species is *U. europaeus*, with *E. umbellata* and *E. cinerea* present to a lesser degree. The high values of species richness are due to the herb species here.

The *E. tetralix* community is one of the most diverse communities, both in herbaceous and woody species. This community is rarely exploited. It is markedly hygrophytic and its plant components are well adapted to conditions of impeded drainage, acid soil and nutrient shortage.

Another diverse community is the understory of *Q. robur* woodlands. Both heathlands and the *Q. robur* community are minimally disturbed by man, whereas the remaining communities (broom shrublands, gorse shrublands and the understory of *P. pinaster* and *E. globulus*) are subject to moderate to very intense human influence. The most disturbed and floristically least defined communities are gorse shrublands (*U. europaeus* and *U. minor* communities) and the understory of *P. pinaster* and *E. globulus* woodlands; these 2 reforestation species are usually planted in previous gorse shrublands. The 4 communities are similar in floristic composition, and are composed of species with a wide tolerance to varied environmental conditions and resistant to frequent and generally intense disturbances. In general, the effect of management seems to be a uniformity of floristic composition rather than a clear decrease in diversity, at least for the most disturbed shrublands. Diversity, whether total or for herbs or shrubs only, is higher in weakly disturbed communities.

References

Armesto, J.J. & Pickett, S.T.A. 1985. Experiments on disturbance in old-field plant communities: Impact on species richness and abundance. Ecology 66: 230–240.

Baker, H.G. 1966. Volatile growth inhibitors produced by *Eucalyptus globulus*. Madroño 18: 206–210.

Bannister, P. 1964. The water relations of certain heath plants with reference to ecological amplitude. III. Experimental studies and general conclusions. J. Ecol. 52: 499–509.

Basanta, M. 1984. Estructura de los sistemas de matorral de la cuenca del Tambre (La Coruña). Tesis Doctoral, Universidad de Santiago.

Basanta, M., Díaz Vizcaíno, E. & Casal, M. 1988. Structure of shrubland communities in Galicia (NW Spain). In: During, H.J., Werger, M.J.A. & Willems, J.H. (eds), Diversity and pattern in plant communities, pp. 25–36. SPB Academic Publishing, The Hague.

Bazzaz, F.A. 1975. Plant species diversity in old-field successional ecosystems in Southern Illinois. Ecology 56: 485–488.

Bellot, F. 1966. La vegetación de Galicia. An. del. Inst. A.J. Cavanilles, Madrid.

Carballeira, A. & Cuervo, A. 1980. Seasonal variation in allelopathic potential of soils from *Erica australis* L. heathland. Oecol. Plant. 1: 335–344.

Carballeira, A., Devesa, C., Retuerto, R., Santillán, E. & Ucieda, F. 1983. Bioclimatología de Galicia. Fundación Barrié de la Maza, La Coruña. 391 pp.

Dalda, J. 1978. Los efectos del fuego en la vegetación forestal de Galicia. Natur. Hispan. 16.

del Moral, R. & Fleming, R.S. 1980. Structure of coniferous forest communities in Western Washington: Diversity and ecotope properties. Vegetatio 41: 143–154.

Denslow, J.S. 1980. Patterns of plant species diversity during succession under different disturbance regimes. Oecologia (Berl.) 46: 18–21.

Díaz Vizcaíno, E. 1985. Ecología del matorral de la cuenca des Tambre (La Coruña): Relación con factores ambientales. Tesis Doctoral, Universidad de Santiago.

Fernández Alés, R., Marañón, T., Figueroa, M.E. & García Novo, F. 1984. Interacciones entre geomorfología e intervención humana sobre la composición del matorral en la cuenca del río Guadalupejo (Extremadura). Studia Oecologica 5: 35–53.

Géhu-Franck, J. 1974. Contribution a l'étude auto- et synecologique de l'ajonc d'Europe (*Ulex europaeus* L.). Thèse d'Etat, Université de Lille II.

Gimingham, C.H. 1972. Ecology of heathlands. Chapman and Hall, London.

Gimingham, C.H., Chapman, S.B. & Webb, N.R. 1979. European heathlands. In: Specht, R.L. (ed.), Heathlands and related shrublands, pp. 365–413. Elsevier, Amsterdam.

Gimingham, C.H., Hobbs, R.J. & Mallik, A.U. 1981. Community dynamics in relation to management of heathland vegetation in Scotland. Vegetatio 46: 149–155.

Glitzenstein, J.S., Harcombe, P.A. & Streng, D.R. 1986. Disturbance, succession, and maintenance of species diversity in an East Texas forest. Ecol. Monogr. 56: 243–258.

Goodman, D. 1975. The theory of diversity-stability relationships in ecology. Quart. Rev. Biol. 50: 237–266.

Gounot, M. 1969. Méthodes d'étude quantitative de la végétation. Masson, Paris.

Greig-Smith, P. 1983. Quantitative plant ecology (3rd ed.). Blackwell, Oxford.

Houssard, C., Escarré, J. & Romane, F. 1980. Development of species diversity in some mediterranean plant communities. Vegetatio 43: 59–72.

Jacobs, J. 1975. Diversity, stability and maturity in ecosystems influenced by human activities. In: van Dobben, W.H. & Lowe-McConnell, R.H. (eds), Unifying concepts in ecology, pp. 187–207. Junk, The Hague.

King, A.W. & Pimm, S.L. 1983. Complexity, diversity, and stability: A reconciliation of theoretical and empirical results. Amer. Nat. 122: 229–239.

MacCarter, L.E. & Gaynor, D.L. 1980. Gorse: A subject for biological control in New Zealand. N.Z.J. Exp. Agric. 8: 321–330.

Miles; J. & Young, W.F. 1980. The effects on heathland and moorland soils in Scotland and Northern England following colonization by birch (*Betula* spp.). Bull. Ecol. 11: 233–242.

Miller, T.E. 1982. Community diversity and interactions between the size and frequency of disturbance. Amer. Nat. 120: 533–536.

Moore, J.J., Fitzsimons, P., Lambe, E. & White, J. 1970. A comparison and evaluation of some phytosociological techniques. Vegetatio 20: 1–20.

Mueller-Dombois, D. & Ellenberg, H. 1974. Aims and methods of vegetation ecology. Wiley, New York.

Naveh, Z. & Whittaker, R.H. 1979. Structural and floristic diversity of shrublands and woodlands in Northern Israel and other mediterranean areas. Vegetatio 41: 171–190.

Parga Pondal, I. 1967. Datos geológico-petrográficos de la provincia de La Coruña. In: Inst. de Inv. Geol., Edafol. y

Agrobiol. de Galicia, Estudio Agrobiológico de la provincia de La Coruña, pp. 35–76. Publ. Excma. Diputacíon Provincial de La Coruña, La Coruña.

Pianka, E.R. 1974. Evolutionary ecology. Harper and Row, New York.

Rigueiro, A. & Silva-Pando, F.J. 1983. Algunas consideraciones sobre los efectos del *Eucalyptus globulus* Labill. sobre el medio natural gallego. Cuad. Area C. Agrarias 4: 426–444.

Rivas Martínez, S. 1979. Brezales y jarales de Europa occidental (Revisión fitosociológica de las clases Calluno-Ulicetea y Cisto-Lavanduletea). Lazaroa 1: 5–127.

van der Maarel, E. 1988. Species diversity in plant communities in relation to structure and dynamics. In: During, H.J., Werger, M.J.A. & Willems, J.H. (eds), Diversity and pattern in plant communities, pp. 1–14, SPB Academic Publishing, The Hague.

Webb, N.R. 1980. Aménagement et conservation des landes: Synthèse. Bull. Ecol. 11: 655–658.

Westhoff, V. & van der Maarel, E. 1978. The Braun-Blanquet approach. In: Whittaker, R.H. (ed.), Classification of plant communities, pp. 287–399. Junk, The Hague.

Whittaker, R.H. 1965. Dominance and diversity in land plant communities. Science 147: 250–260.

Williams, P.A. 1981. Aspects of the ecology of broom (*Cytisus scoparius*) in Canterbury, New Zealand. N.Z.J. Bot. 19: 31–43.