SMALL MAMMAL COMMUNITY STRUCTURE IN TWO SUCCESSIONAL STAGES OF A MEDITERRANEAN ECOSYSTEM

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ABSTRACT

In this study the influence of habitat differences on the composition and structure of small mammals' communities was investigated. Two sites representing different stages of ecological succession were selected. One of the sites was dominated by shrubs – Macchia, while the other was mainly occupied by herbs - Grassland. Both sites were located near Évora, southern Portugal, a region characterised by Mediterranean-type climate, with two distinct seasons: a wet and cold winter and a hot and dry summer. Monthly surveys were based on capture-recapture techniques. Small mammal's assemblages included in each site the Wood mouse *Apodemus sylvaticus* Linnaeus, 1758 (Rodentia, Muridae), the Algerian mouse *Mus spretus* Lataste, 1883 (Rodentia, Muridae) and the Common shrew *Crocidura russula* Hermann, 1780 (Insectivora, Soricidae). The structure of each community changed over time, following distinct patterns. The highest numbers of *A. sylvaticus* were recorded in the Macchia over winter, whereas *M. spretus* reached its highest numbers apparently over summer with no clear differences between the two study areas. *C. russula* occurred with higher numbers in the Grassland, with no clear differences throughout the annual cycle in both sites. The 1-Simpson diversity index values were lower in the Macchia than in the Grassland, reflecting the high numbers of *A. sylvaticus* in the former and suggesting that the Grassland is ecologically more unstable.

Keywords: Ecological Succession, Mediterranean habitats, Small Mammals.

RESUMEN

Estructura de la comunidad de micromamíferos en dos estadios de la sucesión en un ecosistema mediterráneo

El presente estudio analiza la influencia de distintos hábitats en la composición de las comunidades de micromamíferos. Fueron seleccionados dos biotopos que representan distintos estadios de la sucesión vegetal: en una de las áreas predominan los arbustos (Maquia), en el otro las plantas herbáceas (Herbazal), los dos localizados cerca de Évora, sur de Portugal. El clima en esta región es típicamente mediterráneo, con dos estaciones distintas: un invierno frío y húmedo y un verano caluroso y seco. Se realizaron mustreos mensuales basados en técnicas de captura-recaptura. Las especies identificadas fueron las siguientes: el ratón de campo *Apodemus sylvaticus* Linnaeus, 1758 (Rodentia, Muridae), el ratón moruno *Mus spretus* Lataste, 1883 (Rodentia, Muridae) y la musaraña común *Crocidura russula* Hermann, 1780 (Insectivora, Soricidae). La estructura de cada una de las comunidades varió con el tiempo, apreciándose distintos patrones en cada uno de los biotopos estudiados: *A. sylvaticus* alcanzó mayores abundancias en la Maquia durante el Invierno, mientras que las mayores abundancias de *M. spretus* se registraron aparentemente durante el Verano, sin apreciarse diferencias claras entre los dos biotopos. *C. russula* alcanzó mayores abundancias en el Herbazal, sin claras oscilaciones en el desarrollo del año. Los valores del índice de diversidad 1-Simpson fueron menores en la Maquia, reflejando la elevada densidad de *A. sylvaticus* en este biotopo y demostrando la mayor inestabilidad en el Herbazal.

Palabras clave: hábitats mediterráneos, micromamíferos, sucesión ecológica.

INTRODUCTION

The human impact upon Mediterranean ecosystems throughout the last centuries has lead to a complex vegetation structure (Pena et al. 1985), corresponding to different stages of ecological succession (progressive or regressive). In the Mediterranean Basin the patchy pattern of land use allows for a rich niche segregation and a high biotic diversity (Pignatti 1983).

Temporal changes in plant communities associated with changes in animal communities, their richness or diversity, have been addressed in several studies (e.g. Foster and Gaines 1991, Fernández et al. 1994). Usually data were gathered through simultaneous sampling at distinct successional sites (chronosequency method), instead of in a single site over time (Hill 1986 in Fernández et al. 1994, Michener 2000). This approach has been used to investigate the responses of mammals to ecological succession in European forests (e.g. Wolk and Wolk 1982, Hanson 1987, Fernández et al. 1994) and in old field plant communities in North America (eg. Schweiger et al. 2000).

The abundance of small mammals in patches submitted to different types of management, like herbicide treatments (Runciman and Sullivan 1996, Sullivan 1996, Sullivan et al. 1997, Sullivan et al. 1998), fire disturbances (Christian 1997, Fons et al. 1988, Simons 1991, Fa and Sánchez-Cordero 1993, Fons et al. 1996, Sullivan and Boateng 1996), or clear-cutting (Mitchell 1995), suggests that succession can strongly affect their population parameters. So, the experimental studies concerning the changes in small mammal communities, induced by different successional stages, assume a great importance (Foster and Gains 1991), since most species encounter their preferred habitat as patches embedded in a matrix of less favourable habitats (Forman and Gordon 1981, 1986 in Mauritzen et al. 1999).

In the present study, species diversity and abundance were analysed and compared in two different small mammals assemblages inhabiting a mesophyl Macchia and a Grassland. By doing this we shall be able to understand the influence of habitat characteristics on spatiotemporal dynamics in natural populations.

MATERIAL AND METHODS

Study areas

This study was carried out in two different successional habitats (a Macchia and a Grassland) in Herdade da Mitra, Évora, Southern Portugal, a region characterised by Mediterranean-type climate, with cold and wet winters and hot and dry summers.

Macchia

This habitat is characterised by a very dense vegetation cover (over 90%). Vegetation is dominated by sclerophyl evergreen shrubs, which reach the arboreal form (microfanerophyts) creating a shadowy and humid sub-cover, with a poor herbaceous stratum during summer. Dominant species were the dwarf kermes oak (*Quercus coccifera*), the strawberry tree (*Arbutus unedo*), the rock-roses (*Cistus sp*), the honeysuckle (*Lonicera implexa*), the heather-family shrubs (*Erica scoparia* and *Calluna vulgaris*), the rosemary (*Rosmarinos officinalis*), and the lavander (*Lavandula luisieri*).

Grassland

This habitat represents an open area with a simple structure. Dominant herbs species were the following: *Avena barbata*, *Brisa maxima*, *Vulpia geniculata* and *Agrostis pourret*. Disperse spots of shrubs (mainly *Cistus salvifolius*) and recently planted pines (*Pinus* sp) and Cork oaks (*Quercus suber*), reaching no more than 50 cm high, were also present.

Small mammals sampling

Small mammals were live-trapped monthly between October of 1999 and August of 2000 in the Macchia and between November of 1999 and September of 2000 in the Grassland. A grid of 100 Sherman live-traps (10 rows x 10 columns) was set up at 10 m intervals in each area for four consecutive nights in each trapping session. Traps were baited with a mixture of oat-flakes, sardines and vegetable oil. Cotton was used as bedding. Each four-night session was preceded by a three night pre-trapping period during which traps were placed unset and unbaited. During trapping sessions, traps were checked out every morning at sunrise and all small mammals caught were identified, sexed and, when possible, aged and evaluated for reproductive condition. All individuals captured were marked by toe clipping (Begon 1979) and released at trapping points immediately after data collection.

Vegetation sampling

Several parameters describing the vegetation structure were measured in a total of 100 squares (each one with 5 x 5 m) centred in each trap. Considering that temporal and spatial variability are inherent to ecological patterns, the data collection was replicated at two different times of the annual cycle, in order to get information concerning to the hot and dry season (DS) and to the cold and moisted one (WS). Variables were selected taking in account their possible direct or indirect influence on small mammals' populations. In the Macchia six variables were measured: shrub cover percentage (%SC), herbaceous cover percentage (%HC), litter cover percentage (%LC), mean shrub height (SH), mean herbaceous height (HH) and number of acorns (NA). In the Grassland, only %SC, %HC, %LC, SH and HH were measured, since there were no acorns in this area. For %SC, %HC and %LC an ocular estimate was made in each of 100 squares. For AN, counts were made in four sub-squares with 50 x 50 cm randomly placed inside each of the 5 x 5 m square.

Data analysis

Minimal number of animals known to be alive (MNKA) was used as an assessment of the monthly abundance of each species in each habitat (Slade and Blair 2000). For monthly diversity measures, the complement of the Simpson diversity index (*D*), i.e. 1-*D* (Decher and Bahian, 1999), sensitive to changes in the more abundant species (Sullivan *et al* 1998), was used. The index 1-*D* describes the probability of picking up two organisms from different species (Decher and Bahian, 1999). Factorial ANOVAs (Sokal and Rohlf 1995, Underwood 1997) were used for comparisons of MNKAs values of each species between sites and between two different annual periods: October to March – Wet Season (WS); April to September – Dry season (DS), after a square-root transformation ($\sqrt{[MNKA+0.5]}$) (Sokal and Rohlf 1995, Underwood 1997). Differences in diversity indexes were also evaluated between habitats and between WS and DS, by ANOVA procedures (Sokal and Rohlf 1995, Underwood 1997). Previously to this analysis, diversity indexes were log transformed ($\log[(1\text{-}D)+1]$) (Sokal and Rohlf 1995, Underwood 1997). Bonferroni correction for multiple comparisons was applied to small mammal's data set, in order to conserve *p*-value=0.05 (four tests, significant *p*-value= 0.013). Vegetation descriptors measured simultaneously in both areas were compared between habitats by season, performing one-way ANOVA. Before this analysis variables dealing with proportions were arc-sin transformed ($\text{arc-sin}[\sqrt{(X/100)}]$) and the others were square-root transformed ($\sqrt{[X+0.5]}$) (Sokal and Rohlf 1995, Underwood 1997). Also Bonferroni correction for multiple comparisons was used to this set of data (a total of eight tests were performed, so the significant *p*-value was 0.006).

Results

A total of 210 individuals were captured 889 times. 102 occurred in the Macchia and were captured in 495 occasions, while the remaining 108 individuals were captured in the Grassland, in 394 occasions. Three species were identified: two rodents (Wood mouse, *Apodemus sylvaticus* and Algerian mouse, *Mus spretus*) and one insectivore (Common shrew, *Crocidura russula*). In the Macchia 75 *A. sylvaticus* were captured 444 times; 13 *M. spretus* were captured 24 times and 15 *C. russula* were captured 27 times. In the Grassland 50 *A. sylvaticus* were captured 230 times; 28 *M. spretus* were captured 77 times and 30 *C. russula* were captured 77 times.

Table 1
Minimal Number of Animals Known to be Alive (MNKA) and 1-*D* diversity index (*D* = Simpson diversity index) by month in the Macchia (A) and in the Grassland (B)

Número Mínimo de Individuos que se sabe que están vivos e índices de diversidad 1-*D* (*D* = índice de diversidad de Simpson) en cada mes en el Maquia (A) y en el Herbazal (B)

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.
A. s.	13	25	32	29	23	19	16	11	11	11	6
M. s.	1	1	0	0	0	0	0	0	0	2	9
C. r.	0	5	4	2	1	2	1	1	1	2	4
Total	14	32	36	31	24	21	17	12	12	14	19
1-*D*	0.132	0.322	0.197	0.120	0.079	0.172	0.110	0.152	0.152	0.426	0.656

A

	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
A. s.	2	16	15	21	14	8	14	3	8	2	0
M. s.	0	0	0	0	1	0	0	2	11	9	15
C. r.	7	4	11	10	7	5	2	7	3	3	5
Total	9	20	26	31	22	13	15	12	22	14	20
1-*D*	0.346	0.320	0.488	0.437	0.492	0.473	0.219	0.569	0.599	0.520	0.375

B

The monthly values of MNKA for each species and the monthly diversity (measured as 1-*D*) in both sites, are presented in table 1 (A and B). In both the Macchia and the Grassland, MNKAs of *A. sylvaticus* were highest during the coldest and wettest months, with peaks in December in the Macchia and in February in the Grassland. A trend for a decline throughout the hottest and driest months is also evident. However, in the Macchia, MNKAs of *A. sylvaticus* were always higher than in the Grassland, where this species was even absent during September. MNKAs of *M. spretus* increased during the hottest and driest months. This species was absent in both habitats during most of the study period, in spite of occurring with an apparent higher abundance in the Grassland. *C. russula* seemed to reach higher abundance during the coldest and wettest months, being present throughout the year in the Grassland, and absent in the Macchia in October, area where it was generally captured in smaller numbers.

TABLE 2
Results of factorial ANOVAs analysis performed to test the effect of type of habitat, season and interaction habitat*season in each species abundance and in 1-*D* diversity index (*D* = Simpson diversity index)

Resultados de las ANOVAs factoriales realizadas para testar el efecto del tipo de hábitat, estación e interacción hábitat*estación en la abundancia de cada especie y en el índice de diversidad 1-*D* (*D* = índice de diversidad de Simpson)

	A. sylvaticus		*M. spretus*		*C. russula*		*Diversity 1-D*	
	F	*p*	*F*	*p*	*F*	*p*	*F*	*p*
Habitat	8.356	0.0097	1.544	0.2299	20.749	0.0002	11.649	0.0031
Season	12.337	0.0025	5.941	0.0253	4.033	0.0599	1.718	0.2063
Habitat*Season	0.057	0.8134	2.046	0.1698	2.082	0.1663	0.530	0.4759

Diversity seems to be globally higher in the Grassland, with no clear signs of differences throughout the study period in both areas.

The effects of the successional habitat and season on abundance of each species and on diversity are summarised in table 2. Considering the level of significance $p=0.05$, the differences in MNKAs between habitats were statistically significant for *A. sylvaticus* and for *C. russula* ($p<0.013$, with Bonferroni correction) and non-significant for *M. spretus* ($p>0.013$, with Bonferroni correction). Between seasons differences in MNKAs were only significant for *A. sylvaticus* ($p<0.013$, with Bonferroni correction). For *M. spretus* although the *p*-value was near significance (considering Bonferroni correction), MNKAs were not statistically different between seasons, on the basis of the criteria followed for the entire study ($p<0.05$). Nevertheless, the inequalities above should be considered meaningful (Sokal and Rohlf 1995). Concerning the diversity indexes, only differences between habitats were statistically significant ($p<0.013$, with Bonferroni correction). The effect of the interaction between habitat and season was not significant for the abundance of each species, as well as for the diversity indexes ($p>0.013$, with Bonferroni correction). This means that the recorded differences between patches are equal for each season and the recorded differences between seasons are identical for both habitats.

TABLE 3

Mean values and respective standard errors of the vegetation descriptors in the Macchia and in the Grassland in Wet season (A) and in Dry season (B). The *F*-values and respective *p*-values resulted from one-way ANOVA comparisons of each variable at each season are also presented

Valores medios y respectivos errores patrón de las variables que fueron seleccionadas para describir la vegetación en el Maquia y en el Herbazal durante WS (A) y durante DS (B). Se presentan también los valores de *F* y *p* resultantes de las comparaciones por ANOVA simples de cada variable en cada estación

	Macchia		Grassland			
	mean	Std error	Mean	Std error	*F*	*p*
% shrub cover	61.05	2.02	20.54	1.19	278.63	<0.0001
% herbaceous cover	7.49	0.55	52.99	1.75	725.65	<0.0001
% litter cover	56.45	2.32	21.93	1.03	174.26	<0.0001
shrub mean height	175.42	6.43	46.01	1.44	609.47	<0.0001
Herbaceous mean height	4.63	0.21	8.31	0.58	36.53	<0.0001
nr of acorns	35.52	2.64	0	0	-	-

(A)

	Macchia		Grassland			
	mean	Std error	Mean	Std error	*F*	*p*
% shrub cover	66.16	2.09	24.38	1.23	267.19	<0.0001
% herbaceous cover	0	0	63.25	1.74	-	-
% litter cover	60.35	2.53	17.89	1.02	235.86	<0.0001
shrub mean height	177.6	6.52	51.23	1.49	583.76	<0.0001
Herbaceous mean height	0	0	19.08	0.71	-	-
nr of acorns	35.6	2.69	0	0	-	-

(B)

Descriptive statistics for the variables describing the vegetation structure and results of one-way ANOVA comparisons between habitats, are shown in Table 3. In both seasons the shrub cover and height and the litter cover were significantly higher in the Macchia (*p*<0.006, with Bonferroni correction), while herbaceous cover and height were significantly higher in the Grassland in the WS (*p*<0.006, with Bonferroni correction). During the DS this stratum was absent in the Macchia. Acorns were present in both season in the Macchia, but absent in the Grassland.

DISCUSSION

In the two successional habitats studied we found the same species composition. The three species captured are among the commonest Mediterranean small mammals (Gonsálbez and López-Fuster 1985, Fons et al. 1988, Fons et al. 1996, Paillat and Butet 1997, Cagnin et al. 1998, Solis et al. 2000). However, results revealed different spatial and temporal patterns in abundance of each species. In both sites, a significant decline of *A. sylvaticus* from the WS to the DS, was recorded, in opposition to a trend towards an increase in *M. spretus* numbers from the WS to the DS. As for *C. russula* no clear changes in numbers throughout the study period were noted either in the Macchia or in the Grassland. A seasonal pattern in numbers of *A. sylvaticus* has already been reported elsewhere (e.g. Bengtson et al. 1989, Montgomery 1989, Tellería et al. 1991, Wilson et al. 1993, Tattersall 1999, Solis et al. 2000). The higher abundance of this species during the WS, is in apparent accordance with an increased proportion of sexually active individuals (mainly females) during this period in Mediterranean coastal areas (Ricardo Pita unpublished data, Solis et al. 2000). Yet, the reproductive strategy verified does not settle in all parts of Iberian Peninsula. Sans-Coma and Gosálbez (1976) registered in the north-eastern Iberia that the breeding season of *A. sylvaticus* extended over summer. Gomes (1986) recorded in Parque Nacional da Peneda-Gerês (north Portugal) a higher proportion of reproductive individuals during summer. Fons and Saint Girons (1993) found different reproductive strategies in Mediterranean mountains and in Mediterranean coastal areas. The different results ahead show the high ecological plasticity of this species, concerning reproductive patterns.

The increase in numbers of *M. spretus*, from the WS to the DS seems to be in agreement with Moreira and Naumann-Etienne (1987) findings in Portugal. According to these authors *M. spretus* undergoes strong annual fluctuations, decreasing during winter and reaching higher densities (sometimes 300 or more individuals/ha) between August and November. Mira and Mathias (1996) also referred that winter is the most unfavourable period for this species. The higher abundance of *M. spretus* during the DS, seems to correlate with the reproductive period in southern Portugal which, following Mira and Mathias (1994), peaks on spring and summer.

The abundance of *C. russula* seems to be similar throughout the studied period, with the exception of late winter. During this period, the higher numbers recorded may reflect the recruitment of young, following the reproductive period which, in Mediterranean populations, occurs mainly during winter (Solis et al. 2000).

Temporal changes in numbers of each species presented similar trends in both patches. However, there are strong differences on numbers of individuals between the Macchia and the Grassland, especially concerning *A. sylvaticus* and *C. russula*.

The differences of MNKA estimates for *A. sylvaticus* between successional habitats suggest a higher affinity of this species by the Macchia. Available data concerning to vegetation structure in the two studied habitats, have shown that shrub and litter cover was about three to four times higher in the Macchia than in the Grassland, fact that, associated with the greater shrub heights in the former area, can account for the higher abundance of *A. sylvaticus* recorded in the first patch. Following Moreira and Naumann-Etienne (1987) and Tew and MacDonald (1993), this species often occurs in dense forests and only occasionally in open fields. Indeed, although recorded in many types of habitats (Madureira and Ramalhinho 1981, Fons et al. 1988), *A. sylvaticus* is very often associated to fields with high forest cover (Angelstam et al. 1987, Fons et al. 1988, Tellería et al. 1991). Churchfield and Brown (1987), also referred the *A. sylvaticus* preference by aged successional stages like the Macchia. In addition, dwarf kerme oak acorns, can provide an important food resource for *A. sylvaticus* in the Macchia (Ricardo Pita personal observations). These fruits were absent in the Grassland.

Although for *M. spretus* the results suggest a trend to a preference for the Grassland, the differences in abundances between habitats are not significant. The low numbers of *M. spretus* throughout most of the study period, despite its expressive appearance in the latest months, apparently different in each area, do not allow statistically significant differences to be found. Possibly a longer study would show an effective inequality in *M. spretus* abundances between the seccessional stages, with higher numbers in the Grassland. In this habitat the grass cover was always higher throughout the year. Habitats were mostly different on summer, when no grasses appeared in the Macchia. According to Moreira and Naumann-Etienne (1987), *M. spretus* prefers open fields with high grasses, occurring in shrubby areas only when gramineas are present. Fons et al. (1988) also recorded a positive correlation between *M. spretus* numbers and grass cover. Moreira and Neumann-Etienne (1987) referred that *M. spretus* eats all types of fruits, herbs and occasionally insects and other types of animal food items. So, it is plausible to suppose that the Grassland provides more adequate food resources for *M. spretus* than the Macchia, afforded by its more diverse and dense herb structure as well as the invertebrate fauna associated to it.

C. russula revealed clear differences in abundance between habitats, being much more abundant in the Grassland. This preference may be related with higher food availability, in this area. Indeed, a greater availability of small terrestrial invertebrates, which play a major role in *C. russula* diet (Fons et al. 1988, Churchfield et al. 1991), is expected in the Grassland, due to better microclimate conditions for these organisms, afforded by the dense grass cover.

The higher diversity values in the Grassland may reflect both the high numbers of *A. sylvaticus* in the Macchia community and a higher instability in the Grassland. This instability may be related with the presence of a high number of annual plants, and fewer perennial plants, the later being the commonest formations in the Macchia. Fernández et al. (1994) also reported higher diversity indexes in earlier successional stages and support their results on the basis of the higher variability in plant species which diversified ecological niches, allowing for the presence of distinct small mammal species.

Globally, our results are in agreement with other authors findings for the same species in Mediterranean environments. Although concerning only three species, which are among the commonest small mammals in Iberia, the present study is relevant due to the scarcity of this kind of data on the south western part of the peninsula. The results also illustrate different species-specific strategies to face habitat and temporal environmental changes, that are common in the Mediterranean region. This suggests a wide range of responses to succession in Mediterranean ecosystems and the need for clarification of processes lying beneath.

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