

A LIST OF ARTHROPOD SPECIES OF SOWN AND SEMI-NATURAL PASTURES OF THREE AZOREAN ISLANDS (S. MARIA, TERCEIRA AND PICO) WITH SOME CONSERVATION REMARKS

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ABSTRACT

During the years 1994 and 1995 arthropod sampling was carried out at twelve pasture sites (two replicates of recently sown and old semi-natural pastures) in three Azorean islands (S. Maria, Terceira and Pico). By means of pitfall traps, a suction machine (VORTIS) and direct sampling a total of 237 herbivorous and predatory arthropod species were collected. This contribution lists those species together with information on their feeding habits, colonization status and distribution. In terms of species richness patterns, the results showed that there is no consistent habitat effect in indigenous and introduced arthropod species richness in sown and semi-natural pastures. Rather, the regional effect seems to be of overwhelming importance in shaping the local species distributions. However, introduced predators are more common in sown pastures and the abundance of the endemic spider *Pardosa açorensis* is higher in the semi-natural than in sown pastures from S. Maria and Pico.

RESUMO

Durante os anos de 1994 e 1995 investigou-se a fauna de artrópodes em doze pastagens (duas réplicas de pastagem semeada e duas réplicas de pastagem semi-natural) em três ilhas açorianas (S. Maria, Terceira e Pico). Um total de 237 espécies de artrópodes herbívoros e predadores foram inventariados usando armadilhas *pitfall*, um aspirador mecânico (VORTIS) e colheitas directas. Na presente contribuição listamos todas as espécies, apresentando para cada uma informação sobre os seus hábitos alimentares, tipo de colonização e distribuição. Em termos de padrões de riqueza de espécies, os resultados mostram que não existe um efeito do habitat no número de espécies autóctones e introduzidas presentes nas pastagens semeadas e semi-naturais. Pelo contrário, o tipo de ilha parece ser mais importante na determinação da riqueza de espécies ao nível local. No entanto, os predadores introduzidos são mais ricos em espécies nas pastagens semeadas e a abundância da aranha endémica *Pardosa açorensis* é mais elevada nas pastagens semi-naturais do que nas pastagens recentemente semeadas de S. Maria e Pico.

INTRODUCTION

The Azorean islands are rich in pasture habitats, which occupy more than 50% of its surface (Garcia & Furtado, 1991). According to the plant species composition, Oliveira (1989) described five types of permanent sown pastures and two types of semi-natural pastures in the largest Azorean island, S. Miguel.

Oceanic islands are recognized as being highly susceptible to biological invasions (Elton, 1958; Coblenz, 1990; Begon *et al.*, 1996; Vermeij, 1996; Williamson, 1996), although D'Antonio & Dudley (1995) point out that it is often difficult to find experimental support for this dogma. The extent of biological invasions in the Azorean islands is still poorly recorded, but some evidences suggest that they are important (see Hansen, 1988; Borges, 1992).

The arthropod diversity of recent sowed and old semi-natural pastures from three Azorean islands, S. Maria, Terceira and Pico was recently investigated (see Borges, 1997, 1999; Borges & Brown, 1999). The proportion of introduced, native and endemic arthropods in sown and semi-natural Azorean pastures is unknown, but should be investigated for several reasons: a) to test the importance of semi-natural pastures for the indigenous arthropods; b) to have an idea of the assemblage of potential damaging

species for the pasture vegetation; c) to know the predatory species available for future biological control programs.

Studies describing the arthropod fauna from the Azorean pastures are lacking, the only studies available being about some insects causing damage on pastures (see a detailed list of references on Vieira & Borges, 1993).

The purposes of this paper are to: 1) List the arthropod species found in replicates of sown and semi-natural pastures of three Azorean islands (S. Maria, Terceira and Pico) with information on their feeding habits and colonization status. 2) Document patterns of species richness of introduced, native and endemic pasture-dwelling arthropods in two types of pasture, old semi-natural and recent sowed, on the three studied islands. 3) Address the implications of the results in terms of Conservation Management of semi-natural pastures and indigenous pastureland arthropod species in the Azores.

MATERIAL AND METHODS

Study areas and experimental design

All sample areas within the islands were cattle-grazed upland pastures of two different types: a) recent sown pastures (3-4 years old); b) wet semi-natural old pastures (more than 35 years old). The major aim of having the two

types of pasture was to detect ecological differences between improved highly productive pastures (originally sown with *Trifolium repens* L., *Lolium perenne* L. and other perennial grasses) and old semi-natural pastures. Two 900 m² replicates of each type were selected in each island at a high-altitude level. For a detailed description of the sites see Borges (1997). In all the 12 pastures (3 islands x 2 pasture types x 2 replicates), an area of at least 900 m² was fenced during January and February 1994 with posts and barbed wire. Rabbit fences to avoid differential rabbit grazing pressure were erected in April 1994. All field sites were grazed regularly by dairy and beef cattle, thereby maintaining the traditional management of the sites.

Arthropod sampling

All the sampling periods occurred at least three weeks after a grazing period, allowing regrowth of the vegetation. A total of three complete samples occurred during the first year of field work (1994) in the following months: 1) May - June (Spring); 2) July - August (Summer); 3) September - October (Autumn). In 1995, two major sampling periods occurred: 4) May - June (Spring) and 5) end of July - August - early September (Summer).

During four main sampling periods (Spring, Summer and Autumn 1994;

Summer 1995), two commonly used methods of sampling arthropods were used: pitfall traps and suction.

The pitfall sampling consisted of seven consecutive days (nights) of sampling in the 12 field sites. A set of twenty pitfall traps was used, and positioned according to a grid structure. The pitfall trap used was a plastic cup with a trap diameter of 110 mm and a depth of 70 mm. The killing-preserving agent used was ethylene glycol (anti-freeze). Each trap was half-filled with the preservative with a little detergent (Teepol) added to lower the surface tension of the solution. Each trap was also protected against the rain with a white plastic dish cover fixed to the ground by three pieces of wire. Each sample was stored in a one-way baby nappy liner in large bottles with 70% ethylene with some drops of glycerol prior to sorting.

Two identical VORTIS suction apparatus (Burkhard Scientific - Sales - Ltd., Rickmansworth, Hertfordshire, England) were used to sample the herbivore and predatory arthropod assemblages in the sites. The sampling on each occasion was carried out between 11.00 and 18.00, and only when the vegetation was completely dry and the wind conditions acceptable. In each of the 20 plots of each field site, four random subsamples were taken, one in each corner of the 3x3m square plots, covering a total of

0.8 m². The collection nozzle was held in position for 30 seconds on each occasion. To simplify the sorting process, the four subsamples were taken successively without changing the collection vial. The samples were stored in tubes with 70% ethylene with some drops of glycerol prior to sorting.

The sample data were enhanced by direct field observations of insect herbivores taken during the Spring (May - June) and Summer 1995, with equal additional sampling effort being applied to all plots.

Species sorting and identification

A total of 960 pitfall samples (20 pitfall traps x 12 sites x 4 sampling periods) and 960 suction samples (20 suction samples x 12 sites x 4 sampling periods) were taken during the course of the study. Before starting the sorting process, a decision was taken concerning the arthropod groups to be studied. Taking into account the sampling methods used to sample the arthropods, sap-feeding and chewing herbivores and all the predatory groups were chosen for analysis. For the guild assignment of each taxonomic group, I followed Moran & Southwood (1982) and Stork (1987).

The sorting process was a major project and divided into several parts. 1) Spring and Summer 1994 suction samples were sorted into the major groups in these 480 samples; 2) the morpho-species were

defined. The Summer 1994 sample was chosen as more appropriate because a great proportion of the specimens were adults and therefore easier to identify. It is nowadays very common to use morpho-species in bio-diversity studies without compromising scientific accuracy (Oliver & Beattie, 1996) and with some clear advantages due to the difficulty in getting expertise in all taxonomic groups (Gaston, 1996); 3) the morphospecies were sent to several taxonomists for species identification: Diplopoda (H. Enghoff), Heteroptera (J. Hollier and J. Ribes), Homoptera-Auchenorrhyncha (J. Hollier), Coccoidea (G. Watson), Aphididae (F. Ilharco and R. Blackman), Thysanoptera (G. J. du Heaume and R. zur Strassen), Lepidoptera (V. Vieira), Chrysomelidae (D. Erber and myself), Curculionidae (R. Booth, A. Serrano and myself), other Coleoptera (myself), Chilopoda (myself), Araneae (J. Wunderlich) and Neuroptera (V. J. Monserrat). The Opiliones and Pseudoscorpiones still need identification.

As a result of the specialists' identification work, some errors in the morphospecies assignment were detected, mainly synonyms between developmental stages of the same species. Such type or splitting errors were expected and occurred mainly with the Aphididae and Lepidoptera. As a consequence of sexual dimorphism, some spider morphospecies were also grouped together. Cases of lumping together two

or more species as one morphospecies occurred rarely, but I am aware of the fact. As only some specimens of each morphospecies were sent for identification some species may have been overlooked.

Data analysis

The experimental design as described previously is a split-plot design. In order to test for island or habitat effects on species richness of native, endemic and introduced herbivore and predatory arthropods, the procedures of GLIM (Generalized Linear Interactive Modelling) (Crawley, 1993) indicated for a nested analysis were applied. The sampling event effect was also tested and included in the split-plot design (2 sites/habitat x 2 habitats/island x 3 islands/sampling event x 4 sampling events) to test the activity density of the endemic Azorean lycosid spider *Pardosa acoreensis* in pitfall traps. This species was selected because it was the only endemic species that was found in all the twelve sampled sites consistently throughout all the sampling occasions. Pitfall samples were chosen instead of suction samples, because the species is a larger spider not sampled accurately with the VORTIS machine. As the pitfall traps usually measure activity rather than true abundance, the captures have been expressed as "species activity-density" (number of individuals of a species caught per trap and per day).

RESULTS

List of species

A total of 128 herbivorous and 117 predatory arthropod species were sampled. Table 1 lists the 237 arthropod species collected (some species were listed as both herbivores and predators), showing that the species richness of most taxa at a local scale, at a habitat scale and at an island scale is higher on S. Maria and lower on Pico (for details see Borges & Brown, 1999).

A total of 53 (41%) herbivore species are exotic (47 species at S. Maria; 31 species at Terceira; 20 species at Pico). Concerning the predators, 49 species (42%) are human introductions (41 species at S. Maria; 26 species at Terceira; 19 species at Pico) (see Table 1).

Endemic species numbers and percentages in relation to the indigenous numbers were: S. Maria = 18 spp. (17%); Terceira = 10 spp. (14%); Pico = 5 spp. (10%). Several of the sampled arthropod species are new records for the Azores or individual islands (Borges *et al.*, in prep.).

Figure 1 shows that most chewer species in the studied pastures are polyphagous. In the sucker species, there is a more even distribution of diet types. In both assemblages, there are very few species in the most specialist diet category.

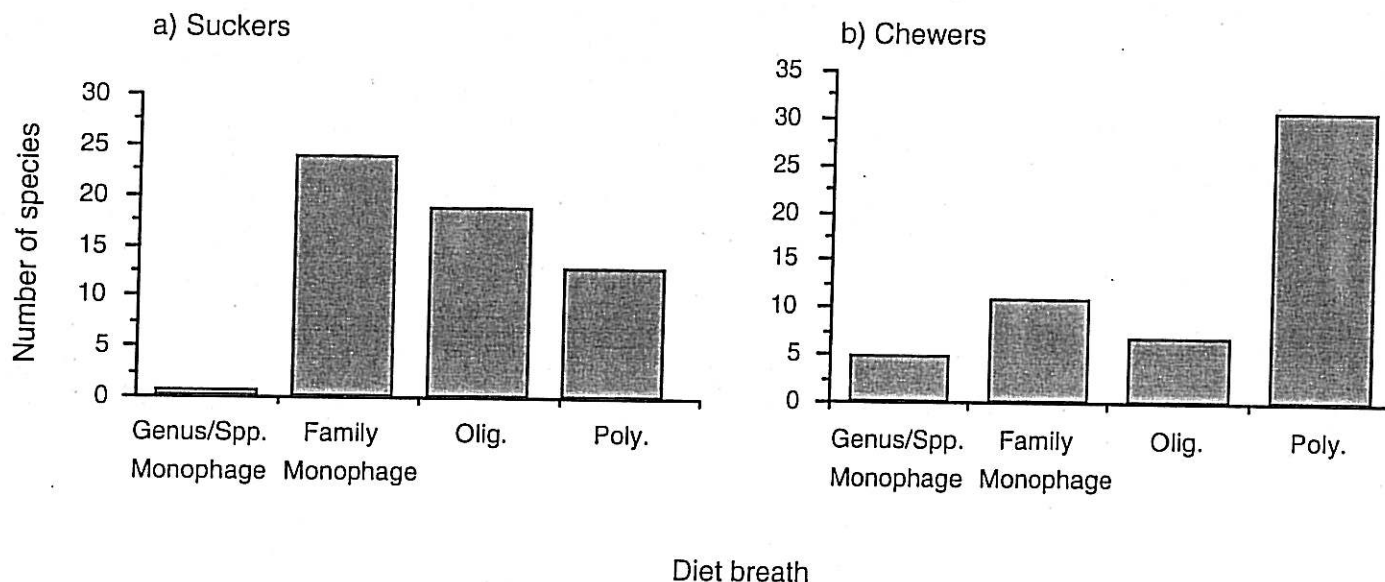


FIGURE 1. Number of species of suckers (a) and chewers (b) in each diet breadth category. Spp., Species; Olig., Oligophage; Poly., Polyphage

In the phytophagous assemblage, it is remarkable the diversity of Lepidoptera and Coleoptera species, but the highest numbers of specimens was found in the Homoptera (Cicadellidae, Delphacidae and Aphididae) and Thysanoptera.

The Heteroptera were not particularly abundant but it is a diverse group in the Azorean pastures studied.

The Arachnida are well represented in Azorean pasture communities studied, representing almost half of the predatory species (53 species). They are also the most abundant, in particular the species of Linyphiidae. Other important predatory groups in terms of diversity and abundance are the beetle families Staphylinidae and Carabidae (Coleoptera).

The predatory fauna includes also the large lithobiomorph centipedes

(Chilopoda), the common Nabiiidae *Nabis pseudoferus ibericus* Remane (Heteroptera), one species of Thysanoptera, two species of Neuroptera and three more families of Coleoptera (Melyridae, Cucujidae and Coccinellidae).

Concerning the feeding type, there were 66 species of forb-feeders, 28 species of grass-feeders and 37 species of web-building spiders (see Table 1).

Patterns in species richness of native, endemic and introduced species in the two habitats

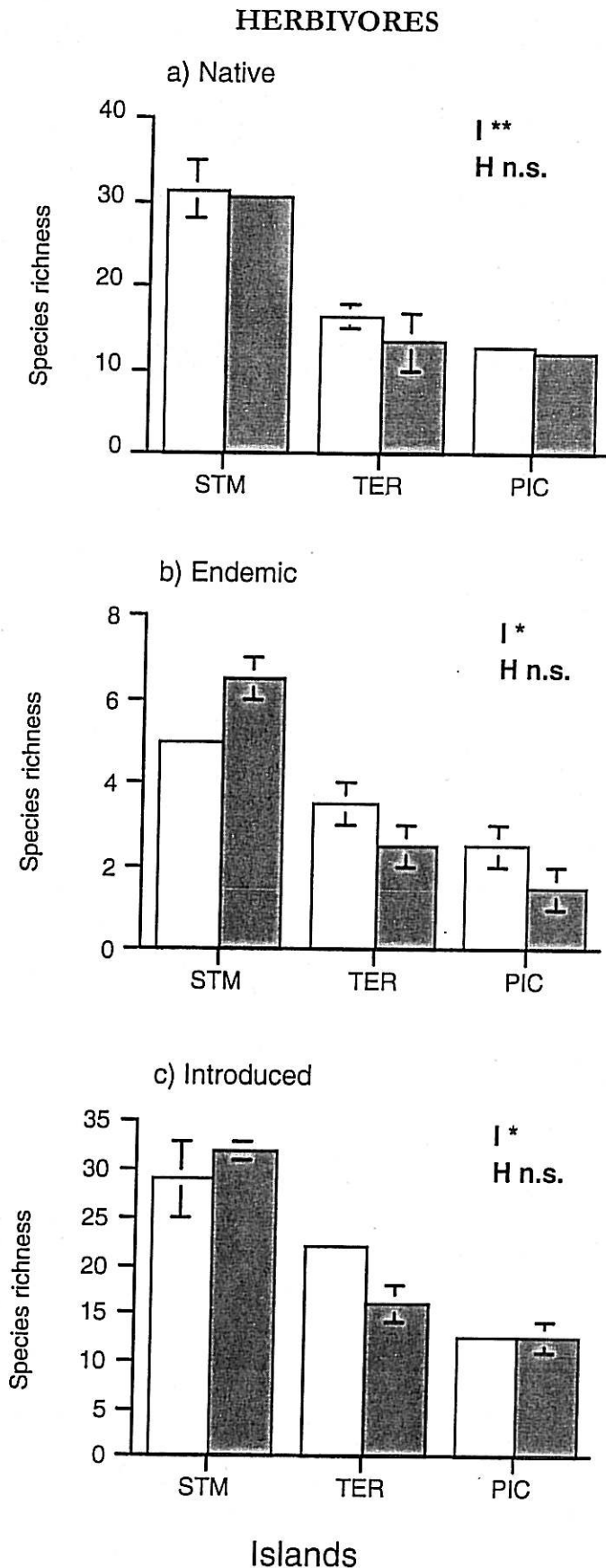
For the species richness of native, endemic and introduced assemblages of herbivore arthropods, no habitat effect was obtained confirming the results obtained elsewhere (see Borges & Brown, 1999) with the total and endemic species of herbivores. The

TABLE 1. (Continued)

Species	Diet	F.G.	D	C.S.	S. MARIA				TERCEIRA				PICO			
					Sown 1.1	1.2	Semi-natural 2.1	2.2	Sown 3.1	3.2	Semi-natural 4.1	4.2	Sown 5.1	5.2	Semi-natural 6.1	6.2
HOMOPTERA																
Cicadellidae																
<i>Anoscopus albifrons</i> (Linnaeus)	O	GF	H	I?	*+	*+	*+	*+	*+	*+	*+	*+	*+	*+	*+	
<i>Eupteryx azorica</i> Ribaut	FM		Az.	E					+							
<i>Eupteryx filicum</i> (Newman)	FM		P	N	#		+					+				
<i>Euscelidius variegatus</i> (Kirschbaum)	FM	GF	P	I?	*+	*+	*+	*+	*+	*+						
<i>Macrosteles sexnotatus</i> (Fallén)	FM	GF	P	N?	*+		*+	+	*+	*+		+	*+			
Delphacidae																
Gen. sp. a					+	+		+								
Gen. sp. b					+	+		+								
Gen. sp. c					+			+								
<i>Kelisia ribauti</i> Wagner	FM		WP	N?	*+	+	+	*+			+		*+	+		
<i>Megamelodes quadrimaculatus</i> (Signoret)	FM		WP	N?	+	+	*+	*+	+	+	*+	*+	+	*+		
<i>Muellerianella</i> sp. a	O?	GF		N?	*+	*+	*+	*+	*+	*+	*+	*+	+	*+		
Coccidae																
Gen. sp. a					*+	*+	*+									
Gen. sp. b						+	*					*		*+		
Pseudococcidae																
Gen. sp. a						*										
Gen. sp. b						+		*								
Aphididae																
<i>Acyrtosiphon pisum</i> (Harris)	FM	FF	C	N	*+	*+	*+	*+	*+	*+	*+	*+	*+	*+		
<i>Anoecia corni</i> (Fabricius)	FM	GF	H-O	I	*+		*+	*+	+	*+		+	*+	+		
<i>Aphis craccivora</i> Koch	P	FF	C	N	+		+	*+		+				+		
<i>Aphis fabae</i> Scopoli	P	FF	C	I	#											
<i>Aphis gossypii</i> Glover	P	FF	C	N				+								
<i>Dysaphis (Pomaphis) aucupariae</i> (Buckton)	M	FF	P	I	*+		*+	*+	*	+		+	*+			
<i>Myzus cymbalariae</i> Stroyan	P	FF	C	I								+				
<i>Nasonovia ribisnigri</i> (Mosley)	O	FF	H	I	+	+		+	*+				+			
<i>Neotrama maritima</i> Eastop	FM	FF	P	N												
<i>Pseudacaudella rubida</i> (Börner)	FM		H	I				*			+	*+	*+	*+		
<i>Rhopalosiphoninus tulipaeillus</i> (Theobald)	P	FF	WP	I				*+								
<i>Rhopalosiphum insertum</i> (Walker)	FM	GF	H	I	*+	+	*+	+	+	*+	*+	*+	*+	*+		
<i>Rhopalosiphum padi</i> (Linnaeus)	O	GF	C	I												
<i>Saltusaphis scirpus</i> Theobald	FM		C	N		+		+	+				+			
<i>Schizaphis graminum</i> (Rondani)	FM	GF	C	N	+											
<i>Thecabius affinis</i> (Kaltenbach)	FM	FF	P	I								+				
<i>Therioaphis trifolii</i> (Monell)	FM	FF	H-O	N	*+	*+		+	+							
<i>Uroleucon sonchi</i> (Linnaeus)	FM	FF	C	N	#											
THYSANOPTERA																
Aeolothripidae																
<i>Aeolothrips fasciatus</i> (Linnaeus)	P	FF	C	I	+	*+	+	+	*+							
Phlaeothripidae																
<i>Apterygothrips</i> sp. (n. sp. ?)			Az.	E		+		*+								
<i>Haplothrips ? niger</i> (Osborn)	P	GF	H	N		*+		*+	*+					*		
<i>Haplothrips</i> sp. a		FF						+								
<i>Hoplothrips corticis</i> (De Geer)	FM		H	N									+			
<i>Hoplothrips semicaecus</i> (Uzel)	FM		WP	N				*								
<i>Nesothrips propinquus</i> (Bagnall)	FM	GF	O	I	+	*+	+	*+								
Thripidae																
<i>Aptinothrips rufus</i> (Haliday)	FM	GF	C	N	*+	*+	*+	*+	*+	*+	*+	*+	+	*+		
<i>Heliotothrips haemorrhoidalis</i> (Bouché)	P	FF	ST	I	+			+	+	*+						
<i>Hercinothrips bicinctus</i> (Bagnall)	O	FF	ST	I	+											
<i>Plesiothrips perplexus</i> (Beach)	P	GF	ST	I				+	+							
<i>Thrips atratus</i> Haliday	P	FF	H	N	*											
LEPIDOPTERA																
Coleophoridae																
<i>??Coleophora versurella</i> Zeller	O?	FF	P	N?	*+	*+	*	*+	*	*+						
Blastobasidae																
<i>Blastobasis</i> sp. a		FF			*	*	*	*								
Gelechiidae																
<i>Aproaerema anthyllidela</i> (Hübner)	FM	FF	P	I?	*+	+		*+						*		
Yponomeutidae																
<i>Argyresithia atlanticella</i> Rebel	FM	FF	Az.	E			+	+		+			*+	*		
Choreutidae																
<i>Tebenna bjerkandrella</i> (Thunberg)	S	FF	C	I					*+	*+						
Tortricidae																
Gen. sp. a		FF							*+	*+						
Pyralidae																
Gen. sp. a		FF			*+	*+	*+	*+	*+	*+	*+	*+	+	*+		
Gen. sp. b		FF			*			#	+							
<i>Scoparia</i> sp. a		FF	Az.	E	+			*+	+			*	*+	*+		
<i>Scoparia</i> sp. b		FF	Az.	E	*			+	*	*	*					
Pieridae																
<i>Colias crocea</i> (Geoffroy)	FM	FF	H-MT	N	*+		+	+				#				
<i>Pieris brassicae azorensis</i> Rebel	O	FF	AZ.	E					#							

TABLE 1. (Continued)

Species	Diet	F.G.	D	C.S.	S. MARIA				TERCEIRA				PICO			
					1.1	1.2	2.1	2.2	3.1	3.2	4.1	4.2	5.1	5.2	6.1	6.2
INSECTA																
HETEROPTERA																
Nabiidae																
<i>Nabis pseudoferus ibericus</i> Remane			MT	N	*+	*+	*+	*+	*+	*+	+	*+	*+	*+	*+	*+
<i>Nabis (Tropiconabis) capsiformis</i> Germar			C			+										
Miridae																
§Gen. sp. a	O				+	#			+							
§ <i>Pithanus maerkeli</i> (Herrich-Schaeffer)	FM		E-MT	N							+	*+		+	+	*+
§ <i>Polymerus (Poeciloscytus) cognatus</i> (Fieber)	O		H													+
Anthocoridae																
<i>Orius laevigatus</i> (Fieoloer)			E-MT			+		*+								
THYSANOPTERA																
Aeolothripidae																
§ <i>Aeolothrips fasciatus</i> (Linnaeus)			C	I	+	*+	+	+	+							
NEUROPTERA																
Hemerobiidae																
<i>Micromus angulatus</i> (Stephens)			H	N	+	+		*+	*+	*+						
Chrysopidae																
<i>Chrysoperla carnea</i> (Stephens)			P	N				*								
COLEOPTERA																
Carabidae																
<i>Acupalpus dubius</i> Schilsky			WP	I				*								
<i>Agonum mulleri</i> (Herbst)			H	I	*											
§ <i>Amara aenea</i> (De Geer)			H	I	*		*	*	*	*				*+	*+	*
<i>Anchus ruficornis</i> (Goeze)			H	I	*+											
<i>Anisodactylus binotatus</i> (Fabricius)			H	I	*	*	*	*	*	*	*	*	*	*	*	*
<i>Campalita olivieri</i> (Dejean)			EO	N				*	*	*				+	*	*
§ <i>Harpalus distinguendus</i> (Duftschmidt)			P	I	*											*+
<i>Lagarus vernalis</i> (Panzer)			P	I					*+	*	*+	*	*+	*+	*+	*+
<i>Notiophilus quadripunctatus</i> Dejean			WP	I	*+	*+	*	*	*	*+						*+
<i>Ocys harpaloides</i> (Audinet-Serville)			WP	N			*									
§ <i>Ophonus ardosianus</i> (Lutshnik)			MT	I	*	*	*									
<i>Olisthopus inclavatus</i> Israelson			Az.	END	+	*+		*+								
<i>Philorhizus melanocephalus</i> (Dejean)			WP	I				+								
§ <i>Pseudophonus rufipes</i> (De Geer)			H	I	*	*	*	*	*	*						
Staphylinidae																
<i>Aleochara bipustulata</i> (Linnaeus)			H	I	*+	*	*	*	*	*						
<i>Amisha analis</i> (Gravenhorst)			H	I	*+	*+	*+	*+	*+	*+						+
<i>Anotylus complanatus</i> (Erichson)			WP	I	*	+					*+	*+	*+	*+	*+	*+
<i>Astenus longelytrata</i> Palm			WP	N	*	*+	*+	*+	+		*+	*+	*	*	*+	*+
<i>Astenus</i> sp. a																
<i>Atheta (Datomica) nigra</i> (Kraatz)			C	I				*								
<i>Atheta (Microdota) amicala</i> (Stephens)			P	I												
<i>Atheta (Mocytia) fungi</i> (Gravenhorst)			WP	I	*+	*+	*+	*+	+	*+				*+	+	+
<i>Atheta</i> (s. str.) <i>acucollis</i> (Sharp)			P	I	*+	*										
<i>Atheta</i> (s. str.) <i>atramentaria</i> (Gyllenhal)			P	I	*	*		*	*	*	*	*	*	*	*	*
<i>Atheta</i> sp. a					*	*+	*+	*	*	*	*	*	*	*	*	*
?? <i>Brundinia meridionalis</i> Mulsant & Rey								*	*	*	*	*	*	*	*	*
<i>Carpelimus</i> sp. a																
<i>Carpelimus</i> sp. b														+	*+	+
<i>Cilea silphoides</i> (Linnaeus)			H	I	*+	*+	*+	*+								*
<i>Cordalia obscura</i> (Gravenhorst)			P	I	*+	*+	*+	*+	*+	*+	*	*	*	*	*	*
<i>Gabrius nigritulus</i> (Gravenhorst)			C	I			*	*	*	*						*
<i>Ocypus olens</i> (Müller)			WP	N	*	*	*	*	*	*	*	*	*	*	*	*
<i>Oligota parva</i> Kraatz			C	I	*+	*+		+		*+						*
<i>Philonthus ventralis proximus</i> Wollaston			MC	N			*									*
<i>Pseudocypus aethiops</i> (Waltl)			P	N							*	*				*
<i>Quedius curtipennis</i> Bernhauer			P	N			*									*
<i>Quedius simplicifrons</i> (Fairmaire)			WP	N					*+	*+	*+	*+	*+	*+	*	*+
<i>Rugilus orbiculatus</i> (Paykull)			P	N	*+	*	*+	*+			*+	*+	*+	*	*	*+
<i>Sepedophilus lusitanicus</i> Hammond			WP	N	*	*	*	*			*	*+	*+	*+	*	*
<i>Sunius propinquus</i> (Brisout de Barneville)			WP	N	*+	*+										*
<i>Tachyporus chrysomelinus</i> (Linnaeus)			H	I			+	*+				+				+
<i>Tachyporus nitidulus</i> (Fabricius)			H	I	*+	*+	*+	*+	*+	*+	*+	*+	+			+
<i>Xantholinus longiventris</i> Heer			WP	N	*+	*	*+	*+	*+	*+	*+	*+	*+	*+	*+	*+
Melyridae																
<i>Psilothrix viridicaeruleus</i> (Fourcroy)			WP	N		+										
Cucujidae																
<i>Cryptomorpha desjardinsi</i> (Guérin Méneville)			A	I	*+	*	*+									
Coccinellidae																
<i>Scymnus interruptus</i> (Goeze)			P	N	*			*+	+							
<i>Scymnus levaillantii</i> Mulsant			MT	N		*	+	*	*	*						
<i>Rhyzobius litura</i> (Fabricius)			WP	N	*+			*								
<i>Coccinella undecimpunctata</i> Linnaeus			H	I	*	*		*	+							



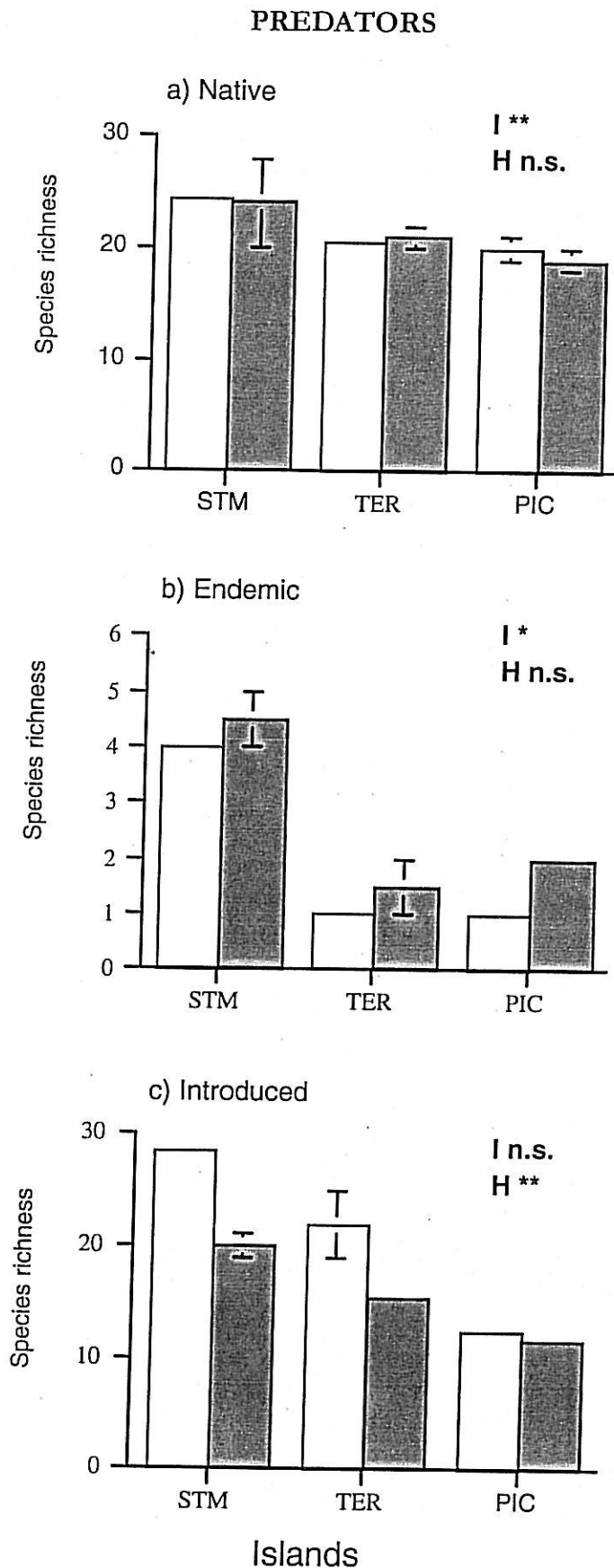
results are summarized in Figure 2 where the species richness of native species ($F_{2,3} = 109.91$, $p < 0.01$), endemic species ($F_{2,3} = 10.61$, $p < 0.05$) and introduced species ($F_{2,3} = 22.16$, $p < 0.05$) in the sown and semi-natural pastures follow an island rather than an habitat effect. More species tend to occur in the sites of S. Maria, followed by Terceira and Pico in decreasing order.

The predators present a slightly different pattern. An island effect was also obtained for the native ($F_{2,3} = 48.5$, $p < 0.01$) (Figure 3a) and endemic ($F_{2,3} = 22.17$, $p < 0.05$) (Figure 3b) assemblages. More species of native and endemic predators occur in S. Maria, the other two islands having lower numbers. However, a habitat effect rather than an island effect was obtained for the introduced predatory assemblage ($F_{3,6} = 10.51$, $p < 0.01$) (Figure 3c). Sown pastures tend to have more introduced predatory arthropods than semi-natural pastures.

Patterns in the endemic species

A total of twenty six (16 herbivores and 10 predators) endemic arthropod species were sampled in the twelve studied sites during the five sampling occasions (see Table 1). Eighteen species were

FIGURE 2. Mean species richness (\pm SEM) of arthropod herbivores in sown pastures (open bars) and semi-natural pastures (filled bars) of the three studied islands (STM, S. Maria; TER, Terceira; PIC, Pico). a) Native species; b) Endemic species; c) Introduced species. I, island effect; H, habitat effect. * $p < 0.05$; ** $p < 0.01$.



collected in S. Maria (10 herbivores and 8 predators), ten in Terceira (8 herbivores and 2 predators) and five in Pico (3 herbivores and 2 predators). Most of these species were not persistent in time, 10 out of the 16 herbivore species and 6 out of the 10 predatory species having been collected only in one or two sampling occasions. Some of the species are also not true grassland dwellers (e.g. *Pinalitus oromii*, *Heteroderes azoricus*, *Laparocerus azoricus*, *Olisthopus inclavatus*) and may be considered as tourists in the studied habitats.

Patterns in the occurrence of the endemic species in sown and semi-natural pasture sites are illustrated in Figure 4. The species codes over the line are those that were sampled in the same number of sown and semi-natural sites and totalled six (4 herbivores and 2 predators). The lycosid spider *Pardosa acoreensis* (code number 16, Figure 4) was the only species to be sampled in all the twelve sites, and in most of the sites was persistent throughout all the sampling occasions. Eight species were sampled only in semi-natural pastures (3 herbivores and 5 predators) and another eight species were sampled only in sown pastures (6 herbivores and 2 predators). The pyralid moth *Scoparia* sp. 1 was sampled in all the semi-natural sites in most sampling occasions

FIGURE 3. Mean species richness (\pm SEM) of predatory arthropods in sown pastures (open bars) and semi-natural pastures (filled bars) of the three studied islands (STM, S. Maria; TER, Terceira; PIC, Pico). a) Native species; b) Endemic species; c) Introduced species. I, island effect; H, habitat effect. * $p < 0.05$; ** $p < 0.01$.

but only sampled in four sown sites, only once in three of them and twice in the site Achada -1 from Pico.

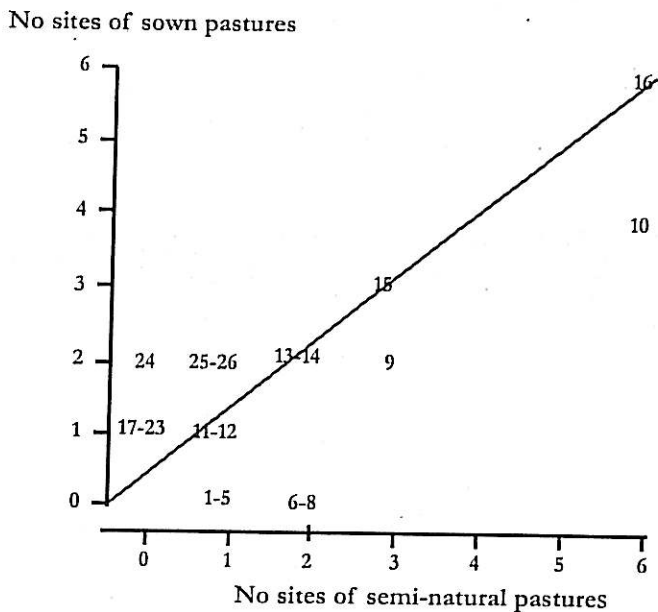


FIGURE 4. Number of sites of sown and semi-natural pasture in which each endemic arthropod species was sampled. The species over the line are those that were sampled in the same number of sites in the two habitats. The species below the line are those that were sampled in more semi-natural pasture sites. The species above the line are those that were sampled in more sown pasture sites. Numbers are codes for each endemic arthropod species as follow: 1, *Xanthorhoe ? inaequata* (Geometridae); 2, *Laparocerus azoricus* (Curculionidae); 3, *Leucognatha acoreensis* (Tetragnathidae); 4, *Gibbaranea occidentalis* (Araneidae); 5, *Minicia* n. sp. (Linyphiidae); 6, *Donus* n.sp.? (Curculionidae); 7, *Minicia picoensis* (Linyphiidae); 8, *Lasaeola oceanica* (Theridiidae); 9, *Scoparia* sp. 2 (Pyralidae); 10, *Scoparia* sp. 1 (Pyralidae); 11, *Apterygothrips* n. sp. (Phlaeothripidae); 12, *Cathormiocerus ? lepidopterus* (Curculionidae); 13, *Cyclophora p. granti* (Geometridae); 14, *Trachyzelotes* n. sp. (Gnaphosidae); 15, *Argyresthia atlanticella* (Yponomeutidae); 16, *Pardosa acoreensis* (Lycosidae); 17, *Pinalitus oronii* (Miridae); 18, *Eupteryx azorica* (Cicadellidae); 19, *Cyclophora azorensis* (Geometridae); 20, *Heteroderes m. moreleti* (Elateridae); 21, *Rugathodes acoreensis* (Theridiidae); 22, *Neon* n. sp. (Salticidae); 23, *Pieris b. azorensis* (Pieridae); 24, *Oñiorhynchus t. azoricus* (Curculionidae); 25, *Heteroderes azoricus* (Elateridae); 26, *Olisthopus inclavatus* (Carabidae).

Four out of the six endemic herbivore arthropods sampled only in the sown pastures are oligophagous or polyphagous, which may explain their capacity to occur in a less diverse habitat. Of the three endemic herbivore species only found in the semi-natural pastures, one is a specialist feeder, other is polyphagous and a third one has not known feeding habits.

Patterns in abundance

The mean activity-density in sown and semi-natural pastures of the endemic lycosid spider (*Pardosa acoreensis*) collected by means of pitfall traps in four sampling occasions is showed in Figure 5. There was a sampling event effect ($F_{3,8} = 7.39$, $p < 0.05$) with higher densities in the Spring 1994 and Summer 1995, and also a habitat effect ($F_{8,12} = 3.44$, $p < 0.05$). This endemic spider tended to be more abundant in the semi-natural pastures of S. Maria and Pico, but in Terceira was consistently more abundant in the sown pastures in all the sampling occasions (Figure 5).

DISCUSSION

As a result our field work carried out in sown and semi-natural pastures from S. Maria, Terceira and Pico, 237 arthropod species belonging to six Classes of arthropods and seven Orders

Pardosa acorensis

Sampling event *

Island n.s.

Habitat *

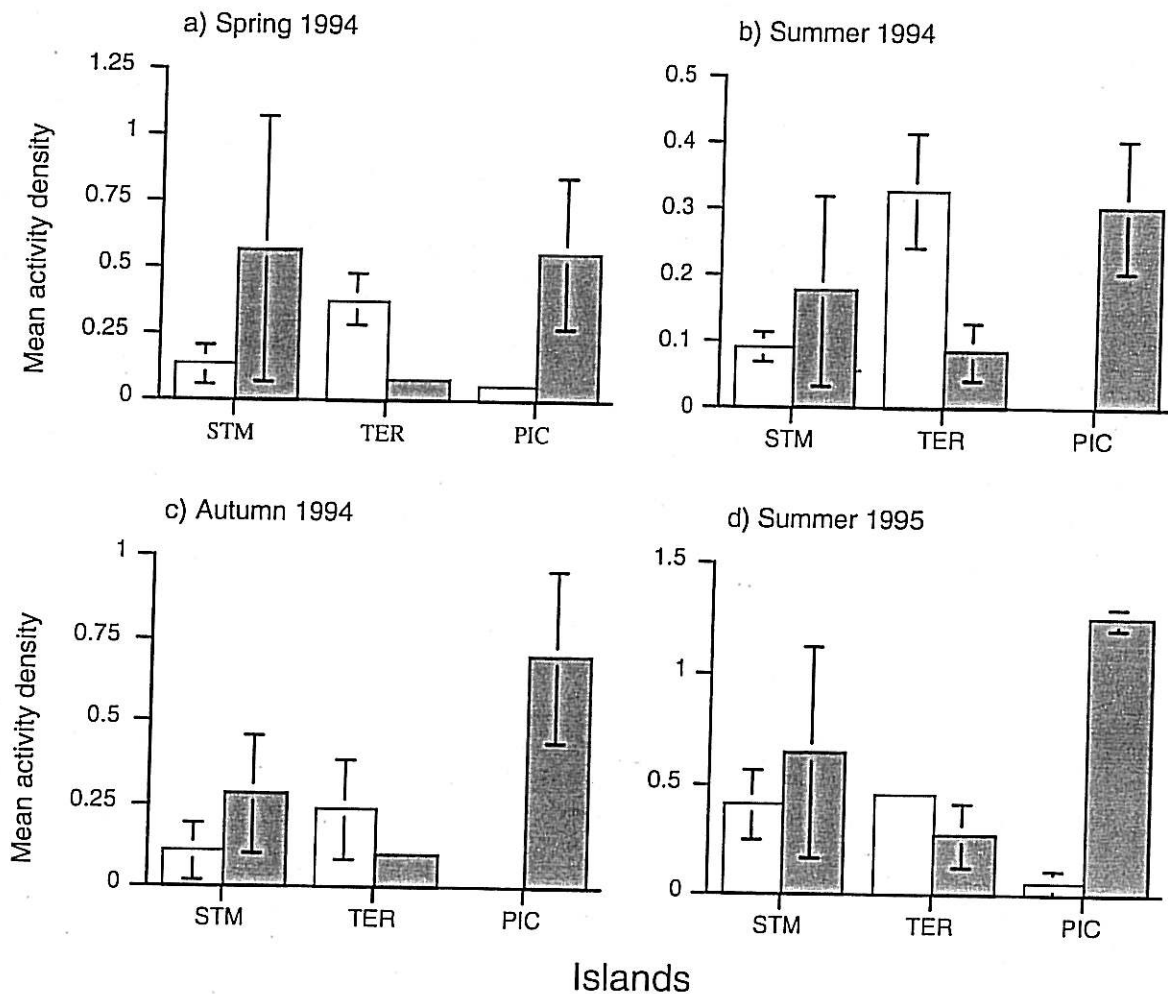


FIGURE 5. Mean activity density (number of specimens per trap per day) (\pm SEM) of the endemic lycosid spider *Pardosa acorensis* in sown pastures (open bars) and semi-natural pastures (filled bars) of the three studied islands (STM, S. Maria; TER, Terceira; PIC, Pico). a) Spring 1994; b) Summer 1994; c) Autumn 1994; d) Summer 1995. * $p < 0.05$.

of insects are known from these habitats (see Table 1). A complete list covering this *taxa* in all Azorean islands will probably contain many more species, but the most common species are probably already listed.

The list of species presented together with the associated information on their feeding habits and colonization strategies

could be a very useful information for future ecological and applied studies on the Azorean pasture communities. Moreover, some of the predators, namely some species of spiders (Araneae), rove-beetles (Staphylinidae) and ground-beetles (Carabidae) are very important in controlling the densities of potentially damaging herbivore species. Therefore,

they may be used in biological control programs.

The three studied islands differ greatly in the way native and man-made habitats are partitioned in the landscape. Moreover, sown and semi-natural pastureland areas also differ in their distribution in the islands. Consequently, indigenous and introduced pasture arthropods might respond to those differences and the results obtained confirm this. The hypothesis that more diverse communities are hypothesized to resist invasion and to be the source of successful colonists into other communities (Elton, 1958; Vermeij, 1991; Lodge, 1993) was only partly confirmed in the present study. In fact, the introduced predatory arthropods tend to be more diverse in recent sown than in the semi-natural pastures from S. Maria and Terceira (see Fig. 3).

Moreover, the fact that the semi-natural pastures from S. Maria have a great proportion of exotic plant species (Borges, 1997; Borges & Brown, 1999), probably because of historical and landscape management reasons, was not an obstacle for the occurrence of endemic arthropod species. Even slow moving forest-dwelling species like the endemic Colydiidae *Tarphius depressus* Israelson, was collected in the site St. Espírito (preliminary sampling period in March 1994) in pitfall traps.

It is known that the inputs in fertilizers and pesticides and several other management practices are important in setting the quality of the pasturelands for the arthropods (Rushton & Luff, 1988; Eyre *et al.*, 1990; Curry, 1994). The presence of endemic arthropods in the Azorean pastures may be explained by the fact that the input in fertilizers in the Azorean pastureland is three times inferior to the mean of the European countries (Garcia & Furtado, 1991). This fact, together with the low inputs in pesticides in the Azores, that only increase when an outbreak of *Mythimna unipuncta* occurs, may create an uniform quality in both sown and semi-natural pastures in these islands.

Thus, with only one exception (more introduced predatory species in sown pastures than in semi-natural pastures) the introduced and indigenous arthropod species are able to freely colonize both habitats, the species richness at the local sites depending more on the regional pool of species than on local abiotic or management pressures (see also Borges & Brown, 1999). The results obtained with the endemic lycosid spider *Pardosa acoreensis* were consistent with the "semi-natural pasture habitat quality hypothesis" for Pico and S. Maria, but also contained an unexpected element (sites from Terceira). The fact that this species was sampled in all the twelve local experimental sites in all the sam-

ling occasions and in statistically measurable densities, made it a good potential indicator of habitat quality. In two of the islands (S. Maria and Pico) its activity-density in pitfall traps was consistently higher in the semi-natural pastures.

The results obtained in Terceira are indicative of another pattern, that is, "endemics as invaders". In all the sampling occasions covering two different years the high density-activity of *Pardosa coreensis* occurred consistently in the own pastures at Terceira. So, surprisingly, there was an invasion of a recent man-made monoculture habitat by an endemic spider. The explanation for this result cannot be related with poor quality of the semi-natural pastures from Terceira, since they are very similar in plant species composition (see Borges, 1999) and structure (have also the "hummock" structure) to those of Pico. Two possible explanations for this result are:

1) "field margin effects", each site of own pasture from Terceira is located near the edge of a main larger pasture (near field margins), one of which (sites - 2) near a forested wind protection. If the main populations of the spider live in this field margins, they may rapidly invade the sites after a grazing event, therefore, creating an artefactually high density sink population; 2) "grazing disturbance effect", the main pastures

were more or less continuously grazed during most of the year. The sites were fenced and the grazing events within each site occurred only 5-6 times per year. Thus, assuming that this species has "source" populations in the main pastures, as grazing was occurring continuously outside the experimental sites creating a sort of disturbance, the spider invaded the fenced experimental sites, also creating a high activity-density artefact. Much additional information on the population dynamics of this species in Terceira will be needed before extracting conclusions of the results obtained for this island.

Greenslade (1992) obtained results supporting the hypothesis that native invertebrates are usually restricted to native grasslands and are unable to colonize exotic pastures in Australia. This is not supported by my results. Here, it will be useful to introduce a new model of thinking the native species, that is "natives as invaders". An extreme case of the "natives as invaders" model is the fact that some native Hawaiian insects become agricultural pests (see Howarth & Ramsay, 1991). In the Azores, as in other isolated archipelagoes of volcanic islands, most of the native forests were all cleared by the earlier European colonizers by fire and other processes. No control occurred in the introduction of exotic species and the impact of man

probably exceeded that of the climatic fluctuations of the last Pleistocene glaciations (see Goodfriend *et al.*, 1994). Those indigenous species that survived either the volcanic activity, the Pleistocene glaciations, the man-made habitat and landscape dramatic changes and the potential competitive effect of exotic species, are probably competitive enough to colonize even less diverse and temporary habitats like the recently sown pastures. In fact, in a small island like S. Maria with almost no native habitats, there is a rich native and endemic arthropod biota persisting in the regional pool (see Borges & Brown, 1999), being able to colonize freely both sown and semi-natural pastures. As a consequence of the native forest clearance the pasture monoculture covers 44% of the area of these islands (Garcia & Furtado, 1991). The indigenous Azorean arthropods have probably responded to these modifications with an extension of ranges.

The analysis of the distribution of endemic arthropods showed that there is more than twice the number of species of endemic predators restricted to semi-natural pastures than restricted to the sown pastures. This finding together with the significant higher number of introduced predator species in the sown pastures, may signify that the predator assemblage is a better indicator than the herbivore assemblage of differences in

pasture type. Most of the endemic predators in this study are spiders, a group that is highly sensitive to habitat structure (Uetz, 1991; Wise, 1995). The semi-natural pastures from Terceira and Pico are highly complex in topographical (e.g. lava tubes ceilings) and vegetation structure (e.g. "hummocks"), promoting a high diversity of micro-sites where species sensitive to grazing and trampling (e.g. the endemic grass *Holcus rigidus*) are able to survive. I suggest that the type of pasture (semi-natural or sown) affects more predators than phytophagous arthropods, which confirms results obtained by Kruess & Tschardt (1994) that natural enemies are more affected by habitat fragmentation than their phytophagous hosts.

According to the evidence presented here, sown and semi-natural pastures in the three studied islands, are (with minor exceptions) equally invulnerable by both native, endemic and introduced arthropod species. This conclusion has some similarities to the findings of Crawley (1987) that all British plant communities are invulnerable. Williamson (1996) refers that propagule pressure is probably more important than habitat invulnerability. If the characteristics of the invading species are more important than the attributes of target communities (see Simberloff, 1986), than I suggest that, as a whole, both native and introduced Azorean pasture-dwelling

arthropods (mainly the herbivores) have similar invasibility abilities in sown and semi-natural pastures.

CONCLUSIONS

The low N and pesticide inputs by the farmers in the Azorean pastureland are probably reducing the differences in habitat suitability between sown and semi-natural pastures. Although the mechanisms that are making possible some endemic species to occupy with success the Azorean sown pastures are not clear, management efforts should be exercised to avoid the replacement of the semi-natural pastures by temporary sown pastures. In S. Maria the landscape is highly heterogeneous when compared with the other two studied islands, with a mosaic of semi-natural pastures, sown pastures (for sheep and cattle), forested areas, agricultural fields and urban areas. This, probably, made possible some endemic species to track the original habitat clearance occupying less intensively managed fragments.

In Terceira, the Lagoa do Negro-Algar do Carvão plateau is dominated by low productive, semi-natural pasture with some areas of natural forest very near the two studied semi-natural sites. However, the results showed higher densities of an endemic lycosid spider in the sown pastures. This gives support to the

idea that there is in the Azores a low-intensity farming system. However, this result does not avoid that I consider the semi-natural pastures from Terceira of great importance for the maintenance of populations of grassland native plants and arthropods (e.g. the endemic grass *Holcus rigidus* and the small linyphiid spider *Minicia* sp.).

In Pico the great area of semi-natural pastureland now covering the island will probably insure the maintenance of the native species. However, some care should be taken to avoid more fragmentation of these areas with the implementation of better monoculture pasture. This will result in the erosion of a poor recent volcanic soil, less topographical complexity and low vegetation structural complexity, which were shown not to be of particular preference by an endemic lycosid spider.

Finally, although the magnitude of the differences between the two habitats was not so important as originally expected, mainly as a consequence of the invasibility abilities of some native species in sown pastures, local or even regional extinctions are likely to occur if intensification of cattle production continues in the islands. Moreover, the islands are small, and the Azorean land is heatedly disputed (Martins, 1993). Remnants of true natural grassland are scattered and isolated at high altitudes (Caldeira da

Serra de S. Bárbara in Terceira, Landroal-Caveiro areas in Pico). Semi-natural pastureland as a low productive and low-intense farming system is probably a compromised and still a suitable habitat for some indigenous arthropods, since it can be considered as a "source habitat". In Europe some attention is now being given to semi-natural vegetation as structures of conservation value (Bignal & McCracken, 1996). For instance, in Europe a greater diversity of Lepidoptera is usually found in secondary grassland still managed in a traditional way (Erhardt & Thomas, 1991). Thus, more efforts should be directed to study the effects of different types of grazing management in the semi-natural pasture arthropod populations in these islands. In the near future, the principal threat against the semi-natural pastures is probably the creation of better pastures, but also the plantation of exotic conifer trees.

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