Neotrop Entomol (2013) 42:240–245
DOI 10.1007/s13744-013-0116-6

ECOLOGY, BEHAVIOR AND BIONOMICS

Andropogon bicornis (Poales, Poaceae): A Hibernation Site for Pentatomoidea (Hemiptera: Heteroptera) in a Rice-Growing Region of Southern Brazil

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Keywords
Agroecosystem, Pentatomidae, refuge, tussocks

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Edited by Antonio R Panizzi – Embrapa Trigo

Received 20 April 2012 and accepted 31 January 2013
Published online 7 March 2013

Abstract
Tussocks of *Andropogon bicornis* (Poaceae) make up a significant part of the landscape of the rice-growing region of south Brazil. However, little is known about their role in maintaining insect diversity in anthropized regions. We tested the hypothesis that *A. bicornis* is a hibernation site for Pentatomoidea (Hemiptera: Heteroptera) by analyzing the composition, structure, and diversity of pentatomoid assemblages over the course of a year. A total of 208 tussocks were removed at fortnightly intervals from April 2010 to March 2011. We collected 3,423 pentatomoid specimens belonging to 22 species distributed in 13 genera of three families, Pentatomidae, Scutelleridae, and Thyreocoridae. The most common species was *Tibraca limbativentris* Stål, the main rice pest in southern Brazil, followed by *Oebalus ypsilongriseus* (De Geer) and *Edessa meditabunda* (Fabricius). Abundance and species richness were the lowest in January, February, and March and the highest in July, August, and September. A combination of high species diversity observed during the colder months, including several unrelated to rice, and the absence of immature specimens in the tussocks strengthens the hypothesis that *A. bicornis* is a hibernation site for pentatomoids in the region.

Introduction

The role of grass tussocks as shelter for invertebrates has long been emphasized (Pearce 1948, Luff 1966). Vegetation structure at the edges of agroecosystems may play an important role in insect survival during cold periods (Dennis *et al* 1994) in terms of providing a favorable microclimate and serving as hibernation sites (Geiger *et al* 2009, Helden *et al* 2010). Tussocks form dense bushes and are easily distinguishable from the surrounding vegetation by the proximity between their leaves and stems, accumulation of dry foliage around the base, and distance from nearby grasses (Luff 1965).

Tussocks of *Andropogon bicornis* (Poaceae) are commonly distributed at the edges of fields, roadsides, and remaining fragments of forest in Rio Grande do Sul, which has extensive irrigated rice cultivation. This grass, known as West Indian foxtail, is native to the Americas and preferentially inhabits humid places throughout the year (Kissmann and Groth 2000). As such, tussocks represent an available resource for numerous species of arthropods, including hemipterans associated with rice in southern Brazil.

Pentatomoids (Hemiptera: Heteroptera) are widely known for their number of species of agricultural interest and several species have been found to be associated with rice and grasses in general (Panizzi *et al* 2000). Study of these insects in natural environments can contribute to decision making regarding implementation of measures to control pest species (Mendonça *et al* 2009). Pentatomoidea includes around 5,720 nominal species, of which more than 600 are found in Brazil (Grazia *et al* 1999).

This study sought to evaluate the role of tussocks of *A. bicornis* in the composition, structure, and diversity of an assemblage of pentatomoids at the edge of a rice culture. More specifically, the study aimed to test the hypothesis that *A. bicornis* may serve as a hibernation site for these species by detecting seasonal diversity patterns.

Material and Methods

Study area

The study was carried out in the county of Eldorado do Sul, Rio Grande do Sul (30°02′S, 51°23′W). It is a region with extensive low-altitude (~10 m) plains (Rambo 1994) and a humid subtropical climate, with an average annual temperature of 19.5°C (Maluf 2000).

Owing to the climate, soil, and topography of the region, the main agricultural activity in the region is irrigated rice culture, alternating over time and space with cattle and sheep breeding. In winters, native vegetation and stubble grow in the fields. Throughout the year, many grass tussocks grow at the edges of the fields and roads.

Sampling

The sampling sites were four strips at the edges of irrigated rice fields, which were selected since abundance of tussocks has been observed at the sides of secondary roads. The width of these sites ranged from 4 to 20 m and the length ranged from 30 to 50 m. From April 2010 to March 2011, on every fortnight, two tussocks of *A. bicornis* were removed, each up to 30 m away from the crop and with a distance of at least 4 m between the tussocks; removal was alternated between the opposite edges of each strip.

Data analysis

Pentatomids and scutellerids were identified on the basis of previous descriptions in the literature (Schouteden 1904, Rolston & McDonald 1979, 1981, 1984, Rolston *et al* 1980) and by comparisons with identified material from scientific collections. Thyreocoridae specimens were identified by a specialist (Viviana Cauduro Matesco, MSc, Universidade Federal do Rio Grande do Sul, Porto Alegre, Brazil). Voucher specimens were deposited in the collection at the Museu de Ciências Naturais, Fundação Zoobotânica, Porto Alegre, Brazil.

Sampling sufficiency curves for the number of species obtained at each sampling time with 500 randomizations were obtained by using Colwell's EstimateS software (2005). The observed species richness was estimated with Bootstrap and Jackknife 1 by using the same software. Species were classified as follows on the basis of abundance (logarithmic scale): rare, log $n \leq 1$; intermediate, $1 <$ log $n \leq 2$; and dominant, log $n < 2$. Correlations between abundance and the variables tussock diameter and distance from the rice culture were analyzed by Spearman's correlation coefficient by using Bioestat 5.0 software (Ayres *et al* 2007). Species diversity in each season was estimated by the Berger–Parker (d), Margalef (D_{Mg}), Shannon–Wiener (H′), and Simpson's complementary indices (1-D; Moreno 2001, Magurran 2004) by using Past 2.02 software (Hammer *et al* 2001). The adopted significance level was 5% in all analyses.

Results and Discussion

In landscapes dominated by extensive irrigated rice cultures, tussocks of *A. bicornis* are important shelters for several pentatomoid species. Tussocks serve as refuges for invertebrate fauna, including isopod crustaceans, spiders, and several groups of insects (Pearce 1948, Luff 1965, 1966). This shelter function is directly related to the microclimate provided by the vegetation structure (Bossenbroek *et al* 1977), which is more stable than the microclimates in open environments.

We sampled 3,423 adult specimens of 22 species of Pentatomoidea distributed in 13 genera belonging to three families: Pentatomidae, Scutelleridae, and Thyreocoridae. Pentatomidae showed the highest abundance and species richness (3,358 specimens of 14 species), followed by Thyreocoridae (59 specimens of seven species) and Scutelleridae (six specimens of a single species; Table 1).

The highest abundance and species richness were expected for Pentatomidae, since it is the largest family in the group (Schmidt & Barcellos 2007). Currently, around 4,100 Pentatomidae species and 760 genera are recognized (Schuh & Slater 1995, Grazia *et al* 1999, Grazia & Schwertner 2008). Although Thyreocoridae had markedly lower abundance, its species richness was the second highest. *Galgupha* Amyot & Serville had the highest number of species (seven) among all the pentatomoids. Species of this genus are commonly found in the state of Rio Grande do Sul (Mendonça *et al* 2009). Thyreocoridae was the second most abundant and species-rich family in a study in northwestern Rio Grande do Sul (Schmidt & Barcellos 2007) as well. Taxonomic and biological information about this family is still missing, but it is estimated that about 220 species of this group have already been described. These heteropterans are usually found in grasses, invading plants and shrubs, where they feed and lay their eggs mostly on flowers and developing fruits (McPherson 1971, 1972, Biehler & McPherson 1982). In this study, the following three species of Thyreocoridae were recorded for

the first time in Rio Grande do Sul: *Alkindus crassicosta* Horvath, *Galgupha longirostris* Berg, and *Galgupha porcata* Horvath.

Abundance and species richness were the lowest in January, February, and March and the highest in July, August, and September. With regard to different seasons, abundance and species richness were the highest in winter, followed by autumn, spring, and summer (Table 1). Throughout the sampling period, no pentatomoid eggs or nymphs were found in tussocks. No predatory pentatomids (Asopinae) were found throughout our samplings.

Thomas *et al* (1992) found a higher density of predatory beetles *Tachyporus hypnorum* Fabricius (Staphylinidae) and *Demetrias atricapillus* L. (Carabidae) in tussocks than in the adjacent vegetation with different growth structures. Tussocks of the grasses *Holcus lanatus*, *Festuca rubra*, and *Poa trivialis*, which have structures similar to that of *A. bicornis*, showed a higher capacity for temperature regulation than species in shrub or rosette form (Bossenbroek *et al* 1977). At low temperatures, animals sheltered in plants with dense structures have a higher chance of survival than those in open environments, and under these conditions, the protection provided by tussocks may be a major advantage for these species over those in open environments (Bossenbroek *et al* 1977).

The use of tussocks by these species as protection against extremes of temperature and humidity (Luff 1965, Bossenbroek *et al* 1977) was not verified during summer, when the abundance and species richness in this shelter were practically null. Rather, the highest diversity of pentatomoid bugs was recorded during the colder months. These results corroborate the hypothesis that tussocks of *A. bicornis* serve as hibernation sites for several species, as in the case of beetles that take shelter in tussocks of *Dactylis glomerata* (Luff 1966). In fact, imaginal diapause has been observed in *Tibraca limbativentris* Stål (Klein *et al* 2012).

The absence of immature specimens throughout the year suggests that *A. bicornis* is not a host plant for pentatomoids in the region according to the criteria established by Schoonhofen *et al* (2005). These authors defined a host as a plant that allows feeding and reproduction of individuals of

Table 1 Pentatomoidea (Hemiptera) species recorded in tussocks of *Andropogon bicornis* in Eldorado do Sul, RS, Brazil, by season (*rf* relative frequency).

Taxa	Autumn	Winter	Spring	Summer	fr (%)
Pentatomidae					
Acledra kinbergi (Stål)	1				0.02
Chinavia musiva (Berg)		1			0.02
Chinavia nigridorsata (Breddin)	4	3			0.20
Dichelops australis Klein & Grazia	1				0.02
Dichelops furcatus (Fabricius)	7	3			0.30
Edessa meditabunda (Fabricius)	135	274	2		12.0
Edessa rufomarginata (De Geer)		1			0.02
Glyphepomis adroguensis Berg		4			0.13
Hypatropis inermis (Stål)	7	42			1.43
Oebalus poecilus (Dallas)	3	7	1		0.33
Oebalus ypsilongriseus (De Geer)	239	323	88		19.0
Poriptus luctans Stål	5		1		0.17
Thoreyella cornuta Berg		1			0.02
Tibraca limbativentris Stål	417	1509	276	3	64.4
Scutelleridae					
Orsilochides leucoptera (Germar)	3	3			0.18
Thyreocoridae					
Alkindus crassicosta Horvath	3				0.08
Galgupha fossata McAtee & Malloch		2			0.05
Galgupha longirostris Berg				5	0.15
Galgupha neobisignata McAtee & Malloch	3	13			0.46
Galgupha oblonga McAtee & Malloch	4		27		0.90
Galgupha porcata Horvath		1			0.02
Galgupha sp.				1	0.02
Abundance	832	2187	395	9	100
Species richness	14	15	6	3	

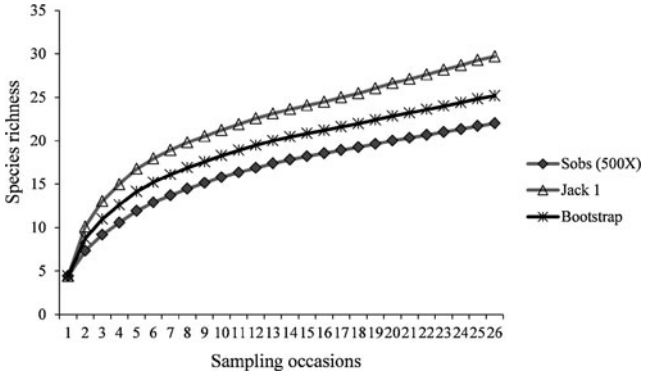

Fig 1 Species accumulation curve and estimated species richness of pentatomoids sampled in tussocks of *Andropogon bicornis* from April 2010 to March 2011 in Eldorado do Sul, Rio Grande do Sul, Brazil.

a single species. Studies performed to identify host plants for pentatomoids in the central region of Rio Grande do Sul (Lopes *et al* 1974, Garlet *et al* 2010) have not mentioned collection of immature specimens or described any feeding activity; therefore, the association between the insect and the host plant remains unclear.

Bunde *et al* (2010) considered a host to be the vegetation in which adults or nymphs could feed on or in a state of diapause; this criterion differs from the concept described by Schoonhofen *et al* (2005), which was the used in this study. Nevertheless, records of the plant species from which insects were collected are relevant. Twenty-six species of grasses were listed as being associated with pentatomids in Rio Grande do Sul (Link & Grazia 1987).

The species accumulation curve (Fig 1) showed a tendency towards asymptote, which suggests that the number of sampled species is close to the estimated species richness. Species richness estimated using Bootstrap and Jackknife 1 indicated that 87.4% and 74.1% of the species, respectively, were sampled.

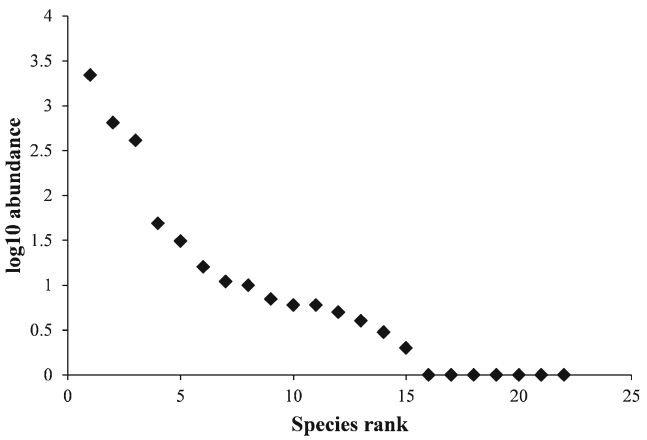

Fig 2 Distribution of Pentatomoidea species abundance recorded from April 2010 to March 2011 in tussocks of *Andropogon bicornis* collected in Eldorado do Sul, Rio Grande do Sul, Brazil.

The assemblage structure of Pentatomoidea had three dominant, five intermediate, and 14 rare species, of which 36.4% corresponded to singletons and doubletons (Fig 2). The three dominant species in decreasing order of abundance were *T. limbativentris*, *Oebalus ypsilongriseus* (De Geer), and *Edessa meditabunda* (Fabricius). The first species was present in all seasons, and no individual belonging to the other two species was found among the population sampled in summer.

The two most abundant species (*T. limbativentris* and *O. ypsilongriseus*) use rice as a host (Panizzi *et al* 2000). In particular, *T. limbativentris* is considered a rice culture pest. Most of the recorded species in the related literature, however, are not known to use rice as the host plant, which suggests that *A. bicornis* serves as a hibernation site for different species of pentatomoids.

The highest species richness was observed in winter and was demonstrated by the highest Margalef index value in that season (D_{Mg}=1.949). On the other hand, indices based on the proportional abundance of species, such as Shannon–Wiener and Simpson's complementary indices (Magurran 2004), showed higher values for autumn, thereby indicating lower dominance by *T. limbativentris* (H′= 1.236) and (1-D=0.6375), respectively. The Berger–Parker index, which expresses the proportional abundance of the most abundant species, indicated spring to be the season with the highest species diversity (d=0.6987).

At three Atlantic Rainforest fragments in the state of Santa Catarina, the lowest values of abundance and species richness were recorded in winter, whereas the highest corresponding values were recorded in December, March, and April (Campos *et al* 2009). In savanna–steppe type vegetation in southeastern Rio Grande do Sul, the highest abundance was recorded in autumn and summer (Bunde *et al* 2010). The difference between the patterns found in this study and those recorded by other authors can be attributed to the differences in the sampling methods used, which included beating and/or sweeping, as well as differences in environment types.

There was a significant correlation between tussock diameter and abundance of specimens in autumn (r_s= 0.346, P=0.0158), winter (r_s=0.358, P=0.0066), and spring (r_s=0.308, P=0.0329). This is a reasonable finding since bigger tussocks would allow a larger number of stinkbugs to take shelter, thus decreasing the competition for space. The stability of the populations that use these tussocks depends, among other factors, on their size (Pearce 1948).

With regard to the distance from the rice culture, we initially assumed that tussocks that were closer would show greater abundance of species associated with rice; however, this did not prove significant within the scale studied. This finding can be attributed to the flight ability and dispersion of these stink bugs. In the laboratory,

specimens of different populations of diapause-induced *Nezara viridula* (L.) flew more intensely than those that did not receive the stimulus (Gu & Walter 1989). In the field, we observed that individuals that would later hibernate flew longer distances than those that kept feeding and showed no evidence of diapause.

At large scale, presence of tussocks adds heterogeneity to the landscape, affecting the diversity of invertebrates (Helden *et al* 2010). *Andropogon bicornis* is widely distributed on the edges of cultivated fields and on roadsides in the region. In a mainly rice-growing region, with only a few remnants of alluvial woods, these tussocks play an important role as refuges for various species in adverse conditions. The high species richness observed in the colder months, resulting from the presence of species related to rice as well as unrelated species, combined with the absence of immature specimens in the tussocks supports our hypothesis that *A. bicornis* may serve as a hibernation site for pentatomoids.

Acknowledgments The authors would like to thank Viviana Cauduro Matesco, MSc for Thyreocoridae identification and CNPq and CAPES for fellowships to two of the authors.

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