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ORIGINAL PAPER

Improving Orthoptera knowledge in north arid Argentine Patagonia

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Abstract
Orthopterans are among the most abundant insects in extra-Andean Patagonia. However, despite their ecological and economic importance, their knowledge there is scarce. The objective of this work was to estimate the taxonomic composition and trophic structure of the Orthoptera communities in arid and semi-arid regions of the Chubut province, located in Argentine Patagonia. Samplings were carried out with pitfall traps considering the main climatic and environmental gradient. The composition and community structure were inspected using rank-abundance curves. The variation among trophic guilds abundances was analyzed using generalized linear models. Seventeen species of orthopteran (seven families) were collected. The most abundant families were Mogoplistidae and Acrididae, while *Microgryllus pallipes* (Philippi, 1863) (Mogoplistidae) was the most common species. The community structure was best-described by the Mandelbrot model, determined by few high-abundance species and several low-abundance species. Omnivorous and herbivorous species were collected in similar proportions, so the trophic community structure was balanced. We also obtained the first records of six species for the Chubut province, including a new record for Argentina and the first records of the Mogoplistidae and Rhaphidophoridae families for this province. This work represents a valuable contribution to the knowledge of Orthoptera and to the improvement of future conservation strategies.
Implications for insect conservation This work makes valuable contributions to the knowledge of Orthoptera in arid Patagonia, which can improve the current conservation strategies of these fragile ecosystems and the services they provide.

Keywords Diversity · Trophic guild · Pitfall traps · Acrididae · Mogoplistidae

Introduction

One of the greatest challenges of conservation biology is to explore the few remote and little-known territories that still remain on our planet (Ward 2016). Despite covering more than 50% of the surface and having great biodiversity with several endemic species, deserts in South America have received little attention in comparison to other environments. Due to its size and ecosystem services, improving the knowledge of arid South American ecosystems is extremely important (Cheli et al. 2010). The extra-Andean Patagonia constitutes the largest arid environment in southern South America (Domínguez et al. 2006) and is one of the few continental territories in the world that, extending beyond 40° south, sustains relatively unaltered complex biotic communities (Pardiñas et al. 2000). However, current knowledge of many aspects of arid Patagonia continues to be scarce, especially regarding its entomofauna (Domínguez et al. 2006; Cheli et al. 2010).

Insects, the most abundant and diverse animal group in deserts, play key roles in the functioning of these ecosystems (Whitford 2000; Ayal 2007), providing and regulating many ecosystem services, such as pollination, soil nutrient dynamics, and energy flow in food webs, among others (Noriega et al. 2018; Cheli et al. 2022). Also, the ecological roles they develop are enhanced in deserts because they are less limited by low water availability and extreme temperatures than other animals (Whitford 2000). In northern Patagonia, Orthoptera are among the most abundant insect orders (Cheli et al. 2010); however, their knowledge in this region is scarce. Most of the studies on this group are focused specifically on the Acridoidea superfamily and particularly

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on the Pampean region (Cigliano et al. 2002; De Wysiecki et al. 2004; Mariottini et al. 2012, 2022a). In arid Patagonia, knowledge comes from isolated and sporadic expeditions carried out during the last century (Liebermann 1949) or from local-scale studies on potentially harmful species for agriculture and livestock (Amadio et al. 2021; Mariottini et al. 2022b). Given their mainly herbivorous nature, orthopterans (especially the Acridoidea superfamily) are frequently considered detrimental to agricultural-livestock activities (Cigliano et al. 2014; Lecoq and Zhang 2019). However, they play a fundamental role as primary consumers in the cycling of soil nutrients and energy in food webs in grassland ecosystems (Zhong-Wei et al. 2006; Song et al. 2018), while other species that consume weeds or seeds of exotic species are effective biological controllers (Franceschini et al. 2014; Ichihara et al. 2015). Similarly, several species are sensitive indicators of environmental change (Bazelet and Samways 2011; Alignan et al. 2018; Löffler et al. 2019).

Even though other insects and arachnids have proven to be good indicators of both natural and anthropic environmental change in arid Patagonia (Baldi et al. 2017; Cheli and Martínez 2017), the lack of knowledge of some taxonomic groups significantly hinders ecosystem conservation tasks in the face of increasing anthropic disturbances, such as grazing, habitat fragmentation, installation of infrastructure projects, or mining developments (Baldi et al. 2017). In this sense, considering the ecological and economic importance of orthopterans in arid Patagonia, the main objective of this work is to improve the knowledge of this group at the regional scale, estimating their taxonomic composition, their abundance in community structure, and trophic guild variations. This is the first attempt to describe this community through a systematic and long-term sampling design in the Chubut province (Argentina).

Materials and methods

Study area and sampling design

We located 24 sampling sites on a 600 km transect between 43° and 44° south latitude (Fig. 1) considering the main climatic and environmental gradient in temperature and precipitation present in an east-west direction into the province (Oyarzabal et al. 2018). The sampling sites had a minimum separation of five kilometers and ten pitfall traps were arranged in each, distributed in two parallel transects of five traps each, separated by a minimum distance of 20 m from each other. Two sampling events were carried out in February and November 2014 and a total of 240 traps (120 traps/event) were placed. We chose pitfall trapping to perform orthopteran samplings because: (1) this is the most appropriate method for collecting Orthoptera in environments with xerophytic vegetation (Schirmel et al. 2010); (2) this method is very useful for capturing rare species (Harvey and Gardiner 2006); and (3) this methodology was successfully used to capture Orthoptera in several studies in arid Patagonia (Cheli et al. 2010; Baldi et al. 2017; Cheli and Martínez 2017) as in other parts of the globe (Bieringer and Zulka 2003). The traps had the configuration suggested by Cheli and Corley (2010), who carried out the pitfall traps optimization for the arid region of Patagonia. Each trap consisted of a 1000 cm^3 transparent plastic container, 11 cm deep and 12 cm in diameter; activated with 30% propylene

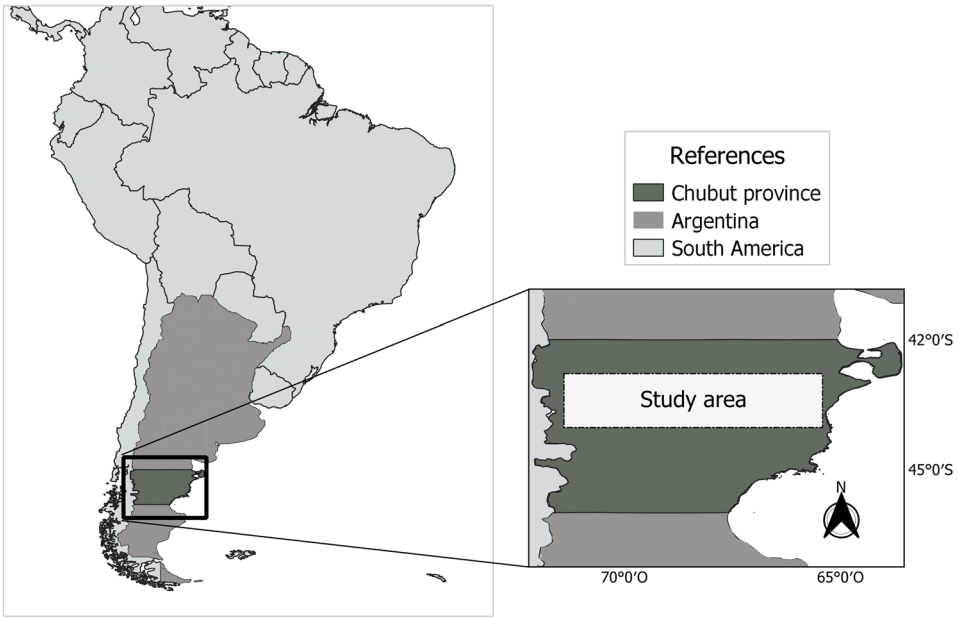


Fig. 1 Location of the study area

glycol, and it was left on-site for two weeks. Orthopterans collected were fixed in 70% alcohol and taken to the laboratory (LAFATE-Laboratorio de Fauna Terrestre, IPEEC-CCT CENPAT CONICET) to be quantified and identified to the level of species (or morphospecies) under a binocular stereomicroscope using taxonomic keys (Bruner 1915; Mello-Leitão 1939; Triplehorn and Johnson 2005; Cigliano et al. 2014), species catalogs (Carbonell et al. 2023), and consulting specialist taxonomists. All the entomological material collected was deposited in the Entomological Collection of IPEEC (CCT CENPAT-CONICET).

Data analyses

The composition and structure of the orthopteran community was described by applying rank-abundance curves at taxonomic levels of families and species, and the fit to the main theoretical models of abundance distribution of species was evaluated. Those models were Broken-stick, Geometric Niche Preemption, Log-normal, Zipf and Zipf-Mandelbrot (Wilson 1991). The model that best described the orthopteran community was identified according to the Akaike Information Criterion (AIC). The trophic structure of the Orthoptera community was inspected classifying the collected species according to their feeding habits as omnivores or herbivores following Di Russo et al. 1996; Triplehorn and Johnson 2005; Cigliano et al. 2014; and Carbonell et al. 2023. The abundance variations between these trophic guilds were analyzed by generalized linear model (GLM) (Crawley 2013) using a *negative Binomial* error structure. The analyses were performed in R (R Core Team 2022–R v 4.0.5) with the *radfit*, *radlattice*, and *glmmTMB* functions of the *vegan* package.

Results

We recorded 630 individuals from 17 species belonging to seven families and nine subfamilies. *Microgryllus pallipes* (Philippi, 1863) represents a new record for Argentina, while *Sinipta dalmani* (Stål 1860), *Tristira magellanica* (Bruner 1900), *Burgilis mendosensis* Rehn, 1913, *Hyperophora major* Brunner von Wattenwyl, 1878, and *Udenus w-nigrum* Brunner, 1900, are new records for the Chubut province (Table 1).

Mogoplistidae and Acrididae were the most abundant families, followed by Rhaphidophoridae. The first two families together accounted for approximately 77% of the captures (Table 1; Fig. 2), while the most common species was *Microgryllus pallipes* (38.9%), followed by *Trimerotropis pallidipennis* (Burmeister 1838) (30.6%), and *Udenus w-nigrum* (11.6%). Five species showed relative abundances between 1% and 6%: *Bufonacris claraziana* (Saussure 1884), *Scyllinula* sp.1, *Tristira magellanica, Borellia bruneri* (Rehn 1906), and *Anchocoema moricata* Mello-Leitão 1939, while nine have abundances lesser than 1% (Table 1; Fig. 3A).

Thus, few very abundant, some intermediate, and several species with lower abundances were observed. Consequently, the Mandelbrot model best-described the orthopteran community structure (AIC = 104.94; Fig. 3B).

Regarding the trophic structure of the orthopteran community, there were not significant differences between relative abundances of omnivorous and herbivorous species ($X^2 = 0.0602$; $p = 0.8062$; Fig. 4).

Discussion

By using a systematic sampling design that covers more than 600 km of environmentally heterogeneous areas, this is the first study that describes the composition and structure of the orthopteran community in northern Patagonia at a regional scale. This study discovered six species that had not been previously reported for the Chubut province; among them, one not previously reported for Argentina, expanding its distribution hundreds of kilometers to the south. This was particularly relevant for species of the Ensifera suborder, which have not had any previous studies in the region, since we recorded two families for the Chubut province for the first time (Mogoplistidae and Rhaphidophoridae). Thereby, in our opinion, the knowledge of this important group of insects in Patagonia has been significantly deepened.

Although the scaly cricket *M. pallipes* (Ensifera: Mogoplistidae) has a wide geographical distribution and is widely distributed in Chile (Lamborot 1985), its presence was previously unknown in Argentina despite it being the most abundant species in the present study. Similarly, *U. w-nigrum* (Ensifera: Rhaphidophoridae), widely known in Chilean Patagonia (Di Russo et al. 1996), had only been reported in Argentina more than 80 years ago in the Santa Cruz province (Pirán 1941). Among the tettigonids, the records of *B. mendosensis* and *H. major* presented in this work establish the southernmost distribution limit in Argentina (Braun and Zubarán 2023). Among the acridids, *S. dalmani* (Caelifera: Acrididae) was previously registered in Patagonia, but only for the Neuquén province and not for Chubut (Carbonell et al. 2023). Among the tristirids, the presence of *T. magellanica* stands out because this species was previously cited only for the Tierra del Fuego and Santa Cruz provinces (Carbonell et al. 2023). Thus, until now, 21 acridomorph species and four tettigonid species were registered for the Chubut province in the existing catalogs in Argentina (Braun and Zubarán 2023; Carbonell et al. 2023). Considering the new records mentioned in this work, the number of acridomorph species in Chubut amounts to 24 (14% more), while

Table 1 Orthoptera collected. Relative abundance (% of the total), trophic guild, altitude and temperature range in which they were found were listed

Taxa	Relative abundance	Trophic guild	Altitude (m.a.s.l.)	[a]Temp. (°C) February mean (min–max)	[a]Temp. (°C) November mean (min–max)
CAELIFERA					
ACRIDIDAE					
Gomphocerinae					
Sinipta dalmani (Stål 1860) *	0.5	Herbivorous	133–990	18.76 (5.5–39.6)	21.36 (13–32.9)
Scyllinula sp.1	3.8	Herbivorous	40–992	20.94 (5.5–40.8)	18.74 (3.7–39.7)
Borellia bruneri (Rehn 1906)	2.1	Herbivorous	90–723	21.61 (5.5–47.7)	21.36 (13–32.9)
Melanoplinae					
Dichroplus vittatus Bruner 1900	0.5	Herbivorous	42–107	25.31 (16.1–40.8)	Not recorded
Dichroplus pratensis Bruner 1900	0.3	Herbivorous	330–792	26.38 (12.6–47.7)	12.60 (4.2–27.8)
Dichroplus maculipennis (Blanchard 1851)	0.3	Herbivorous	40	25.31 (16.1–40.8)	Not recorded
Oedipodinae					
Trimerotropis pallidipennis (Burmeister 1838)	30.6	Herbivorous	26-1022	18.41 (5.5–39.6)	16.25 (3.7–39.7)
PROSCOPIIDAE					
Proscopiinae					
Anchocoema moricata Mello-Leitão 1939	1.9	Herbivorous	90–723	22.94 (5.5–47.7)	17.64 (4.5–35.8)
Anchocoema illudens Mello-Leitão 1939	0.6	Herbivorous	320–723	17.04 (5.5–35.7)	18.89 (7.9–35.8)
TRISTIRIDAE					
Tristirinae					
Tristira magellanica (Bruner 1900)*	2.2	Herbivorous	619–990	26.38 (5.5–38.7)	12.92 (3.7–29.4)
Bufonacris claraziana (Saussure 1884)	5.1	Herbivorous	663–905	17.72 (5.5–36.9)	12.60 (4.2–27.8)
Bufonacris terrestris Walker 1871	0.3	Herbivorous	136–578	Not recorded	20.90 (7.9–39.7)
ENSIFERA					
GRYLLIDAE					
Gryllinae					
Gryllini sp.1	0.1	Omnivorous	107	Not recorded	21.36 (13–32.9)
MOGOPLISTIDAE					
Mogoplistinae					
Microgryllus pallipes (Philippi 1863)#	38.9	Omnivorous	36–992	21.00 (5.5–47.7)	16.25 (3.7–39.7)
RHAPHIDOPHORIDAE					
Macropathinae					
Udenus w-nigrum Brunner, 1900*	11.6	Omnivorous	618–866	18.17 (5.5–39.6)	12.77 (3.7–29.4)
TETTIGONIIDAE					
Phaneropterinae					
Burgilis mendosensis Rehn, 1913*	0.9	Herbivorous	90–467	25.85 (12.6–47.7)	20.42 (7.9–39.7)
Hyperophora major Brunner von Wattenwyl, 1878*	0.1	Herbivorous	704	18.42 (5.5–38.7)	Not recorded

*First record for Chubut province, while numeral sign denotes first record for Argentina; [a]soil-surface temperature data were extracted from https://www.ready.noaa.gov/READYamet.php (Rolph et al. 2017)

tettigonid species amount to six (50% more), increasing by 20% the number of species cited in this province in these catalogs.

The orthopteran families Mogoplistidae and Rhaphidophoridae are little known in Argentina and this study is among the first contributions on these taxa in the country. The Mogoplistidae family, the so-called scaly crickets, comprises three subfamilies, one of them extinct (Protomogoplistinae) and another limited to the islands of the African continent (Malgasiinae). Mogoplistinae is the most diverse subfamily of the clade and has the widest distribution (Cigliano et al. 2023), however there were no records in Argentine Patagonia before the present work. Regarding Rhaphidophoridae, there are only two old records for southern Argentine Patagonia near Lago Argentino and in the Río Turbio Valley (Ander 1932; Pirán 1941) without it having

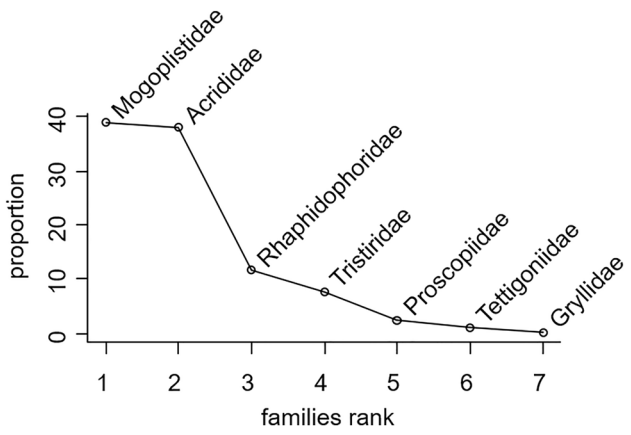
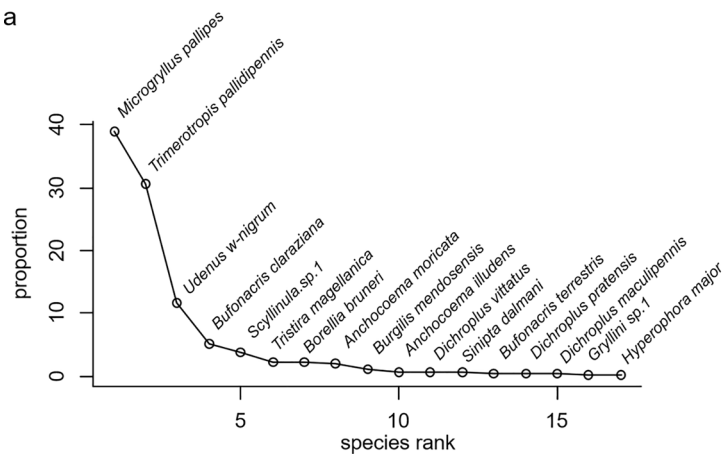


Fig. 2 Rank-abundance curve (in proportions) of the orthopteran families collected

been recorded again in Argentine territory until today. Thus, those presented here are the first for this family in northern Argentine Patagonia. This, added to the records of *M. pallipes* and *Udenus w-nigrum*, of whose families there are no catalogs in Argentina.

The present work demonstrated that Mogoplistidae and Acrididae as the most abundant orthopteran families in arid north of Patagonia. This partially agree with other studies in Chaco (Argentina) and Atacama-Coquimbo (Chile) where Acrididae and Tettigoniidae are the most common orthopteran taxa (Pocco et al. 2010; Alfaro et al. 2013). The taxonomic discrepancies referred to Mogoplistidae may be explained in part by sampling methodology implemented in each cases, since said works applied entomological nets as the main collection method while pitfall traps were used in the present study. Pitfall traps are known to be an excellent method of collecting ground crickets (Schirmel et al. 2010), so a bias in Grylloidea abundance could be expected in this work. However, in the present study Acrididae was also among the most abundant taxa, similar to those carried out in Chaco and Atacama-Coquimbo with entomological nets. Therefore, in our opinion, the discrepancies in Orthopteran taxonomic dominances between northern Patagonia and those other northern arid regions may be determined by differences in environmental conditions (both in habitat and climate) among the studied areas. As previously mentioned, given the xerophytic environmental characteristics of the region studied, (where shrub steppes deeply adapted to aridity with large spines are the dominate vegetation units), the use of entomological nets is virtually impossible in most places. So, we are confident that pitfall traps are the best sampling methodology to perform entomological biodiversity estimations in those environments. Besides, pitfall traps

Fig. 4 Trophic guilds. Abundance of omnivorous and herbivorous orthopterans per transect. Equal letters indicate that there are no significant differences



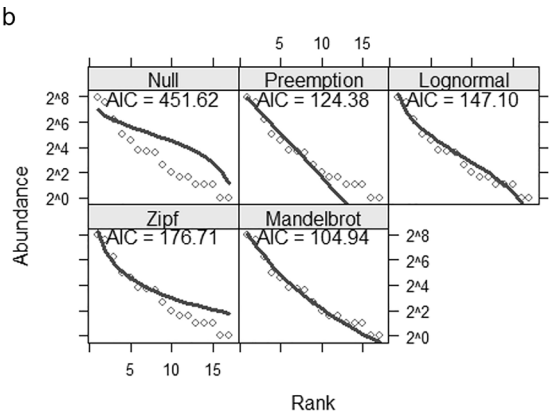


Fig. 3 **a** Rank-abundance curve (in proportions) of the collected orthopteran species; **b** Comparison between the data collected at the species level and the different abundance distribution models. The Mandelbrot model best- described the orthopteran community structure (AIC = 104.94)

allow the collection of rare species and those with nocturnal habits, which are not usually detected using nets.

Agreeing with other orthopteran communities of Argentina (Pocco et al. 2010; Mariottini et al. 2012), few orthopteran species were very abundant in northern Patagonia, while the remaining were rare. This distribution of species abundances was best-described by the Mandelbrot Model. This model is related to environments with a rapid initial colonization by pioneer species and then succession, a slow process of colonization by secondary and tertiary species. Thus, pioneer species present less difficulty to establish, while late successional species have a higher cost and will therefore be rare (Magurran 2004). Likewise, this model suggests that many factors act sequentially on the orthopteran species community (Wilson 1991). Agreeing with this, several factors, both natural and anthropic, may be modeling the orthopteran community in arid Patagonia. The natural environmental heterogeneity of arid Patagonia, determined by the east-west gradients of precipitation, temperature and altitude from the Andes Mountain to the Atlantic Ocean coasts (Oyarzabal et al. 2018), undoubtedly could be a determinant factor on the orthopteran community. In addition, arid Patagonia has been grazed (mainly by sheep) for at least 120 years, and the environmental consequences are palpable in soil, vegetation, and entomofauna (Cheli 2009; Cheli et al. 2016; Baldi et al. 2017).

It is interesting to note that the species abundance structure of the orthopteran community evidenced in this work contrasts with what was found by Cheli et al. (2010) using pitfall traps for ants and epigean beetles in Peninsula Valdes, located 100 km east to the nearest sampling site of this study. Those authors found that the *Logarithmic Series Model* was the model that best-fit as a consequence of a greater number of species with intermediate abundances. Our results also partially disagree regarding the community trophic structure, since Cheli et al. (2010) found a higher proportion of herbivore orthopterans than omnivorous, while in the present study both trophic guilds were equally abundant. These differences may be a consequence of the dissimilar environmental requirements among taxa, but also due to the different scale at which both studies were carried out. Cheli et al. (2010) studied an area comprising about 4,000 km^2 while the present work covered almost 60,000 km^2.

However, discrepancies may also be determined by the relative level of anthropogenic disturbance. It is worth mentioning that grazing may deeply modify abundances of arthropod species and trophic guilds in arid environments (Molina et al. 1999; Cheli 2009; Cheli and Martínez 2017). In this sense, the study by Cheli et al. (2010) was carried out in the natural reserve Peninsula Valdes, declared a Natural Heritage site by UNESCO. According to the classification of conservation units of IUCN, it has been categorized as VI (Managed Resource Protected Area), so several restrictions to anthropic activities (e.g. grazing) have been implemented since 1983 (Cheli et al. 2010; Baldi et al. 2017). On the other hand, only three protected areas are established within the present study area, representing only about 2.5% of the total area (Ministerio de Turismo y Áreas Naturales Protegidas de la Provincia del Chubut 2023). In addition, as noted earlier, the major economic activity in this area has been sheep grazing for at least 120 years. Consequently, this region displays major signs of anthropic desertification of arid Patagonia, which surely impacts their insect communities.

To conclude, although Orthoptera from other areas of arid Patagonia still need to be studied in their relationship with environmental heterogeneity and anthropogenic disturbances, this work makes valuable contributions to the knowledge of these insects in arid Patagonia, which should improve the current conservation strategies of these fragile ecosystems and the services they provide.

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Author contributions GHC carried out the sampling design and the capture of orthopterans. LEC and YM carried out the taxonomic determination of the specimens. LEC and GHC conducted the data analysis. All authors wrote the original draft, reviewed and edited the document and approved the final manuscript.

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Data availability For questions about the dataset used contact to corresponding author. All the entomological material collected was deposited in the Entomological Collection of IPEEC (CCT CENPAT-CONICET), which is public. For questions about the entomological material contact the curator of the Entomological Collection of IPEEC.

Declarations

Competing interests The authors declare no competing interests.

Ethical approval Not applicable.

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