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### Diversity of planthoppers (Hemiptera: Fulgoromorpha) in rice associated with weeds in Argentina

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## ORIGINAL ARTICLE

### Diversity of planthoppers (Hemiptera: Fulgoromorpha) in rice associated with weeds in Argentina

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An assemblage of Fulgoromorpha in a rice agroecosystem from La Plata city was studied for the first time in Argentina, considering those species associated with rice and the surrounding weeds, their seasonality, sex ratios and parasitoidism. Samples were obtained from 2006 to 2010 in a rice field and in the surrounding weeds. Fourteen species from three families of Fulgoromorpha were associated with rice, most of them native species. The delphacids *Chionomus haywardi*, *Toya propinqua* and *Delphacodes kuscheli* were the most abundant on rice. Population peaks occurred after flooding of rice and before anthesis. The native *C. haywardi* was more abundant in rice than in weeds, while the opposite was confirmed for *T. propinqua*, a well-known cosmopolitan grass specialist. The difference of abundances of *D. kuscheli* in rice and weeds was not significant. Our results highlight the dominance of *C. haywardi* during all sampling years in the rice agroecosystem as well as the role of surrounding weeds as an alternative microhabitat for planthoppers instead of rice. The strepsipteran *Elenchus tenuicornis* was the only recorded parasitoid and showed no preference for any of the insect hosts.

**Keywords:** Delphacidae; Cixiidae; rice; abundance; seasonality; Argentina

#### Introduction

Rice (*Oryza sativa* L.) is the main food source for one-third of the human population, and the third most cultivated plant worldwide in terms of production (millions of tons) (Food and Agriculture Organization of the United Nations 2012). Economically important insect pests in rice reduce the global production of this crop by 12% (Pantoja et al. 1997). Planthoppers are one of the most important insect pests of rice. The brown planthopper (BPH), *Nilaparvata lugens* (Stål), the whitebacked planthopper (WBPH), *Sogatella furcifera* (Horvath), and the small brown planthopper (SBPH), *Laodelphax striatellus* Fallén, affect most rice-growing areas and disperse severe pathogenic diseases to plants (Weintraub & Beanland 2006; Hogenhout et al. 2008). For instance, the delphacid *N. lugens* is the most important rice pest in Asia, causing extensive damage (“hopperburn”) due to injuries in plant tissues made with its mouthparts and ovipositor (Zhenga et al. 2007), and due to its role as vector of the Grassy Stunt Virus and the Rice Ragged Stunt Virus (Duppo & Barrion 2009). In Central and South America, rice crops are affected by the delphacid *Tagosodes orizicolus* (Muir) directly through

mechanical damage while feeding, and indirectly through the persistent transmission of Rice Hoja Blanca Virus (Galvez 1968). This transovarially acquired pathogen produces an estimated loss in rice production of 25–100% (Zeigler et al. 1994).

In Argentina, 90% of the production of rice occurs in Entre Ríos and Corrientes provinces. Although no epidemics of diseases transmitted by planthoppers have been reported to date, the presence of *T. orizicolus* and its dispersal in agricultural areas of Argentina (Mariani & Remes Lenicov 2000–2001) involve a potential risk for rice agroecosystems, as well as other well-known vectors affecting gramineous plants in the country such as *Delphacodes kuscheli* Fennah, *Chionomus haywardi* (Muir) and *Toya propinqua* (Fieber) (Remes Lenicov & Paradell 2012).

*Delphacodes kuscheli* was exhaustively studied because it is the most important vector of Mal de Rio Cuarto Virus (MRCV) (Remes Lenicov et al. 1985). Its populations reach high densities in meadowlands between 32° and 35° S, occurring also in some areas of northern Argentina with particular environmental features (Virla & Remes Lenicov 2000). Some aspects of the biology of *D. kuscheli* are known, including its life cycle on different hosts

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(Remes Lenicov et al. 1991; Virla & Remes Lenicov 1991; Maragliano & Virla 1992), feeding behavior (Brentassi & Maldonado 2002; Brentassi & Remes Lenicov 2006, 2007), plant resistance (Costamagna et al. 2005), reproductive behavior (Costamagna 1998), spatial and temporal abundance patterns (Ornaghi et al. 1993; Grilli & Gorla 1997), and natural enemies (De Santis et al. 1988; Remes Lenicov & Tesón 1990; Remes Lenicov et al. 1991; Olmi & Virla 1993; Triapitsyn 1997; Virla & Olmi 1998; Liljestrom & Virla 2004). The other planthopper species, *C. haywardi*, *T. propinqua* and *T. orizicolus*, have been also reported as natural and experimental vectors of MRCV (Presello et al. 1997; Velázquez et al. 2003; Mattio et al. 2008). Immature instar morphology, geographical distribution, and several host plants of *C. haywardi* and *T. propinqua* were studied (Virla & Maragliano 1993; Remes Lenicov & Virla 1996; Remes Lenicov et al. 1997), but there is a lack of information about population dynamics of these species. They are widely distributed in Central Argentina and coexist with *D. kuscheli* within the endemic MRCV area, with *T. propinqua* being a well-known grass specialist in this and other latitudes (Remes Lenicov et al. 1999). All previous studies were conducted on planthoppers from host plants other than rice.

The only previous studies focusing on Auchenorrhyncha of rice from Argentina are a key to species of Cicadellidae found in paddies from Corrientes and Entre Ríos (Remes Lenicov & Tesón 1985) and a report about seasonality and prevalence of pathogenic fungi on *Oliarus dimidiatus* Berg (Cixiidae) feeding in rice paddies (Toledo et al. 2008). The assemblage of Fulgoromorpha species living on rice crops from Argentina remains unidentified.

An obvious key step before pest management strategies are designed is an inventory of the species associated with rice fields. In order to detect

differences in the population dynamics of species we recorded the seasonality of the occurrence and abundance of Fulgoromorpha in relationship to the phenology of rice. We also searched for differences in the relative abundance of planthoppers on rice and surrounding weeds and explored the presence of parasitoids.

## Materials and methods

### Study site

Sampling was performed at the experimental station “Julio Hirschhorn” (Facultad de Ciencias Agrarias y Forestales, UNLP) located in Los Hornos (34°56'57" S, 57°58'22" W), La Plata city, Buenos Aires province. We collected insects from an experimental rice field along four crop cycles, and, for comparison, from weeds surrounding the crop. There were 48 plots ( $\approx 11 \times 11$  m) of rice at this site. The whole area ( $c.0.6$  ha) comprising these plots, had a roughly rectangular shape. Rice plots were surrounded by non-cropped strips, spontaneously colonized by weeds.

Rice cultivars (Table 1) were short (< 90 days to blooming), intermediate (90–100 days), and long (> 100 days) cycle commercial strains. Seeding was made at a density of 350 plants  $m^{-2}$  in lines spaced at 0.20 m on a typical Argiudol soil (see USDA Soil Survey Staff 1999 for a definition; Atlas Ambiental de Buenos Aires 2012). Rice was watered by flooding approximately 30 days after germination. Weeds in rice plots were controlled with the herbicides MCPA, Bentazon and Nominee® (bispyribac-sodium). The following phenological stages were recorded during the life cycle of the rice crop, considering the onset of a stage when it appeared in 50% of plants within a plot: germination (G, emergence of coleoptile), and anthesis (A, emergence of male inflorescence or panicle) (Marchezan 2005). Relevant farming

Table 1. Main features of rice crops cultured in the “Julio Hirschhorn” experimental station, La Plata, Buenos Aires, between 2006 and 2010.

	Crop cycle			
	2006/2007	2007/2008	2008/2009	2009/2010
Rice strain	Don Ignacio-Yeruá-H244	Don Ignacio-Yeruá-H244-IRGA417-RP2	Don Ignacio-Yeruá-H244-IRGA417-RP2	Don Ignacio-IRGA417-RP2
Seeding	3 November 2006	27 October 2007	17 October 2008	25 October 2009
Germination	14 November 2006	25 November 2007	3 November 2008	12 November 2009
Start of watering	20 November 2006	2 December 2007	13 November 2008	21 November 2009
Start of flooding	14 December 2006	21 December 2007	8 December 2008	10 December 2009
Emergence of panicle	20 February 2007	23 February 2008	9 February 2009	12 February 2010
Harvest	5 April 2007	12 April 2008	30 March 2009	1 April 2010

activities such as seeding, flooding and harvest were also recorded for each crop cycle (Table 1).

The most frequent plant species in patches of weeds around rice plots were recorded from 2006 to 2010. Taxa are listed alphabetically within their current higher taxon.

### ***Insect sampling***

Insect collections were made weekly from 2006 to 2010, each year starting around one month after seeding and before flooding of the rice fields, and ending at harvest. Samples were obtained using an entomological sweep net (40 cm in diameter). Six randomly selected plots were chosen every week in the rice crop. Each sample consisted of 50 successive sweeps on the vegetation from each plot (total: 300 sweeps per week). No attempts to collect samples were made if rice foliage had less than four leaves, to avoid damage to young plants. Another 50 sweeps were performed on weeds from each side of the plots (total: 200 sweeps per week). We considered that sampling efforts on rice plots and on weeds stripes were equivalent. Area sampling was  $\approx 5800 \text{ m}^2$  in rice and  $\approx 3520 \text{ m}^2$  in weeds over the sampling period. Both areas comprise 62 and 38% of the total surveyed area. Thus, roughly comparable percentages of the total of sweeps per week were assorted for rice and weeds, in order to allow valid comparisons for hypotheses concerning abundance of species on either rice or weeds.

For identification, sampled insects were killed *in situ* by placing them in glass vials with 70% ethanol. All Auchenorrhyncha specimens were sexed and identified to species. Some species needed dissections and clarification in hot 10% KOH in order to be identified. Dissections were performed following the entomological techniques described in Remes Lenicov & Virla (1993). Taxonomic identification followed specialized literature (Wilson & Claridge 1991; Remes Lenicov & Virla 1999) and the individuals were compared with reference specimens deposited in the Museo de La Plata collection.

The number of parasitized individuals was recorded when external evidence of Strepsiptera was detected. Stylopized planthoppers were distinguished based on the observation of male and female puparium protruding from abdominal segments of the host (Remes Lenicov et al. 1991).

### ***Data analysis***

Abundance was expressed as the percentage of each species of the total Fulgoromorpha caught between 2006 and 2010. Population fluctuation curves were constructed in order to explore seasonality of the

most abundant species of Fulgoromorpha. The sampling period was divided into 10-day intervals and the number of insects for a particular species within each interval was summed across years. This procedure was repeated for samples obtained on rice and on weeds.

To explore sex ratios and the degree of association among insects and host plants, chi-square tests were performed under the null hypotheses of an equal relationship between males and females, and non-dependence between relative abundance of species and host plants (either rice or weeds), respectively.

Presence of parasitoids in samples was measured as prevalence (number of parasitized hosts/number of examined hosts). Percentage of parasitized individuals in rice plots and in weeds were compared with two-tailed *t*-tests, and between parasitized species, with ANOVAs on transformed data following  $Y = \arcsin \sqrt{p}$ , with *p* being the proportion of parasitized individuals. Only positive dates for parasite presence were included in the analysis.

### **Results**

A total of 2000 individuals of Fulgoromorpha were caught between 2006 and 2010 in the rice agroecosystem (966 in rice plots and 1034 in adjacent weeds), belonging to 14 species from three families (Table 2). As almost all individuals were macropterous adults, our results refer only to this stage of development. Of all Fulgoromorpha on rice, the delphacid *C. haywardi* comprised nearly 89%, followed by *T. propinqua* (6%) and *D. kuscheli* (3%). In the nearby weeds, the dominant species were again *C. haywardi* (72%) and *T. propinqua* (14%), but the cixiid *O. dimidiatus* (5%) and *Cixiosoma* sp. (4%) were slightly more abundant than *D. kuscheli* (3%) (Figure 1). Flatidae was also present on weeds, in less than 1%. The main weeds surrounding rice plots are shown in Table 3.

### ***Seasonal dynamics***

We analyzed seasonal population dynamics of only the three dominant species in rice, *C. haywardi*, *T. propinqua* and *D. kuscheli*, over all sampling years. The other taxa were too scarce or occurred too irregularly across crop cycles for a meaningful analysis.

*Chionomus haywardi* showed a bimodal pattern in rice, with a first peak soon after flooding of rice lots (between 40 and 50 days after seeding), and a second, lower peak approximately 40 days later (between 80 and 90 days after seeding) and before anthesis (Figure 2). In the weeds, the highest abundance was recorded approximately 80 days after rice seeding.

Table 2. Species of Fulgoromorpha and number of individuals captured on rice and adjacent weeds in the “J. Hirschhorn” experimental station, La Plata, Buenos Aires, between 2006 and 2010.

Species	Rice	Adjacent weeds
Delphacidae		
<i>Chionomus balboae</i> Muir & Giffard	1	2
<i>Chionomus haywardi</i> Muir	859	743
<i>Delphacodes elongatus</i> Tesón & Remes Lenicov	1	1
<i>Delphacodes kuscheli</i> Fennah	25	40
<i>Delphacodes sitarea</i> Remes Lenicov & Tesón	3	4
<i>Lacertinella australis</i> R. Lenicov & R. Batiz	2	2
<i>Megamelus bellicus</i> Remes Lenicov & Sosa	—	1
<i>Sogatella</i> sp. 1*	1	—
<i>Tagosodes orizicolus</i> (Muir)	—	1
<i>Toya argentinensis</i> (Muir)	1	—
<i>Toya propinqua</i> (Fieber)	58	144
Cixiidae		
<i>Cixiosoma</i> sp.	9	42
<i>Oliarus dimidiatus</i> Berg	6	48
Flatidae		
Undetermined species	—	6

\* This possibly new species is currently under investigation in order to describe it.

Population levels of *C. haywardi* decreased to nearly zero after rice anthesis and until harvest, both in the rice plots and weeds. The seasonality of the species indicates that it occurs firstly on rice and then on weeds.

*Toya propinqua*, a well-known grass specialist delphacid, exhibited the maximum abundance on rice around 60 days after seeding and a second peak after nearly one month later (Figure 3). In weeds, *T. propinqua* displayed high densities between 40 and 100 days after rice seeding, and the population curve showed that there were individuals present even after rice blooming, although in low values, opposite to *C. haywardi*. The seasonality of the species indicates that it occurs firstly on weeds and then on rice.

*Delphacodes kuscheli* showed a bimodal pattern on rice too (Figure 4). The first peak occurred between 50 and 70 days after seeding, and the second, highest peak, between 80 and 90 days after seeding. In weeds, highest abundance was recorded around 85 days after seeding. Additional erratic peaks were registered in the weeds. As in *C. haywardi*, few specimens were captured after rice blooming. The seasonality of the species indicates that it appears on weeds before appearing on rice.

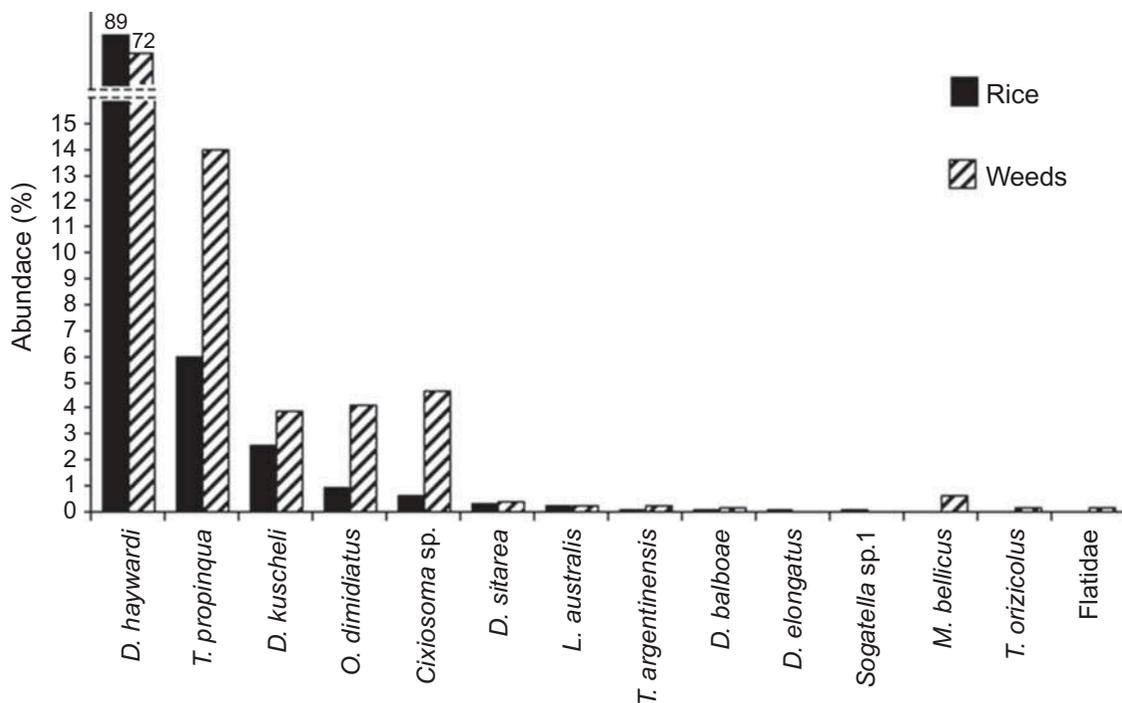


Figure 1. Abundance of species of Fulgoromorpha sampled from rice and adjacent weeds in the “Julio Hirschhorn” experimental station, La Plata, Buenos Aires, between 2006 and 2010, expressed as percentage of total sample.

Table 3. Main weed species associated with rice plots in the “Julio Hirschhorn” Experimental Station, La Plata, Buenos Aires.

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Monocotyledoneae
Alliaceae
<i>Nothoscordum bonariense</i> (Pers.) Beavert
Commelinaceae
<i>Commelina erecta</i> L.
Cyperaceae
<i>Cyperus aggregatus</i> (Willd.) Endl.
<i>Cyperus involucratus</i> Rottb
<i>Cyperus rotundus</i>
Poaceae
<i>Cynodon dactylon</i> L. (Pers.)
Eudicotyledoneae
Apiaceae
<i>Conium maculatum</i> L.
<i>Hydrocotyle bonariensis</i> Lam.
Asteraceae
<i>Cichorium intybus</i> L.
<i>Cirsium vulgare</i> (Savi) Ten.
<i>Matricaria recutita</i> L.
<i>Solidago chilensis</i> Meyen
<i>Taraxacum officinale</i> Weber ex P. H. Wigg.
<i>Wedelia glauca</i> (Ortega) O. Hoffm. Ex Hicken
Boraginaceae
<i>Borago officinalis</i> L.
Brassicaceae
<i>Brassica rapa</i> L.
<i>Capsella bursa-pastoris</i> (L.) Medik.
<i>Raphanus sativus</i> L.
<i>Rapistrum rugosum</i> (L.) All.
Convolvulaceae
<i>Convolvulus arvensis</i> L.
Fabaceae
<i>Galega officinalis</i> L.
<i>Medicago lupulina</i> L.
<i>Medicago sativa</i> L.
<i>Trifolium repens</i> L.
Fumariaceae
<i>Fumaria capreolata</i> L.
Geraniaceae
<i>Geranium molle</i> L.
Martyniaceae
<i>Ibicella lutea</i> (Lindl.) Van Eselt.
Polygonaceae
<i>Rumex</i> sp.

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The overall abundance of delphacids was lower in the crop cycle 2008–2009 than in the other crop cycles (Figure 5). Weather features such as a noticeable lack of rains (data not shown) during the first months of the culture cycle were detrimental for insect populations. Cixiidae had an increase in population levels, coincidentally with the presence of dicots in the surrounding weeds. Predominance of the two cixiid species (*Cixiosoma* sp. and *O. dimidiatus*) was recorded where *Taraxacum officinale*, *Cirsium vulgare* (Asteraceae), *Convolvulus arvensis* (Convolvulaceae),

*Raphanus sativus* (Brassicaceae) and, to a lesser extent, *Cynodon dactylon* were dominant. By contrast, low numbers of delphacids were registered during this crop cycle.

### Sex ratios and association with host plants

There was 1:1 sex ratio among the three most abundant species sampled in the rice plots. In the surrounding weed parcels, there was an equal sex proportion for *D. kuscheli*, males of *C. haywardi* were more abundant than females, whereas the opposite was observed in *T. propinqua* (Table 4). On the other hand, we corroborate that there was a dependence between the abundance of the three delphacid species and the host plant (either rice or weeds) ( $\chi^2 = 47.942$ , 2 df,  $p = 3.89 \times 10^{-11}$ ). *Chionomus haywardi* was more abundant in the rice plots than in weeds, in contrast to *T. propinqua*, whose abundance was higher in weeds. The difference between abundance of *D. kuscheli* in rice and weeds was non-significant, thus the association of this species with rice is similar to the association with weeds (Table 5).

### Parasitism

Individuals of *C. haywardi*, *D. kuscheli*, *T. propinqua*, and *O. dimidiatus* were parasitized by the Strepsiptera *Elenchus tenuicornis* (Kirby). A single individual of the later host species was found parasitized; accordingly, it was excluded from further analysis. Parasitism was 7% (114/1561) for *C. haywardi*, 7% (4/59) for *D. kuscheli*, and 13% (24/180) for *T. propinqua*. Presence of parasites was detected in December, January, and February of all years, except for December 2006. There was a direct relationship between the number of parasitized individuals and the total abundance of Delphacidae (Figure 6). This association followed the following linear regression equation: number of parasitized individuals =  $1 + 0.0928$  (total number of individuals) ( $R^2_{\text{adj}} = 0.445$ ,  $n = 48$ ,  $p < 0.05$ ). There were no significant differences amongst mean prevalence (percentage) of parasitized Fulgoromorpha sampled in rice plots and in weeds (rice,  $\bar{X} = 68.65\%$ ; weeds,  $\bar{X} = 45.82\%$ ; two-tailed *t*-test,  $t = 1.17$ , 12 df,  $p = 0.263$ ), neither there were significant differences between mean prevalence (percentage) among species (*C. haywardi*,  $\bar{X} = 30.6\%$ ; *T. propinqua*,  $\bar{X} = 75.6\%$ ; *D. kuscheli*,  $\bar{X} = 36.5\%$ ) (ANOVA on transformed data;  $F = 3.17$ ; 2, 44 df;  $p = 0.052$ ).

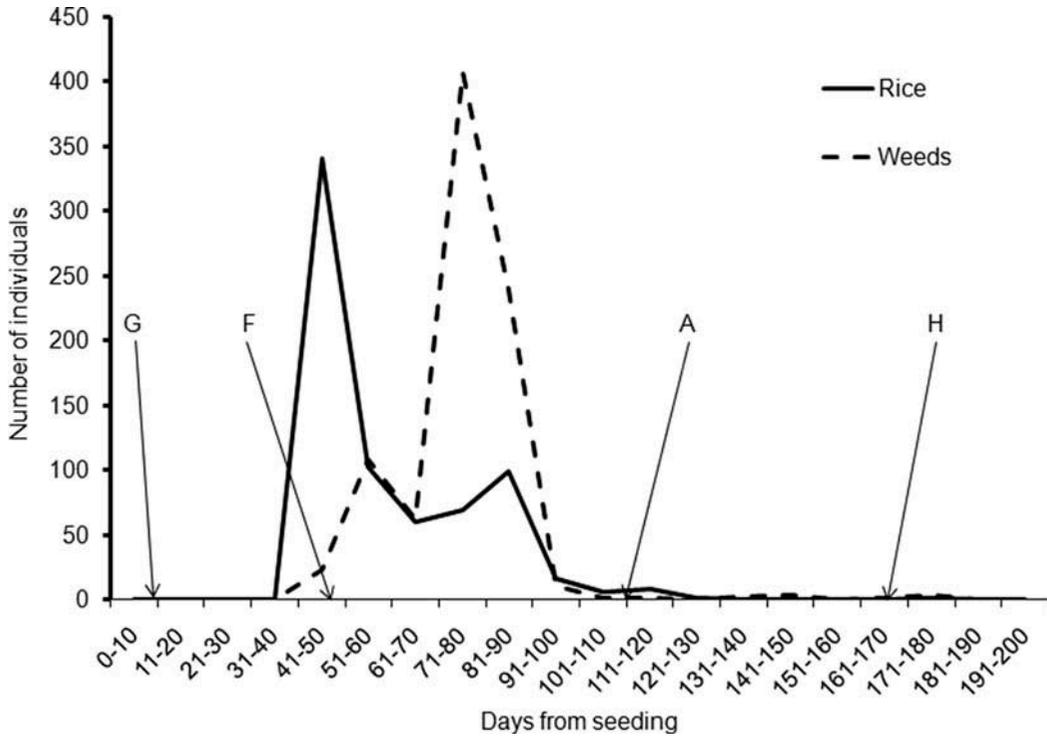


Figure 2. Population fluctuation of *Chionomus haywardi* in rice plots and surrounding weeds in the “Julio Hirschhorn” experimental station, La Plata, Buenos Aires between 2006 and 2010. Arrows show the moments of germination (G), flooding (F), anthesis (A) and harvest (H) of rice. Day 0 corresponds to the date of seeding.

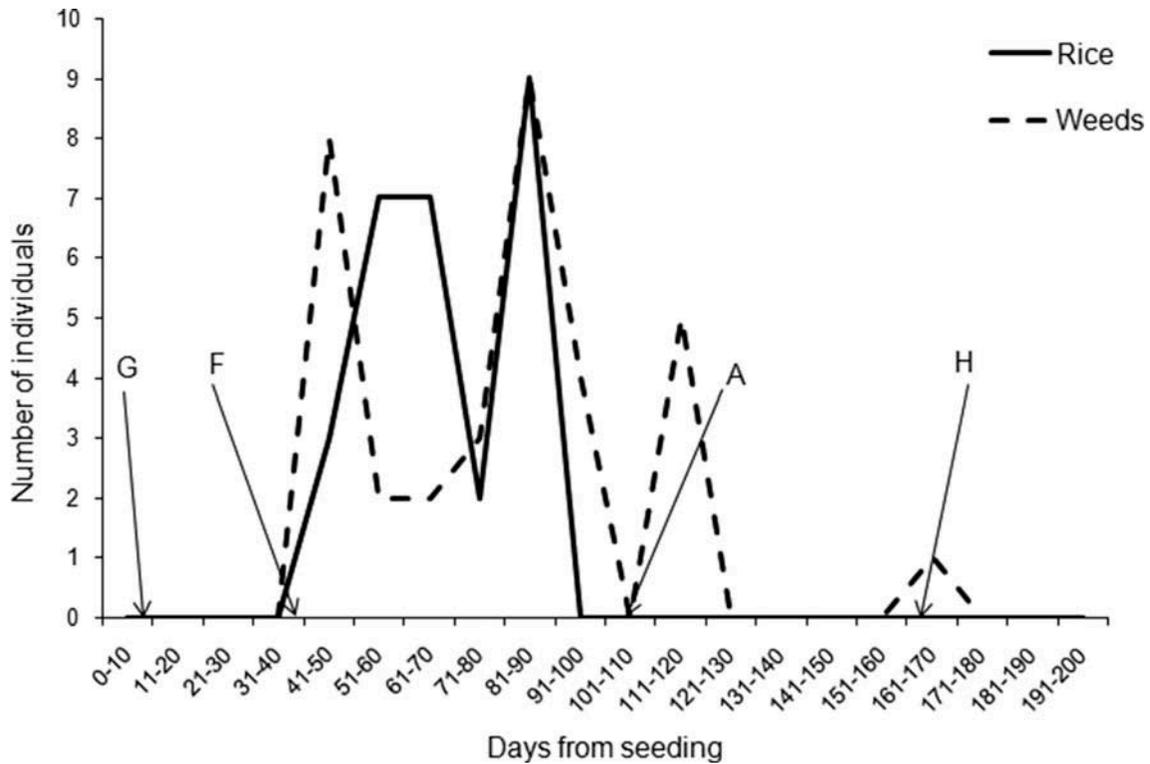


Figure 3. Population fluctuation of *Toya propinqua* in rice plots and surrounding weeds in the “Julio Hirschhorn” experimental station, La Plata, Buenos Aires between 2006 and 2010. Arrows show the moments of germination (G), flooding (F), anthesis (A) and harvest (H) of rice. Day 0 corresponds to the date of seeding.

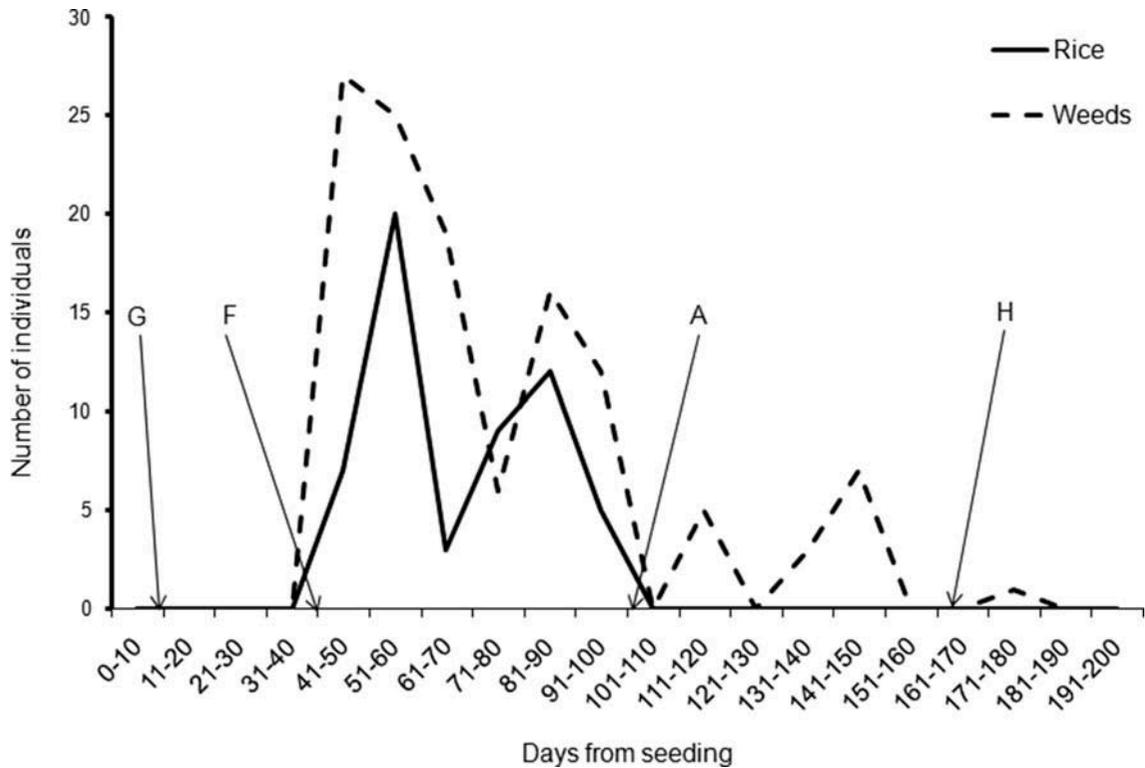


Figure 4. Population fluctuation of *Delphacodes kuscheli* in rice plots and surrounding weeds in the “Julio Hirschhorn” experimental station, La Plata, Buenos Aires between 2006 and 2010. Arrows show the moments of germination (G), flooding (F), anthesis (A) and harvest (H) of rice. Day 0 corresponds to the date of seeding.

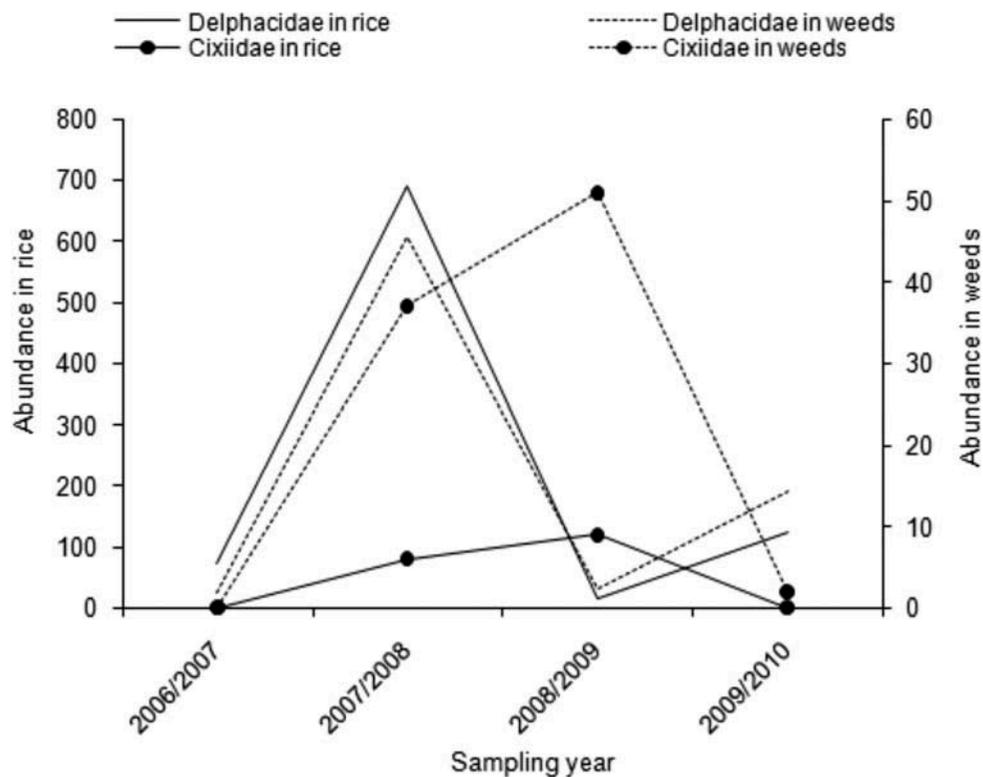


Figure 5. Abundance of Delphacidae and Cixiidae in rice plots and surrounding weeds in the “Julio Hirschhorn” experimental station, La Plata, Buenos Aires between 2006 and 2010.

Table 4. Results of  $\chi^2$  tests for an equal relation between sexes in *Chionomus haywardi*, *Toya propinqua* and *Delphacodes kuscheli*. Numbers of males and females ( $n$ ) show total caught for each species in crop lots and surrounding weeds along crop cycles from 2006 to 2010.

Host plant	Species	$n$ males (%)	$n$ females (%)	$\chi^2$	$p$
Rice	<i>C. haywardi</i>	432 (50)	427 (50)	0.029	0.86
	<i>T. propinqua</i>	25 (43)	33 (57)	1.103	0.29
	<i>D. kuscheli</i>	9 (36)	16 (54)	1.962	0.16
Weeds	<i>C. haywardi</i>	428 (58)	315 (42)	17.186	$3 \times 10^{-5}$
	<i>T. propinqua</i>	50 (35)	94 (65)	12.25	$5 \times 10^{-4}$
	<i>D. kuscheli</i>	15 (37.5)	25 (62.5)	3.103	0.08

Table 5. Results of  $\chi^2$  tests for non-differences between abundances ( $n$ ) of *Chionomus haywardi*, *Delphacodes kuscheli* and *Toya propinqua* among host plants. Numbers of each species show total caught in rice lots and in surrounding weeds along crop cycles from 2006 to 2010.

Species	$n$ in rice	$n$ in weeds	$\chi^2$	$p$
<i>C. haywardi</i>	859	743	8.40	0.004
<i>T. propinqua</i>	58	144	36.61	$1.4 \times 10^{-9}$
<i>D. kuscheli</i>	25	40	3.06	0.080

## Discussion

### Diversity of planthoppers

Fourteen species from three families of Fulgoromorpha were associated with rice in Argentina, most of them native species for this region. Among the species of Fulgoromorpha recorded worldwide on rice, only the cosmopolitan *T.*

*propinqua* and the Neotropical *T. orizicolus* were registered in this study (Wilson & Claridge 1991).

### Seasonal dynamics and association with host plants

The seasonal registers showed the prevalence of macropterous adults both in rice crops and in the weeds, together with the virtual absence of immature stages. We infer that the populations sampled encompass mainly colonizing individuals that were previously present in sectors neighboring the system and are able to reach the sampled plants from some unknown distance. In this case, there would be more opportunities for pathogens to be transmitted amongst different plant species. In this sense, the presence of *C. haywardi* is significant, as it was dominant during all sampling years in the rice agroecosystem, including in the nearby weeds. It is important to

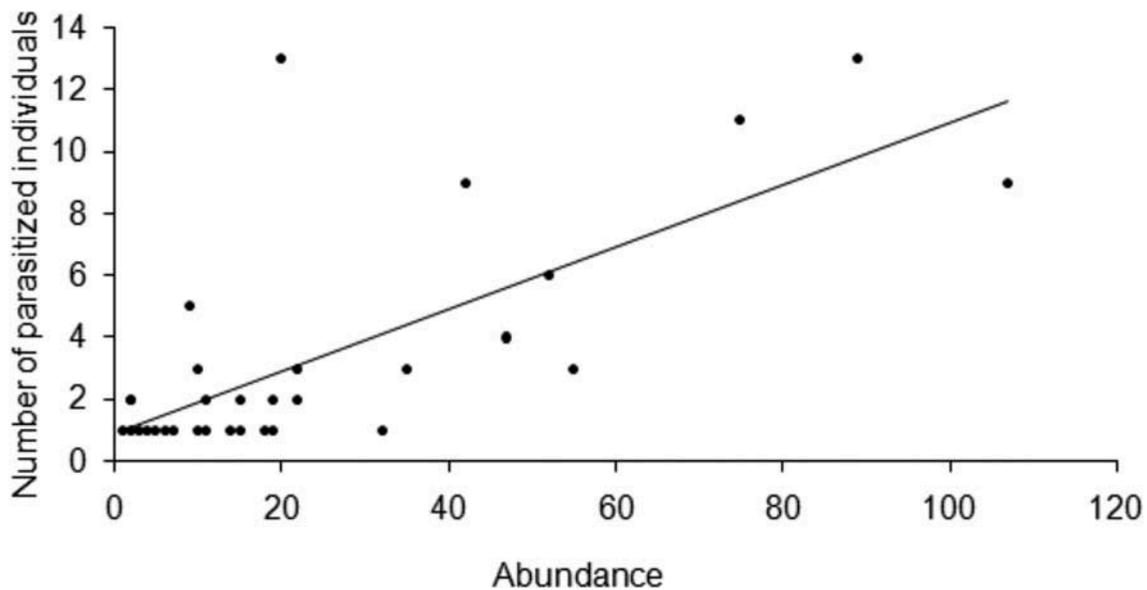


Figure 6. Relation between abundance of total Delphacidae caught between 2006 and 2010, and total number of parasitized individuals.

highlight its capacity as vector of MRCV to several cultivated gramineous and weeds (Velázquez et al. 2003). It would be desirable to know whether *C. haywardi* would have more opportunities to act as a vector of viruses in those crops where *T. propinqua* and *D. kuscheli* are not the most frequent species, which may be true for the rice-growing areas between latitudes between 36 and 39°S.

The only previous work on temporal variation in *C. haywardi* density was conducted on wheat (Remes Lenicov & Virla 1993). Our results cannot be compared with these authors because they sampled planthoppers of wheat along a single growing season. Their samples were taken during winter and early spring (from July to November). Nevertheless, both works suggest that the activity of *C. haywardi* is continuous at least up to end of summer (between July and April) at the latitude of La Plata, using different crops as hosts throughout the year. On both wheat and rice, abundance was high at the first stages of development of plants (September and December, respectively), which are primarily colonized by macropterous adults. Ripening stages are coincident with a decrease in abundance of *C. haywardi* on the crops and an increase on weeds. Accordingly, a displacement from cultivated plants to spontaneous plants would follow decay in the nutritional quality of the crop. In an experiment under laboratory conditions, Virla & Maragliano (1993) showed that *C. haywardi* prefers to feed and oviposit on *C. dactylon* before wheat, *Bromus unioloides*, maize, oat, and rye. These observations suggest that *C. haywardi* exploits rice when paddies concentrate more high quality resources than other hosts, and that population peaks on weeds would occur after rice decline. Furthermore, our chi-square tests indicated that males were more abundant on weeds than on rice, and that a positive association of the species with rice does exist, which could indicate that females prefer to oviposit on rice. Therefore, females may find in rice plants an appropriate host to fulfill their life cycle. Such preference of females for oviposition on rice should be confirmed by direct evidence, for example quantifying eggs on rice or through measures of reproductive status of females. In Argentina, the Pampas region (Cabrera & Willink 1980) is the area where rice is intensively grown (southern Entre Ríos province); it has been observed that *C. haywardi* colonizes the crops and was also the prevalent species on rice (A. M. M. de Remes Lenicov, pers. obs.). In view of this, this planthopper deserves thorough studies about its interactions with this host plant.

*Toya propinqua* was more frequent on weeds, with females being more abundant than males on these plants. This agrees with the knowledge that this

planthopper develops in wild plants rather than in cultivated graminaceous plants, e.g. rice, on which they occasionally feed or rest. More individuals of *T. propinqua* were sampled on non-cropped strips around lots where the dominant plants were grasses and, to a lesser extent, dicots. These are the natural hosts for the species (Remes Lenicov et al. 1999).

Seasonality of *D. kuscheli* was similar to that of *C. haywardi*, with a bimodal fluctuation curve, but the association with rice seems weak. Grilli & Gorla (1997) found a seasonal pattern in Córdoba (temperate Argentina) for populations sampled on and near maize, characterized by an increase in density from October until a peak during December, then decreasing and disappearing in May. As they later pointed out (Grilli & Gorla 1999), *D. kuscheli* has high dispersal ability. Hence the species can easily switch between patches of spontaneous or cultivated vegetation, explaining in part such weak association.

A noteworthy situation for the Fulgoromorpha array was observed in the 2008–2009 crop cycle (Figure 5). During this particular period, remarkably high numbers of Cixiidae and Flatidae were recorded, mainly on weeds, while at the same time members of Delphacidae displayed low densities both in rice and weeds. In fact, if *C. haywardi* and *T. propinqua* are excluded and the four sampling years are considered, the members of Cixiidae were the most abundant species in the list for rice and weeds together. But such high abundance of this family was recorded only for the exceptional conditions of the 2008–2009 crop cycle. We suspect an environmental effect on insect densities because there was a noticeable shortage of humidity as a consequence of scarce rains during spring 2008 and summer 2009. This paucity of precipitation caused a change in the specific composition of the spontaneous vegetation. Under such circumstances, members of Cixiidae would be less affected by dryness owing to their underground habits.

Weeds may play an important role in the rice fields because they contribute to increasing the biodiversity of the agroecosystem. Our methodology did not allow the establishment of a differential abundance of planthoppers on each weed species because we did not attempt to quantify number of planthoppers on individual plants or species. Still, our results suggest that weeds can act as a source of some damaging insect species for rice (*T. propinqua* and *D. kuscheli*), or as an alternative microhabitat instead of rice for others (*C. haywardi*). In this case, elimination of weeds in rice fields could reduce significantly the number of harmful insect species on rice. We highlight the preference of some of the mentioned delphacid species for Poaceae and Cyperaceae

(Wilson et al. 1994), particularly of *C. haywardi* for *C. dactylon* (Maragliano & Virla 1992). The list of weed species given in Table 3 is not the same as weeds associated with rice fields in Corrientes province (Lovato Echeverría et al. 2013) in spite of the similarity of planthopper diversity observed in rice producing areas (Remes Lenicov pers. obs.). Thus, our list can be viewed as a complement of those given by Lovato Echeverría et al. (2013) for a more southern location.

### Parasitism

The only recorded species of parasitoid, the strepsipteran *E. tenuicornis*, showed no preference for any of the planthoppers, as was expected. Remes Lenicov et al. (1991) described the relationships between *E. tenuicornis* and *D. kuscheli*, and *T. propinqua* and *T. argentinensis* from maize, oat and weeds from Córdoba province, Argentina. They estimated that this parasitoid can regulate population levels of *D. kuscheli*, which was the most abundant planthopper in the agroecosystem analyzed by them. As in our study *C. haywardi* was dominant instead of *D. kuscheli* and it was the most parasitized species among delphacids, such regulation by parasitism would be likely also for *C. haywardi*.

As we have shown, *C. haywardi* turned out to be the most important species in the rice agroecosystem from a sampling station in La Plata. Its role as a vector of pathogens is unknown for rice. Thus, thorough studies about its biology should complement the present study, mainly about life history strategies, which were not covered in the present work. Similarly, research about whole communities living on important crops will gather information about natural enemies of planthoppers. Since several species of this group are known as vectors of viral and phytoplasma diseases (Remes Lenicov & Paradell 2012) in the most important agricultural area of Argentina, further work on the epidemiologic importance of the vectors in the rice agroecosystem of the country is worth carrying out.

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