Harmonia axyridis: a threat to Brazilian Coccinellidae?[1]

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ABSTRACT. *Harmonia axyridis*: a threat to Brazilian Coccinellidae? *Harmonia axyridis* (Pallas) (Coleoptera, Coccinellidae) is a polyphagous Asian species, well-known as a classical biological control agent of aphids around the world, introduced probably accidentally in Brazil, sampled for the first time in 2002. It is an important intraguild predator, competing for food with native coccinellids. It was studied *H. axyridis* alimentary sources and host plants, its abundance compared with native and established species, the influence of abiotic factors and the seasons over the abundance of *H. axyridis* throughout one year, and discussed the mechanisms which influence the displacement of species. *Harmonia axyridis* was found in 38 plant species, among them 20 were new records, feeding on 20 aphid species, eight of them new alimentary records. Between 2006/2007, eight Coccinellidae species were collected and *H. axyridis* was the most abundant (91.23%). *Harmonia axyridis* peak of abundance occurred in August and September 2007, probably influenced by the temperature and food availability. From 1999 to 2007 a reduction and variation in the diversity of collected species of Coccinellidae were observed with the predominance of *H. axyridis*, which may indicate their displacement.

KEYWORDS. Aphididae; intraguild predation; invasive species; native species.

RESUMO. *Harmonia axyridis*: uma ameaça aos Coccinellidae brasileiros? *Harmonia axyridis* (Pallas) (Coleoptera, Coccinellidae) é uma espécie asiática, polífaga e reconhecida como agente de controle biológico de afídeos pelo mundo, provavelmente introduzida acidentalmente no Brasil, coletada pela primeira vez em 2002. É um importante predador intraguilda, pois compete por alimento com as espécies nativas de coccinelídeos. Foram estudadas as fontes alimentares de *H. axyridis* e suas plantas hospedeiras, sua abundância em relação às espécies nativas e estabelecidas, a influência dos fatores abióticos e as estações do ano sobre sua abundância durante um ano e discutidos os mecanismos que influenciam no deslocamento das espécies nativas de Coccinellidae. Além disso, foi testada a influência dos fatores abióticos e as estações do ano sobre sua abundância durante um ano. *Harmonia axyridis* foi encontrada em 38 espécies de plantas, sendo 20 delas novos registros, alimentando-se de 20 espécies de afídeos, oito novos registros alimentares. Entre os anos de 2006/2007, oito espécies de Coccinellidae foram coletadas e *H. axyridis* foi a mais abundante (91,23%). O pico de abundância de *H. axyridis* ocorreu em agosto e setembro de 2007, provavelmente influenciado pela temperatura e disponibilidade de alimento. Entre 1999 e 2007, foram observadas a redução e variação na diversidade de espécies de Coccinellidae coletadas, com a predominância de *H. axyridis*, o que pode indicar o desalojamento destas espécies.

PALAVRAS-CHAVE. Aphididae; espécie invasora; espécie nativa; predação intraguilda.

Harmonia axyridis (Pallas, 1773) is an Asiatic polyphagous coccinellid. Its original distribution extended from the southern of Siberia (Altai Mountains) to Manchuria, Korea, Japan and China (Tan 1946). *H. axyridis* has been used successfully as a biological control agent of aphids around the world (Koch 2003). However, it may cause impacts on non-target arthropods through intraguild predation and losses in grape and wine production (Koch & Galvan 2008).

In the United States, the multicolored Asian lady beetle was introduced as a biological control agent at different periods of time: California in 1916, 1964 and 1965; Washington between 1978-1982; New Scotland, Connecticut, Georgia, Louisiana, Maryland, Washington D.C., Delaware, Maine, Mississippi, Ohio, Pennsylvania and North Carolina between 1978-1981 (Gordon 1985). Since the establishment of the first population, which occurred only in 1988 (Chapin & Brou 1991), there has been successful control for some aphid species, such as *Aphis spiraecola* Patch, 1914 on apple orchards (Brown & Miller 1998).

Harmonia axyridis was also introduced as a biological control agent in several European countries (Brown *et al.* 2008). In Belgium, *H. axyridis* has been used for biological control since 1997. However, after 2001, when the first reports of *H. axyridis* were done in the wild, in Ghent, the number of observations increased in cities, anthropogenic sites, and in (semi-)natural habitats such as forests and meadows (Adriaens *et al.* 2003). According to Brown *et al.* (2008), “over a very short time period *H. axyridis* is likely to become one of the most widely distributed coccinellids in Europe”.

In the late 1990’s, *H. axyridis* was first introduced in South

America in Mendoza Province, Argentina, to control aphids of peach culture (Saini 2004). In 2002, it was first detected in Curitiba, Paraná State, Brazil, probably accidently introduced, feeding on *Tinocallis kahawaluokalani* (Kirkaldy, 1907), (Drepanosiphinae) in crape myrtle, *Lagerstroemia indica* L. (Lythraceae) and in young *Pinus* spp. (Pinaceae), feeding on *Cinara atlantica* (Wilson, 1919) and *Cinara pinivora* (Wilson, 1919) (Lachninae) (Almeida & Silva 2002). Recently, occasional appearances of *H. axyridis* were reported in Chile (González 2006) and Peru (González & Vandenberg 2007).

About the establishment of *H. axyridis* in the South American continent, Koch *et al.* (2006) suggest that large areas are likely to become adequate habitats because of the similar climatic conditions with its native countries and the same kind of biomes. Also the prey availability must not be a limiting factor to its establishment in the region, as it is capable to disseminate by flying and also by other means linked to human activities. According to the "Climex" distribution model, *H. axyridis* has the potential to establish in several countries in Latin America. Besides Brazil and Argentina, possible localities for its occupations are Paraguay, Uruguay, Chile, Venezuela, Colombia, Ecuador, Peru and Bolivia (Poutsma *et al.* 2008).

As an invasive species, *H. axyridis* may cause negative impacts, including the displacement of natural native enemies and the suppression or extinction of non-target prey species (Elliot *et al.* 1996). In the United States, this species was observed competing with *Coleomegilla maculata* DeGeer, 1775, an important native predator that feeds on many aphid species, as well as other arthropods and insect eggs (Hodek & Honek 1996). In Brazil, *H. axyridis* has been monitored in the field and may compete with *Cycloneda sanguinea* (Linnaeus, 1763), the main aphidophagous native species.

Considering the worldwide status and effects of *H. axyridis*, it is of great importance to know its behavioral characteristics in Brazil, and determine the dominant species in a Coccinellidae community. This study focuses on *H. axyridis* alimentary sources and host plants and on changes in the abundance and diversity of native and established ladybird species before and after the introduction of *H. axyridis* in Curitiba, Brazil. Furthermore, an investigation was carried out, testing the influence of abiotic factors and the temporal variation (season) on the abundance of *H. axyridis* throughout one year (2006/2007).

MATERIAL AND METHODS

Harmonia axyridis alimentary sources and host plants. These relations were based on the co-occurrence of *H. axyridis* (as egg, larvae and pupae) and aphids on the same plant. From August 2005 to November 2007 plant species were examined and sampled with aphids and adults of *H. axyridis*. Every week, samplings were done manually with a beating tray and a trimmer, in Curitiba and surrounding cities, like Araucaria [Latitude 25º35'35''S; Longitude 49º24'37''W]; and Quatro Barras [Latitude 25°23'30"S; Longitude 49°07'30"W]. The ladybirds were brought to the laboratory and included in Coleção de Entomologia Pe. J. S. Moure of the Department Zoology, (UFPR). Aphids were fixed in ethanol 70%, mounted on microscope slides for identification and included in the insect collection of the Centro de Diagnóstico Marcos Enrietti, in Curitiba.

Sampling of the Coccinellidae community before and after the report of *Harmonia axyridis*. Between October/1999 – September/2000 and September/2001 – August/2002 Coccinellidae exploratory samplings were done in an approximately 5.300 m² area located in the Capão do Tigre field, Curitiba, State of Paraná (25°26'50'' - 25°27'33''S and 49°14'16'' - 49°14'33''W) and between October/2006 and September/2007, new samplings were also done in this area. Capão do Tigre has 15.24 ha and it is located at 900m above sea level. The climate of the region is subtropical mesothermic humid with cool summers, frequent frosts during winter and no dry season, classified as Cfb according to Köppen's classification (Köppen 1948). The annual average temperatures in hot and cold months are below 22°C and 18°C, respectively, and the annual average temperature is 17°C. The annual averages of relative atmospheric humidity and precipitation are 85% and 1,300 to 1,500mm, respectively. The study area is characterized by the presence of secondary forest with predominance of ferns in areas previously occupied by *Araucaria angustifolia* (Bertol.) O. Kuntze (Maack 1981), though *Pinus* sp. and *Baccharis* spp. currently predominate in the area.

Both first (1999/2002) and second sampling periods (2006/2007) were done weekly, for one-hour. Every plant (mainly *Pinus* spp. and *Baccharis* spp.) of the area was examined and coccinellids were sampled manually. From 1999 to 2002, samplings aimed to detect only the local coccinellid species present in the area. However on the second period, plants, aphids and coccinellids were collected. The occurrence and abundance of species in the area during both periods were compared, and possible interferences in the local fauna, influenced by the introduction of *H. axyridis,* were analyzed.

Statistical analysis. Data about temperature, precipitation and relative humidity, from 2006/2007, were obtained daily by Instituto Tecnológico (SIMEPAR-UFPR), in Curitiba.

To test the effects of abiotic factors on patterns of abundance variation of *H. axyridis* a simple linear regression analysis was used, using mensal average abundance and average of abiotic factors. The Kolmorogov-Smirnov test was done to ascertain the normality of the data.

To test for temporal variation in abundance of *H. axyridis* between seasons a one-way ANOVA were used with season and abundance as fixed factors. A posteriori test (tukey HSD) was done to evaluate which groups differ. All statistical analysis was performed with Statistica 5.5 (StatSoft Inc. 2000).

The period that composes seasons in 2006 and 2007 were considered as follows: spring (September 23 - December 20), summer (December 21 - March 19), fall (March 20 - June 20) and winter (June 21 - September 22).

RESULTS

Harmonia axyridis alimentary sources and host plants. From August 2005 to November 2007, *H. axyridis* was sampled feeding on 20 aphid species and on 38 plant species of 18 families (Table I). There were eight new records of aphid used as prey: *Aphis coreopsidis* (Thomas, 1878), *Brachycaudus helichrysi* (Kaltenbach, 1843), *Essigella californica* (Essig, 1909), *Hyperomyzus lactucae* (Linnaeus, 1758), *Macrosiphoniella yomogifoliae* (Shinji, 1924), *Neophyllaphis podocarpini* Carrillo, 1980, *Neotoxoptera formosana* (Takahashi, 1921) and *Uroleucom sonchi* (Linnaeus, 1767) and one Psyllidae, *Triozoida* sp. in *Psidium guajava* L. (Table I).

During the entire experimental period adults, eggs and larvae of *H. axyridis* co-occurred, except in *Chrysanthemum leucanthemum* L., *Duranta repens* L., *Foeniculum vulgare* Miller, *Hipochoeris radicata* L., *Psidium guajava* L., *Rosa* sp., *Schefflera arboricola* (Hayata) Merr., *Tabebuia* sp. and *Tipuana tipu* (Benth.) Kuntze, in which only adults were observed.

All life stages of *H. axyridis* were found on plants with some kind of prey, except on *Cucurbita pepo* var. *melopepo*, *Cucumis sativus* L., *Abelmoschus esculentus* (L.) Moench, *Cucumis melo* L., *Zea mays* L., *Odontonema strictum* Kuntze, *Tabebuia chrysotricha* (Mart. Ex Dc.) Standl and *Sechium edule* Swartz (Table II).

The data obtained with this study (Table I) and in the literature (Koch *et al.* 2006) sum up approximately 77 prey species, found on 83 plants species in 35 families, of which Asteraceae, Pinaceae, Fabaceae and Rosaceae have the largest numbers of tritrophic relations (*H. axyridis* x prey x host) (Table I).

Sampling of the Coccinellidae community before and after *Harmonia axyridis* introduction. After *H. axyridis* introduction, five species were not found anymore and there was a change in the dominant species in the Capão do Tigre area (Table III).

Between 1999/2002, the following Coccinellidae species were sampled: *Cycloneda pulchella* (Klug, 1829), *Cycloneda sanguinea* (L., 1763), *Curinus coeruleus* (Mulsant, 1850), *Eriopsis connexa* (Germar, 1824), *H. axyridis*, *Hippodamia convergens* Guérin-Méneville, 1842, *Hyperaspis festiva* Mulsant, 1850, *Scymnus* sp., *Olla v-nigrum* (Mulsant, 1866), *Psyllobora gratiosa* Mader, 1958 and *Rodolia cardinalis* (Mulsant, 1850). Nine species of Coccinellidae among 539 specimens were recorded between October/1999 – September/2000, before the introduction of *H. axyridis*: *C. sanguinea* (58%); *H. convergens* (20.59%); *Scymnus* sp. (9.65%); *P. gratiosa* (4.82%); *E. connexa* (2.97%); *C. pulchella* (1.85%); *O. v-nigrum* (1.48%); *H. festiva* (0.18%); *R. cardinalis* (0.37%).

Between September 2001 and August 2002, 586 specimens of eight species were found and *C. sanguinea* was the dominant species (84.98%), followed by *H. axyridis* (10.24%); *O. v-nigrum* (1.71%); *H. convergens* (10.24%), *E. connexa* (0.85%); *C. coeruleus* (0.68%); *Scymnus* sp. (0.34%) and *Cycloneda ocelligera* (Crotch, 1874) (0.17%) (Table III).

Between October 2006 and September 2007, 1,038 ladybirds of eight species were collected. In this period, *H. axyridis* was more abundant (91.23%) than all native and/or established species. These species were: *O. v-nigrum* (3.08%), *C. sanguinea* (2.02%), *Coccidophilus citricola* Bréthes, 1905 (1.83%), *Scymnus* sp. (0.96%), *H. convergens* (0.48%), *C. pulchella* (0.29%) and *C. coeruleus* (0.10%) (Table III, IV). *Harmonia axyridis*, *O. v-nigrum, C. sanguinea, C. citricola*, *Scymnus* sp. and *H. convergens* were collected in *Pinus* spp. with the aphids: *C. atlantica, C. pinivora* and *E. californica*. *Harmonia axyridis, C. pulchella*, *C. coeruleus, C. sanguinea* and *H. convergens* were collected in *Baccharis* sp.1 and sp.2 with *A. spiraecola* Patch, 1914, and in *Baccharis* sp.1 with unidentified scales (Coccidae). In *Baccharis* sp.3, only *H. axyridis* and scales were observed.

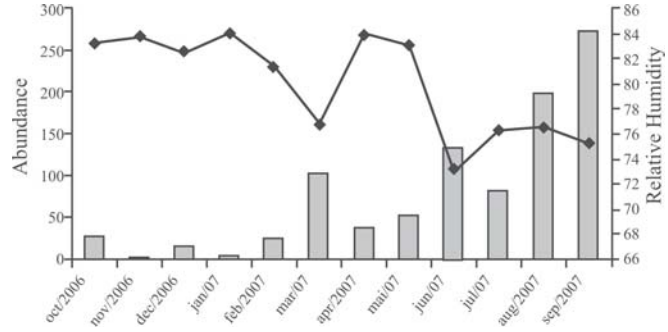

Fig. 1. Relation between fluctuation of *Harmonia axyridis* (Pallas) and relative humidity in the Capão do Tigre, Curitiba, Paraná, Brazil. Period – October, 2006 to September, 2007.

Comparison of monthly abundance of *Harmonia axyridis*. The mean abundance of *H. axyrids* was 23.4 ± 32.49 individuals (mean ± sd), which indicates an aggregated distribution trough seasons. The highest abundance of *H. axyridis* occurred between August and September 2007, with a decrease in November, December 2006 and January 2007 and a small increase in March and June 2007 (Fig. 1).

Since all life stages were found throughout the period of 2006/2007, *H. axyridis* was considered multivoltine in Curitiba. The linear regression analysis showed that the abundance of *H. axyridis* is significantly related to the temperatures ($F_{2,9}$ = 14,978 p<0.00137, R^2=0.7176; values of mean and maximum temperatures p=0.0004, p=0.0006, respectively). The ANOVA revealed that the abundance of *H. axyridis* per season was significantly different ($F_{3,36}$ = 4.7950, p=0.0065) with the number of *H. axyridis* captured during the winter significantly higher when compared with the fall (p=0.03915) and the spring (p=0.01027).

DISCUSSION

Harmonia. axyridis alimentary sources and host plants. Hodek & Honek (1996) indicated that the observation of mutual occurrence of coccinellids and prey insects in a given plant does not necessarily indicate a prey-predator relationship. However, *H. axyridis* lays eggs before or in the highest

Table I. Host plants and prey associated with *Harmonia axyridis*. Complementing Koch *et al*. (2006). * New tritrophic relation; + New host plant registered; º New prey registered; E Eggs; L Larvae; P Pupae; A Adult;

Host plants - Families	obs.	Preys	Life stages
Apiaceae			
Foeniculum vulgare Miller	* +	*Aphis fabae* Scopoli	A
Araliaceae			
Schefflera arboricola (Hayata) Merr.	* +	*Aphis* sp.	A
Asteraceae			
Baccharis sp.1	* +	*Aphis spiraecola* Patch; Coccidae	E, L, P, A
Baccharis sp.2	* +	*Aphis spiraecola* Patch	A
Baccharis sp.3	+	Coccidae	L, A
	* + º	*Aphis coreopsidis* (Thomas);	L, A
Bidens pilosa L.	* + º	*Uroleucon sonchi* (Linnaeus);	A
	* + º	*Hyperomyzus lactucae* (Linnaeus)	A
Bidens sulphurea (Cav.) Sch. Bip.	* + º	*Macrosiphoniella yomogifoliae* (Shinji)	L, A
Chrysanthemum leucanthemum L.	* + º	*Brachycaudus helichrysi* (Kaltenbach)	A
Helianthus annuus L.	* +	*Aphis fabae* Scopoli	E, A
Hipochoeris radicata L.	* +	*Uroleucon ambrosiae* (Thomas)	A
Lactuca sativa L.		*Uroleucon ambrosiae* (Thomas);	L, A
	* + º	*Uroleucom sonchi* (Linnaeus)	L, A
Sonchus oleraceus L.	* + º	*Uroleucom sonchi* (Linnaeus)	E, L, P, A
Bignoniaceae			
Tabebuia sp.	* +	Nimphs of Psyllidae	A
Brassicaceae			
Brassica oleracea L. var. *italica*	* +	*Myzus persicae* (Sulzer);*Lipaphis erysimi* (Kaltenbach)	P
Brassica oleraceae L. var. *capitata*	* +	*Brevicoryne brassicae* (Linnaeus)	L
Brassica oleraceae L. var. *leucocephala*	* +	*Brevicoryne brassicae* (Linnaeus)	E, A
Spartium junceum L.	* +	*Aphis craccivora* (Koch)	E, A
Fabaceae			
Tipuana tipu (Benth.)Kuntze	* +	Psyllidae	A
Liliaceae			
Allium schoenoprasum L.	* + º	*Neotoxoptera formosana* (Takahashi)	E, L, A
Lythraceae			
Lafoensia pacari L.	* +	Psyllidae	E, L, P, A
Lagerstroemia indica L.	*	*Toxoptera aurantii* (Boyer de Fonscolombe)	E, P, A
Malvaceae			
Hibiscus rosa sinensis L.	* +	Nimphs of *Toxoptera* sp.; *Aphis* sp.	E, A
Myrtaceae			
Myrciaria cauliflora (Mart.) O. Berg	+	Larvae of Curculionidae	L, P, A
Psidium guajava L.	* + º	*Triozoida* sp.	A
Pinaceae			
Pinus sp.		*Cinara pinivora* (Wilson); *Cinara atlantica* (Wilson);	E, L, P, A
	* º	*Essigella californica* (Essig)	
Podocarpaceae			
Podocarpus sp.	º	*Neophyllaphis podocarpini* Carrilo	E, A
Rosaceae			
Rosa sp.		*Macrosiphum rosae* (Linnaeus)	A
Rutaceae			
Citrus limon L.		*Toxoptera citricida* (Kirkaldy)	E, L, P, A
Citrus sinensis L.		Aphididae	E, L, P, A
Citrus reticulata L.		Aphididae	E, L, P, A
Verbenaceae			
Duranta repens L.	+	Coccidae	A

population level of aphids on a plant (Hironori & Katsuhiro 1997; Osawa 2000). Consequently, the presence of *H. axyridis* eggs, larvae and pupae in plants with aphids was considered an indication of these coccinellids' development, establishing a prey-predator relation, as they co-inhabit the same host.

In Curitiba, *H. axyridis* was collected together with several prey species (aphids, scales, psyllids) that it may use as food sources, but in some plants there were no alimentary sources available (Table II). However, since larvae and pupae were present in these hosts, some kind of food source has been supposedly there.

Only adults were collected and no food sources were found

Table II. Correlation between the life stages of *H. axyridis* and its host plants found without alimentary sources, collected in Curitiba, Brazil. Period – August 2005 to November 2007.

Coccinellidae				Host Plant
egg	larvae	pupae	adult	
	x			*Cucurbita pepo* var. *melopepo* - Cucurbitaceae
	x		x	*Cucumis sativus L.* - Cucurbitaceae
	x		x	*Abelmoschus esculentus* (L.) Moench - Malvaceae
	x		x	*Cucumis melo* L. - Cucurbitaceae
			x	*Zea mays* L. - Poaceae
			x	*Odontonema strictum* Kuntze - Acanthaceae
x		x	x	*Tabebuia chrysotricha* (Mart. Ex Dc.) Standl. - Bignoniaceae
	x	x		*Sechium edule* Swartz - Cucurbitaceae

in *Zea mays* L.. Nevertheless, *H. axyridis* has already been found in corn, regularly laying eggs and feeding on *Rhopalosiphum maidis* (Fitch, 1856) (Musser & Shelton 2003). Likewise, *Aphis gossypii* Glover, 1877, has already been captured in *Tabebuia chrysotricha* (Mart. ex DC.) Standl. (Peronti & Souza-Silva 2002), *Sechium edule* Swartz (Neupane *et al.* 2006), *Cucumis sativus* L. (Steenis & El-Khawass 1995), *Cucumis melo* L. (Kingler *et al.* 1998) and *Abelmoschus esculentus* (L.) Moench (Leite *et al.* 2007).

Harmonia axyridis was present even when the quantity of aphids was very low in Capão do Tigre area, meaning that it may consumed other food sources. Aphids' replacement by other plant origin products, such as nectar and pollen, may work as alternative food when preys are scarce, reducing mortality and maintaining the Coccinellidae population abundant (Hodek & Honek 1996).

In the lack of aphids *H. axyridis* may feed on different kinds of prey such as on Tetranichidae (Lucas *et al.* 1997), Psyllidae (Michaud 2004), Coccoidea (McClure 1986), Curculionidae (Stuart *et al.* 2002) and Lepidoptera (Koch *et al.* 2003), plant material, damaged fruits (Koch *et al.* 2004), nectar and pollen (LaMana & Miller 1996), which allows a complete development for *H. axyridis* (Berkvens *et al.* 2008).

Comparison of monthly abundance of *Harmonia axyridis*. The linear regression analysis showed that the abundance of *H. axyridis* is related to the temperature. This relationship could be caused by the dependence of *H. axyridis* development on the temperature.

The development of *H. axyridis* immature stages occurs at temperatures that range between 13.2ºC and 23.3ºC. In short days when mean temperatures are lower than 12ºC, *H. axyridis* does not reproduce, and that at temperatures above 23ºC, it changes or prevents eggs incubation and larval development (Ongagna *et al.* 1993). Under laboratory conditions, *H. axyridis* completed its life cycle in 20 days at a temperature that ranged from 20.2 ºC to 25.8ºC (Saini 2004). Throughout the sampling period, the mean temperature reached 22.9ºC, indicating that the south region of Brazil allows *H. axyridis* development.

Harmonia axyridis has at least three generations per year in Curitiba, two in Oregon, United States (LaMana & Miller 1996) and in Antibes, France (Ongagna *et al.* 1993), four generations in Athens, Greece (Katsoyannos *et al.* 1997), and in Japan, its native region, two to three generations (Osawa 1993). The number of generations in Brazil may be higher in locations where temperatures are milder during the winter.

In addition to climatic factors, Coccinellidae development also depends on food quality (Dixon 2000). Osawa (2000), in Japan, concluded that *H. axyridis* life cycle overlaps with the aphids', and that seasonal changes in the number of specimens sampled varied according to the number of aphids available. In Santa Maria (RS), the abundance of Coccinellidae sampled in *Citrus* spp. also varied according to food availability in the field (Arioli & Link 1987). Therefore, in Curitiba, the winter may have provided a greater quantity and quality of food if compared with the other seasons, explaining the high number of individuals captured in this season. There was a great mean deviation in the abundance of *H. axyridis* collected per week, which is probably related to the availability of alimentary sources in the area.

Between 2006/2007, *H. axyridis* was captured in plants infested with four aphid species, especially *C. atlantica* and *C. pinivora*, and one species of Coccidae. In southern Brazil, the highest level of *Cinara* spp. population occurs in cold months, when mean temperatures are approximately 15ºC (Cardoso & Lazzari 2003). This aphid might have been *H. axyridis* main prey during the winter. On the other hand, *A. spiraecola* found on *Baccharis* spp. (Table I) develops in temperatures between 20ºC and 30ºC (Wang & Tsai 2000) and might have been *H. axyridis* food source in spring and summer.

Currently occurring species of Coccinellidae in the Capão do Tigre area and *Harmonia axyridis* introduction in Brazil. Coccinellidae has not been systematic sampled in Brazil and the few systematic samplings are composed by an annual inventory of Coleoptera in Vila Velha, State of Paraná, in which Coccinellidae was the eighth most sampled family (Ganho & Marinoni 2005); and samples made in the city of Santa Maria, State of Rio Grande do Sul (RS), in 1985 and 1986, in which 23 species were captured in orchards of *Citrus* spp. (Arioli & Link 1987).

In Capão do Tigre, 13 Coccinellidae species have been sampled since 1999 (Table III) and five (*P. gratiosa, E. connexa,*

Table III. Relation between species and abundance of Coccinellidae specimens in different periods of sampling: 1999-2002 and 2006-2007, in Capão do Tigre, Curitiba, Paraná, Brazil.

Coccinellidae species	Sep.99 - Sep.00	Rel. Freq.	Sep.01 - Aug.02	Rel. Freq.	Oct.06 - Sep.07	Rel. Freq.
Harmonia axyridis	0		60	10.24%	947	91.23%
Olla v-nigrum	8	1.48%	10	1.71%	32	3.08%
Cycloneda sanguinea	313	58.07%	498	84.98%	21	2.02%
Coccidophilus citricola	0		0		19	1.83%
Scymnus sp.	52	9.65%	2	0.34%	10	0.96%
Hippodamia convergens	111	20.59%	6	1.02%	5	0.48%
Cycloneda pulchella	10	1.85%	0		3	0.29%
Curinus coeruleus	0		4	0.68%	1	0.09%
Psyllobora gratiosa	26	4.82%	0		0	
Eriopis connexa	16	2.97%	5	0.85%	0	
Rodolia cardinalis	2	0.37%	0		0	
Hyperaspis festiva	1	0.18%	0		0	
Cycloneda ocelligera	0		1	0.17%	0	
Total	539	99.98%	586	99.99%	1038	99.98%

R. cardinalis, H. festiva and *C. ocelligera*) were not collected after *H. axyridis* introduction. However, *C. citricola* was found for the first time in the 2006/2007 period and *O. v-nigrum* was more abundant after *H. axyridis* introduction. According to Dixon (2000) some species are more likely to meet and interact than others, because there might be an overlap of habitat preferences. Because *C. citricola* and *O. v-nigrum* feed on secondary food sources (coccids and psyllids), they may occupy different habitats on the plant when compared to *H. axyridis*, minimizing the dietary overlap.

In contrast, *H. convergens* explores the same food source as *H. axyridis,* and its relative frequency changed from 20.59% in prior to the introduction to 0.48% after the introduction.

Before *H. axyridis* detection (1999/2000), the main species were: *C. sanguinea* (58.07%), *H. convergens* (20.59%) and *Scymnus* sp. (9.65%); between 2001/2002, the abundance of *C. sanguinea* was 84.98% and *H. axyridis* 10.24%; in 2006/2007, *H. axyridis* dominated the Coccinellidae community with 91.23% and *C. sanguinea* with just 2.02% of the coccinellids collected.

The displacement of native Coccinellidae species after the introduction of *H. axyrids* has been already reported in the literature, particularly for *C. sanguinea* . In Argentina, Buenos Aires, the abundance of predatory species of the aphid *Monellia caryella* (Fitch, 1855) in pecan varied from 2001/2002 to 2003/2004. *H. axyridis* ranged from 51% to 74% and the native *C. sanguinea* from 20% to 13%, whereas *O. v-nigrum*, *E. connexa*, *Coccinella quadrifasciata* (Schoenherr, 1808) and *Adalia bipunctata* (Linnaeus, 1758) were less representative during all this period (Saini 2004).

In Brazil, Ponta Grossa, Paraná State, the relative frequencies of *H. axyridis* population in orchard trees (lemon, orange, apple, pear and peach trees) between two sampling periods were significantly different, varying from 0.20 to 0.67, from one year to the other (Milléo *et al.* 2008).

A significant decrease in *C. sanguinea* relative abundance and an increase in *H. axyridis* also occurred in United States, Florida (Michaud 2002). In Michigan the species *Brachiacantha ursina* (Fabricius, 1787), *Cycloneda munda* (Say, 1835) and *Chilocorus stigma* (Say, 1835), were apparently affected by the presence of *H. axyridis* (Colunga-Garcia & Gage 1998).

It is possible to suggest explanations for the dominance of *H. axyridis* in the Coccinellidae guild and the displacement of ladybird species based on different authors and specific methodologies, such as the intraguild predation (IGP) (Cottrell 2005; Yasuda *et al.* 2001, Kajita *et al.* 2006), *H. axyridis* aggressiveness (Yasuda *et al.* 2001), and the competition for food (Evans 2000). Regarding the aggressiveness and IGP, in Japan, 80% of *Coccinella septempunctata* (L., 1758) larvae were eaten by *H. axyridis* fourth instar larvae, while the opposite rarely occurred (Yasuda *et al.* 2001). *A. bipunctata* was always the IGP prey and never a predator against *H. axyridis*, which significantly decreases its survival (Kajita *et al.* 2006).

Regarding the competition for food, the high aphid consumption of *H. axyridis* and consequently lower density of alimentary sources availability in an area has already been reported. The displacement of native species in alfalfa fields, in the United States, happened because the exotic species *C. septempunctata* consumed and consequently caused a reduction on the alimentary sources. Native species were forced to change their habitat to where there were more aphids available (Evans 2000). A substantial reduction on the abundance of aphid prey after the establishment of *H. axyridis* in potato crops Maine, United States was also noted (Alyokhin & Sewell 2004).

It is currently known that biological invasions induce large impacts on the environment and are ecological threats in their new ecosystems (Pimentel *et al.* 2001). However, because Coccinellidae numbers varied considerably from year to year in a 12-years study at Blairstown, United States, long-term researches of at least 10 years are required to correctly identify population trends (Day & Tatman 2006).

Table IV. Number of Coccinellidae species sampled in Capão do Tigre, Curitiba, Paraná, Brazil. Period – October 2006 to September 2007.

Species of Coccinellidae	Oct/06	Nov	Dec	Jan/07	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Total	%
Harmonia axyridis	28	2	15	3	24	103	36	52	133	81	197	273	947	91.23
Hippodamia convergens				1	2						1	1	5	0.48
Cycloneda sanguinea					3	6	6	3	2		1		21	2.02
Olla v-nigrum	3				2			1			24	2	32	3.08
Cycloneda pulchella	1		1					1					3	0.29
Curinus coeruleus	1												1	0.10
Scymnus sp.			3					7					10	0.96
Coccidophilus citricola								3	16				19	1.83
Total													1038	100%

The longest long-term study with a ladybird community has 31 years and was performed in northern Maine, United States (Alyokhin & Sewell 2004). It revealed changes in the coccinellid community inhabiting potato crops. Before 1980, two native species *Coccinella transversoguttata* Fald, 1835, and *Hippodamia tredecimpunctata* (L. 1758) comprised the coccinellid communities, but in 1995 and 1996, exotic species *H. axyridis* and *Propylea quatuordecimpunctata* (L. 1758) became prominent members. Their invasion was followed by a significant decline in the abundance of native species and a significant increase in the overall diversity of ladybird community.

Besides negative impacts on native species, other effects, caused by *H. axyridis,* are discussed by some authors, especially in the United States. Recently in Minnesota, *H. axyridis* was seen eating damaged fruits, like pumpkins, apples, grapes, and raspberries (Koch *et al.* 2004). In vineyards *H. axyridis* gathers in clusters of grapes causing issues in wine production, altering its flavor with the presence of alkaloids (Pickering *et al.* 2004). In colder periods, *H. axyridis* invades households searching for shelter and also may be found on food and beverages (Knodel & Hoebeke 1996). In some people, the direct contact with the insects triggers allergic reactions, provoking symptoms, such as rhinitis, conjunctivitis, chronic cough and asthma (Yarbrough *et al.* 1999).

Features considered advantageous in biological control such as the capacity for self replication, the fast population increase, and the high dispersion, raise the likelihood of unexpected ecological effects. After the exotic species proliferation, a pressure to control them emerges, stimulating the need to understand biological control and ecological effects, and also a need for a scientific monitoring in order to measure and foresee possible impacts (Louda *et al.* 2003). Considering *H. axyridis*, there is no available method to diminish its population densities and restrict its impacts over native coccinellids (Kenis *et al.* 2008).

In Brazil, *H. axyridis* was sampled for the first time in 2002 in the city of Curitiba. A survey revealed at least 20 aphid species used as alimentary sources. In 2009, seven years after its introduction, *H. axyridis* is already present in the city of Brasilia, more than 1,000 km far from Curitiba indicating a high dispersal capability. In Capão do Tigre area, *H. axyridis* dominates the Coccinellidae community summing up to 90% of the species sampled. The most abundant species of the area in 1999/2000, *C. sanguinea* and *H. convergens*, were strongly affected by the presence of *H. axyridis*, summing in 2006/2007 less than 3% of the Coccinellidae community. Considering this scenario, future studies should focus on *H. axyridis* sampling methods and monitoring, and on experimental investigations on the interaction between *H. axyrids* and native Coccinellidae species, because little is known about the ecological roles of *H. axyridis* and its potential to compete and displace native Coccinellidae species in South America.

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