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Surveys for ladybirds (Coleoptera: Coccinellidae) in Switzerland and confirmation of the presence of the invasive alien ladybird species, *Harmonia axyridis* (Pallas)

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Surveys were carried out in Switzerland in 2005 and 2006 to make observations on the indigenous ladybird community and to monitor the presence of the harlequin ladybird, *Harmonia axyridis* Pallas, an Asian species presently invading Europe. Ladybirds were collected by beating the branches of trees and shrubs, sweeping grasslands and using black-light traps. Twenty-nine species were found, mainly through beating branches and sweeping grasslands. *H. axyridis* was not found in 2005. In 2006 its presence was recorded in ten cantons and it was particularly abundant in the region of Basel.

INTRODUCTION

Harmonia axyridis (Pallas) (Coleoptera: Coccinellidae), the harlequin ladybird, or multicoloured Asian ladybeetle, is native to East Asia and has been released in the 20th century in Europe and North America as biological control agent against aphids in greenhouses, outdoor crops and orchards (Babendreier 2007). In North America, the first established population was found in 1988 and the species has now spread to most of the USA and southern Canada (Koch 2003). In Europe, established populations were detected in Germany in 1999 (Tolasch 2002) and in Belgium in 2001 (Adriaens *et al.* 2003). Since then, the beetle has also been found in the Netherlands, France, the UK, Luxemburg and Austria (Majerus *et al.* 2006; Rabitsch & Schuh 2006). A single specimen was found in 2004 in the Botanical Garden of Basel at an exhibition of Asian plants (Klausnitzer 2004), but it was not clear whether the species was already established in Switzerland.

In North America, the establishment of this successful invader has led to nuisances for humans, such as massive aggregations of overwintering adults in buildings in autumn and damage to houses as a result (Huelsman *et al.* 2002). Adults may also aggregate on grapes and reduce wine quality when they are pressed with the grapes (Pickering *et al.* 2006). In addition, *H. axyridis* is strongly suspected to negatively affect populations of the native ladybird community and other aphidophagous species, either indirectly through competition for resources such as aphids, or, when not enough aphids are present, directly through inter-specific larval predation (Obrycki *et al.* 1998; Michaud 2002; Bazzocchi *et al.* 2004). Laboratory studies have shown that *H. axyridis* is intrinsically a superior competitor compared to a number of coccinellid species (e.g. Burgio *et al.* 2002), some native to Switzerland. Despite numerous laboratory studies, the impact of *H. axyridis* on

native ladybird communities is not well documented (Koch 2003; Babendreier 2007). In North America, the abundance of several native ladybirds has declined in agricultural environments since the arrival of *H. axyridis* (Brown & Miller 1998; Colunga-Garcia & Gage 1998; Alyokhin & Sewell 2004). In another study, the abundance of some species declined, but the overall effect on the native ladybird community was negligible (Brown 2003). Very limited information is available on the potential impact of *H. axyridis* on ladybird species which are not commonly observed in agricultural settings.

The expected arrival of *H. axyridis* offers the opportunity to study its impact on the native ladybird fauna (Majerus & Roy 2005). However, to assess changes in the native ladybird community after the arrival of *H. axyridis*, the native community needs to have been studied before. Although Coccinellidae have been abundantly studied in Europe (Hodek 1973; Klausnitzer & Klausnitzer 1997), in Switzerland they have rarely, if ever, been the target of specific field studies. According to the unpublished list of the Swiss Center of Fauna Mapping (CSCF), based partly on museum specimens and unpublished observations, 91 coccinellid species can potentially be found in Switzerland. However, the last published list of coccinellids is found in Lucht (1987), who mentions only 58 species in northern Switzerland.

We report here the results of surveys carried out in 2005 and 2006 to record the composition of the native ladybird community of northern Switzerland before the establishment of *H. axyridis*, and to monitor for the presence and distribution of *H. axyridis* in this country.

MATERIAL AND METHODS

In 2005, adults of Coccinellidae were sampled regularly at seven locations along the Swiss-German border. Fluorescent light traps were set up at each of the seven locations. Each trap consisted of a blacklight fluorescent tube (Sylvania blacklight blue 12 V, 15 W), surrounded by four baffles (15 x 50 cm) and protected by a cover against rain. The light in the traps was switched on and off by automatic timers. The energy for each trap was provided by a sealed lead battery. When beetles hit the baffles, they fall down into collection containers with an insecticide to prevent escape of the trapped insects. Moth paper from Gesal (COMPO Jardin AG, Allschwil) or Finito (Mislin and Balthasar AG, Hochdorf) (4 % Chlorpyrivos) was placed in the container. Additionally, the containers were sprayed with Baygon (SC Johnson AG, Dietikon), an insecticide against crawling insects. Five of these traps were positioned at 1 to 9 km from the border of Germany, in Wil (canton Zürich), Etzwil (canton Aargau), Schupfart (canton Aargau), Olsberg (canton Aargau) and Aesch (canton Basel-Landschaft). In addition, one trap was positioned in Kestenholz (32 km south of Basel) and one at ART Reckenholz-Tänikon Research Station in Affoltern close to Zürich. The traps were attached to the lower branches of apple or cherry trees except the one in Etzwil, which was fixed on a three-legged aluminium stand. Meadows, hedges, fruit trees and forests were present at each location. In addition, arable crop fields occurred near the traps in Etzwil, Olsberg and Kestenholz, while the trap in Wil was situated close to a vineyard. Trap locations were selected to minimize the influence of other light sources on the attraction of the blacklight of the traps. Traps were active three nights a week from May to June and from Mid-August to October. Between 1 July and 15 August, the traps were active

only for one night per week which was chosen freely. Batteries were recharged after each night that the traps had been active.

Grassland habitats surrounding the sites of the light trap were sampled weekly from July to October by sweeping for ten minutes with a net of 41 cm diameter. At the same sites and dates, trees were sampled during ten minutes by beating the branches sharply with a stick while holding a 45 x 60 cm beating tray underneath to collect the falling adult coccinellids.

In addition to the repeated samplings at these seven sites, the ladybird communities of grassland and tree-and-shrub sites were sampled twice by net sweeping and beating branches between early July and the beginning of October in four additional geographical regions close to the Swiss borders in the North-East (canton Thurgau), in the canton of Ticino in the South and between Yverdon and Geneva in the West. Two more collections were made in more central parts of Switzerland (cantons Zürich and Schwyz). Sampling effort was between 140 minutes and 306 minutes for each of the eight sampling dates. The adult coccinellid beetles collected were put into vials and frozen for later determination.

In 2006, surveys for ladybirds were carried out between May and September. Over 100 grassland and more than 225 tree-and-shrub sites were sampled once at over 240 locations in the cantons Aargau, Basel-Landschaft, Basel-Stadt, Bern, Jura, Schaffhausen, Solothurn, St. Gallen, Thurgau and Zürich. Approximately half of the sites were located in the cantons Basel-Landschaft, Basel-Stadt and Jura. Additionally, surveys specifically aimed at collecting *H. axyridis* were carried out in May–October, 2006, in the Cantons Bern, Geneva, Lucerne and Neuchâtel at about 50 locations, during which native species were not sampled. Grassland sites were sampled by sweeping 30 times through the vegetation on a transect of 30 m with a 60 cm-diameter sweep net. At each grassland site, two transects were sampled. Tree-and-shrub sites were sampled by beating all branches up to a height of 3.5 m along a 50 m long forest edge or both sides of a hedge with a stick and collecting beetles that fell down into a white, rectangular 90 x 125 cm umbrella. At each site, adult ladybirds were determined to species and released after the sampling of the site was completed.

Identification of adults was made using Zahradnik (1985), Klausnitzer & Klausnitzer (1997) and Baugnée & Branquart (2000). In 2005, all Coccinellidae were considered. In 2006, since the specimens were identified on-site, only «true» ladybirds, i.e. those belonging to the subfamilies Chilocorinae, Coccinellinae and Epilachninae were surveyed, because they are easier to identify in the field than the small Coccidulinae and Scymninae (Baugnée & Branquart 2000). Larvae were not identified, except those of *H. axyridis* and the native *Harmonia quadripunctata* (Pontoppidan), which are easily separated from any other coccinellid.

To obtain additional data on the distribution of *H. axyridis* in Switzerland, an e-mail survey was carried out by sending sampling recommendations and an identification sheet to amateur and professional entomologists and zoologists in Switzerland. Responses were collated until late November and added to our own observations on the distribution of *H. axyridis*.

Tab. 1. Number of adult coccinellids per species caught in 2005 by sweeping grassland and herbaceous vegetation, beating branches of trees and using fluorescent-light traps.

	Beating trees/shrubs	Sweeping meadows	Light trap	Total
Adalia bipunctata (L.)	2	3	1	6
Adalia decempunctata (L.)	3	1	1	5
Aphidecta obliterata (L.)	1	0	2	3
Calvia decemguttata (L.)	0	1	1	2
Coccinella quinquepunctata L.	0	1	0	1
Coccinella septempunctata L.	6	145	4	155
Exochomus quadripustulatus (L.)	2	0	0	2
Halyzia sedecimguttata (L.)	2	2	2	6
Hippodamia septemmaculata (De Geer)	0	2	0	2
Hippodamia tredecimpunctata (L.)	0	25	0	25
Hippodamia variegata (Goeze)	0	240	0	240
Myrrha octodecimguttata (L.)	0	0	1	1
Myzia oblongoguttata (L.)	0	0	1	1
Oenopia conglobata (L.)	0	1	0	1
Propylea quatuordecimpunctata (L.)	15	275	3	293
Psyllobora vigintiduopunctata (L.)	8	77	0	85
Scymnus abietis (Paykull)	23	0	23	46
Scymnus frontalis (F.)	0	1	0	1
Scymnus sp.	0	2	0	2
Scymnus nr. *frontalis* (F.)	0	0	1	1
Subcoccinella vigintiquatuorpunctata (L.)	0	40	0	40
Tytthaspis sedecimpunctata (L.)	0	153	0	153
Vibidia duodecimguttata (Poda)	1	0	0	1
Total adults	63	969	40	1072

RESULTS AND DISCUSSION

Indigenous ladybirds

Twenty-seven identified coccinellid species and two unidentified species belonging to the genus Scymnus were collected during the surveys (Tabs 1 and 2). In 2005, 90.4 % of 1072 beetles were collected by sweeping grasslands and herbaceous vegetation, and only 40 beetles (3.7 %) were caught in the fluorescent light traps (Tab. 1). This suggests that although fluorescent light traps have been effectively used to detect the presence or absence of *H. axyridis* in North America (Hesler *et al.* 2004), it is not a suitable method to catch most native species. Therefore, no light traps were used in the 2006 survey. In 2006, 74.4 % of the total 1847 adults were caught by beating trees and shrubs, the rest by sweeping (Tab. 2).

The most abundant species in both years was *Propylea quatuordecimpunctata* (L.). This species was found in all regions, and with all three sampling methods. Other abundant species found by beating trees and shrubs were *Adalia bipunctata* (L.), *Adalia decempunctata* (L.), *Calvia quatuordecimguttata* (L.) and *Exochomus*

Tab. 2. Number of individuals of coccinellids per species caught in 2006 by sweeping grassland and beating branches of trees. Larvae of *Harmonia axyridis* and *H. quadripunctata* were counted together because they can easily be confounded.

	Beating trees/shrubs	Sweeping meadows	Total
Adalia bipunctata (L.)	331	2	333
Adalia decempunctata (L.)	283	1	284
Anatis ocellata (L.)	1	1	2
Calvia quatuordecimguttata (L.)	98	2	100
Coccinella quinquepunctata L.	1	0	1
Coccinella septempunctata L.	38	29	67
Epilachna argus (Geoffroy in Fourcroy)	3	0	3
Exochomus quadripustulatus (L.)	73	1	74
Halyzia sedecimguttata (L.)	44	0	44
Harmonia quadripunctata (Pontoppidan)	19	0	19
Harmonia axyridis (Pallas)	45	0	45
Hippodamia variegata (Goeze)	2	7	9
Platynaspis luteorubra (Goeze)	20	6	26
Propylea quatuordecimpunctata (L.)	370	144	514
Psyllobora vigintiduopunctata (L.)	46	19	65
Subcoccinella vigintiquatuorpunctata (L.)	1	20	21
Tytthaspis sedecimpunctata (L.)	0	240	240
Total adults	1375	472	1847
Larvae *Harmonia* spp.	50	0	50
Larvae other species	209	50	259
Total larvae	259	50	309

quadripustulatus (L.). *Tytthaspis sedecimpunctata* (L.), *Hippodamia variegata* (Goeze) and *Subcoccinella vigintiquatuorpunctata* (L.) were also abundant but found nearly exclusively by sweeping grasslands, whereas sizeable numbers of *Coccinella septempumctata* L. and *Psyllobora vigintiduopunctata* (L.) were collected in grasslands as well as on trees and shrubs. Light traps caught four species not obtained using the two other methods, i.e. *Myrrha octodecimguttata* (L.), *Myzia oblongoguttata* (L.). *Scymnus abietis* (Paykull), and *Scymnus* nr. *frontalis* (F.). However, these species, which are usually found in conifer forests and not in the habitats we studied, were not properly sampled in this study.

All species collected during this study were already recorded from northern Switzerland (Lucht 1987). It would be interesting to know whether we found endangered species but, unfortunately, ladybirds are very poorly known in Switzerland and, as a consequence, the red list of Switzerland does not include coccinellids. Three of the species collected in this study are in the red list of Bavaria (Schmidl & Esser 2003): *Halyzia sedecimguttata* (L.), *Hippodamia septemmaculata* (De Geer) and *Vibidia duodecimguttata* (Poda).

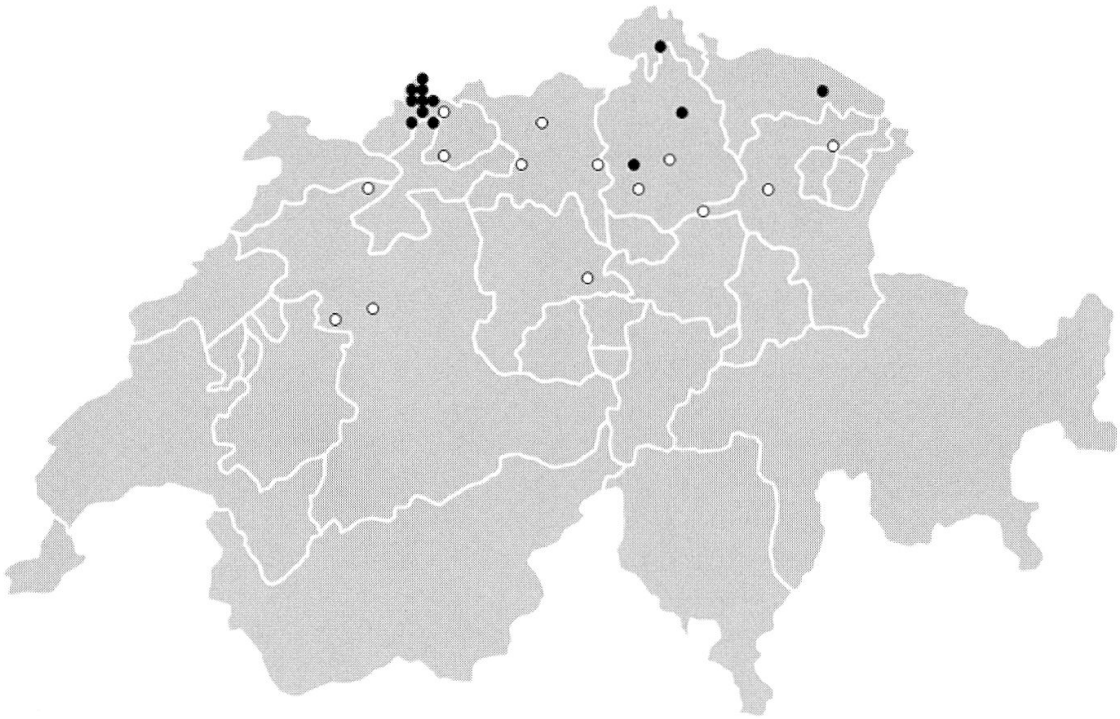

Fig. 1. Distribution of *Harmonia axyridis* in Switzerland in 2006. Solid circles indicate locations where *H. axyridis* was found in the authors' survey, open circles indicate locations where correspondents to a mailing survey observed *H. axyridis*.

Harmonia axyridis

H. axyridis was not found in our 2005 surveys. It was first collected in May 2006 in Riehen (Basel-Stadt), and intensified samplings in the Basel region between May and August resulted in the finding of over 100 adults and larvae, all collected by beating trees and shrubs (Fig 1). Further samples in other cantons as well as records provided by our correspondents revealed that *H. axyridis* is already present in 10 cantons and probably widespread in northern Switzerland. The locations where *H. axyridis* was observed in 2006 were:

Basel (canton Basel-Stadt, > 100 individuals from May to October, own observations)
Oberzeihen (canton Aargau, 2 ind., Oct., obs. M. Keller)
Unterentfelden (canton Aargau, 1 ind., Oct., obs. M. Bollinger)
Widen (canton Aargau, 1 ind., Nov., obs. B. Schelbert)
Riehen (canton Basel-Stadt, 15 ind., May–June, own obs.)
Aesch (canton Basel-Landschaft, 2 ind., July, own obs.)
Birsfelden (canton Basel-Landschaft, 8 ind., July, own obs.)
Liestal (canton Basel-Landschaft, 2 ind., Oct., obs. E. Born)
Muttenz (canton Basel-Landschaft, 13 ind., June–Sept., own obs.)
Oberer Hauenstein (canton Basel-Landschaft, 1 ind., Oct., obs. E. Born)
Pratteln (canton Basel-Landschaft, 2 ind., July, own obs.)
Bern (canton Bern, 1 ind., Nov. obs. J. Grosjean/C. Germann)
Moutier (canton Bern, 1, ind. Oct. obs. J.C. Gerber)
Neuenegg (canton Bern, 1 ind., Oct, obs. D. Al Jabaji)
Luzern (canton Luzern, 1 ind., Oct., own obs.)
Rapperswil-Jona (canton St. Gallen, more than 20 ind., Oct., obs. P. Rindlisbacher)
St. Gallen (canton St. Gallen, 3 ind., Oct., obs. W. Heinzelmann)

Wattwil (canton St. Gallen, 1 ind., Oct., obs, U. Rindlisbacher)
Schaffhausen (canton St. Gallen, 4 ind., July, own obs.)
Nuglar (canton Solothurn, 7 ind., July, own obs.)
Amriswil (canton Thurgau, 1 ind., July, own obs.)
Adliswil (canton Zürich, 1 ind., Oct., obs. B. Wermelinger)
Winterthur (canton Zürich, 1 ind., July, own obs.)
Zurich (canton Zürich, 3 ind., June–Nov., own obs.)

Most individuals of *H. axyridis* were found in city centres and other densely populated areas, mostly on broadleaved trees and shrubs but also in buildings in autumn. Overall, *H. axyridis* was the 7th most abundant species, and in Basel it was the most abundant species at some sites. In autumn, a first case of aggregation was reported on a house in Basel (observation K. Ellenberger-Fankhauser).

The results of the current survey suggest that in Switzerland, the invasion is still at an early stage. Considering the rate of spread, and the rapid increase in abundance of *H. axyridis* in other regions such as Belgium (Adriaens *et al.* 2004) and Michigan, USA (Colunga-Garcia & Gage 1998), we may expect to find the beetle in most of Switzerland within a few years. In parallel to the increasing abundance, it is likely that this generalist species will become established in a wider variety of habitat types. It is difficult to predict what the impact on the native ladybird community and other aphidophagous insects will be in Switzerland, but it may be expected that the abundance of some native ladybirds will decrease, as observed in North America (Brown & Mills 1998; Colunga-Garcia & Gage 1998; Brown 2003; Alyokhin & Sewell 2004). Continuing surveys of *H. axyridis* and native coccinellids at the sites investigated during this study, as well as at new sites in other habitats (e.g. conifer forests) will allow us to describe native beetle populations before the arrival of *H. axyridis* using data collected during several years, and assess the impact of *H. axyridis* on the native ladybird community once the species has become established.

H. axyridis is not only one of the many alien species that have invaded Switzerland in recent years (Kenis 2005); it is also the first case in Europe of a biological control agent turning into a nuisance. Considering its polyphagy and climatic requirements in its region of origin, it must be expected that the beetle will become permanently established in Switzerland and other European countries. Although such cases are rather rare worldwide, it emphasises the need for a proper risk assessment prior to the introduction of an exotic biological control agent.

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