

## **SEASONAL OCCURRENCE AND EXPERIENCES WITH THE INVASIVE INSECTS: *HALYOMORPHA HALYS* (HEMIPTERA: PENTATOMIDAE), *LEPTOGLOSSUS* *OCCIDENTALIS* (HEMIPTERA: COREIDAE), *HARMONIA* *AXYRIDIS* (COLEOPTERA: COCCINELLIDAE), AND *CYDALIMA PERSPECTALIS* (LEPIDOPTERA: CRAMBIDAE) IN SWITZERLAND**

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**Abstract** The invasive species brown marmorated stink bug, western conifer seed bug, harlequin ladybird and box tree moth all appeared in Switzerland within the last 10 years. While the first three species use buildings to over-winter and are a nuisance to home owners in autumn and spring when they enter or leave the buildings, the latter species is a pest of box elder trees and appears mainly from May to September with massive damage to the shrubs. The Urban Pest Advisory Service (UPAS) collects data through people's complaints, mainly from the city of Zurich, but partly also from a larger area of the country. In this paper we present the collected data of UPAS and other institutions over the years since the appearance of these species, show the different influences on occurrence and discuss the declining inquiries. We also show what measures people have taken and which preventive or control measures are successful.

**Key words** Alien species, Brown marmorated stink bug, Western conifer seed bug, Multicolored Asian lady beetle, Harlequin ladybird, Box tree moth

### **INTRODUCTION**

Foreign plants and animals are invading new areas all over the world. Increasing mobility by plane, ship and train and especially increasing worldwide trade with faster transport ways are mainly contributing to the import and establishment of many foreign plants and animals (Ludwig, 2010). Not all species establish at their introduction. The ones that do and that reproduce strongly and show negative impacts on their environment are defined as invasive species (Nentwig, 2011). The Urban Pest Advisory Service (UPAS) of Zurich has already encountered quite a few invasive species, mainly tropical ants and lately mosquitoes like *Aedes japonicus* (Theobald, 1901) and *Aedes albopictus* (Skuse, 1894), but more and more also other species that can become an annoyance to people.

The brown marmorated stink bug, *Halyomorpha halys* (Stål, 1855), the western conifer seed bug, *Leptoglossus occidentalis* (Heidemann, 1910), the harlequin ladybird, *Harmonia axyridis* (Pallas, 1771) are considered a nuisance to people because they aggregate in buildings when seeking hibernation sites in autumn. The fourth invasive species, the box tree moth, *Cydalima perspectalis* (Walker, 1859), is a horticultural pest. *H. halys* is indigenous to Asia (eastern China, Japan, Korea and Taiwan) and was recorded in 2001 for the first time outside its native range in Allentown, Pennsylvania, USA (Bernon, 2004). This bug is highly polyphagous with more than 100 host plants recorded (Wermelinger et al. 2008; Haye et al. 2014a; CABI datasheet) and is now recognized as serious pest of pome and stone fruit (Bernon, 2004).

The origin of *L. occidentalis* is the west coast of the USA. It was first found in the north Italian province Vicenza in 1999 (Bernardinelli and Zandigiaco, 2001). Most probably it was displaced to Europe in containers or in wood shipments (Werner, 2011). According to Rabitsch (2005; 2010) multiple introductions and secondary translocations within Europe are thought to be the cause for the spread of this bug in whole Europe. This possibly occurred with trucks transporting goods as well as with the ornamental plant trade. The western conifer seed bug causes direct damage by sucking on the young cones and seeds of conifer trees (mostly of the genus *Pinus*), therefore reducing the fertility. In Italy, *L. occidentalis* has also been found on *Picea*, *Cedrus*, *Abies* and *Juniperus* (Villa et al., 2001). A complete list of about 40 hosts is available in Werner (2011). This polyphagous nutrition helps *L. occidentalis* to establish and to spread. In North American conifer seed orchards seed losses of up to 50% have been recorded (Bates et al., 2000).

*Harmonia axyridis*, the harlequin ladybird is a well-known aphid predator in its native Asian range. Its origin is central and eastern Asia, with a range extending from the Altai Mountains to the Pacific Coast and Japan and from central Siberia to southern China (Koch, 2003). It was released as biological control agent in North America, dating back to 1916. The first established population was documented in 1988 in North America. *Harmonia axyridis* has been intentionally released as a biological control agent in many European countries since 1982 (Brown et al., 2008). The first feral populations in Europe were found in Germany in 1999 and in Belgium in 2001. Since then *H. axyridis* has spread throughout Europe (Roy and Migeon, 2010).

*C. perspectalis*, the box tree moth was found in masses in Riehen near Basel and across the border in Germany in spring 2007 and established and expanded its population from 25 km<sup>2</sup> in 2007 to around 640 km<sup>2</sup> in 2009 (Leuthard et al., 2010; lepiforum), where they fed on box elder trees until total defoliation and bark damage, which results in the death of the trees (Kenis et al., 2013). As box elder trees are densely leafed and the caterpillars develop on the inside, the damage is not detected until the outer leaves are affected as well. Surveys of plant traders showed that box elder trees in many plant shops were infested with the box tree moth larvae (Leuthardt et al., 2010). It is very probable that the box tree moth was imported from Asia, its origin, with the plant trade. A detailed description of the spread and the distribution of the box tree moth is available on the CABI datasheet. The developmental investigations show that larvae overwinter mainly in their third instar and that a diapause is induced by a day length of about 13.5 h (Nacambo et al., 2014). One and a half to 2 months in the cold are necessary to terminate diapause.

## MATERIALS AND METHODS

The UPAS advises people concerning insects and pests in and around houses. All inquiries are taken up in an online Microsoft Dynamics CRM database with the name of the client, the exact date, the address (location) and the species of concern. Around 2000 inquiries are recorded each year. Selected data from this database and from other sources are taken for the four species and used to show the distributions over time in Zurich greater area and in Switzerland (ESRI arcgis) and also to show the developmental trends (excel bar charts). Other sources, who supplied data for this study are the Centre Suisse de Cartographie de la faune (CSCF), Tim Haye from the Centre for Agriculture and Biosciences International (CABI), Ulrich Schnepf from the Bündner Naturmuseum (BNM), the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) and the Zurich city gardening department (GSZ). The CSCF in Neuchatel is a foundation that collects faunistic data in Switzerland. Table 1. shows an overview of the used data<sup>©</sup> and their source.

## RESULTS AND DISCUSSION

Our data and the literature show that the brown marmorated stink bug and the western conifer seed bug have been introduced to Switzerland at the turn of the century. The harlequin ladybird found its way to Switzerland from France or Germany a couple of years later. After the years of discovery in

Zurich, complaints rose in the following years to a peak and then declined to a low level of complaints in 2015 and 2016. Following their discovery in Zurich, the UPAS wrote fact sheets of these invasive pests available on the internet. At the same time the UPAS informed the news channels so articles in newspapers made people aware of these invasive species. This generated a lot more inquiries in the beginning. These three invasive species are still present but our data and our observations show that they do not appear as dominantly as in the previous years. The people have got used to seeing them around and know how to deal with them, so they do not bother to notify UPAS anymore. These seem to be the main reasons why inquiries about these three species have declined in the last years.

**Table 1.** Origin and number of data cases used for this study.

Invasive species	UPAS	GSZ	CABI	NMB	CSCF	WSL
			T. Haye	U. Schnep-pat		
<i>Halyomorpha halys</i>	330	-	230	-	11	40
<i>Leptoglossus occidentalis</i>	96	-	-	271	103	47
<i>Harmonia axyridis</i>	141	-	-	-	608	-
<i>Cydalima perspectalis</i>	58	353	-	-	150	423

### Brown Marmorated Stink Bug

The brown marmorated stink bug was first identified from Zurich and its surroundings in 2007 (Wermelinger et al., 2008). *H. halys* is very similar to the indigenous pentatomid bug *Raphigaster nebulosa* and can easily be confounded with it (Wyniger and Kment, 2010; Haye and Wyniger, 2012). The UPAS already has had inquiries about *R. nebulosa* since 1995. From 2004 the inquiries for this bug started to rise exponentially (Figure 2). Looking back we realized that 2003 or 2004 *R. nebulosa* must have been displaced by *H. halys* in our inquiries, but through their similarity we did not realize the change until the findings of Wermelinger et al. (2008) were published. In our collection we found two specimens from 2006 marked as *R. nebulosa* that were in fact *H. halys*. With the correct identification the UPAS received many inquiries about this bug in 2008. The amount of inquiries peaked in 2010, then dropped in 2011, just to reach a high level again in 2013 (Figure 1).

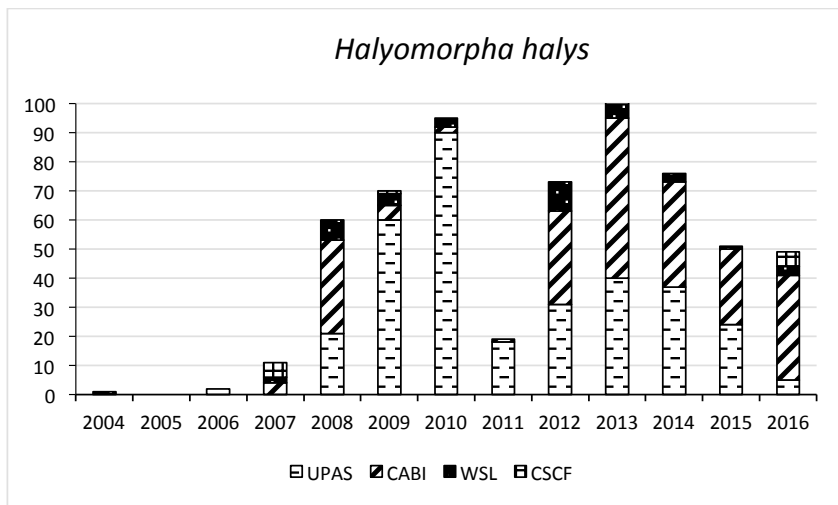
Working through light traps catches, Arnold (2009) found *H. halys* in the catch of Balzers, Lichtenstein from 2004. This does not question Zurich as the first introduction, as we have already had complaints at that time and there is photographic proof of *H. halys* in Zürich in 2004 (Haye et al., 2014a). It shows that *H. halys* had been in Switzerland longer than assumed. While inquiries at the UPAS have dropped continuously until 2016, inquiries in other parts of Switzerland, mainly in the canton Ticino, have risen due to Italian *H. halys* populations moving northwards into Switzerland (pers. communication T. Haye) (Figure 1). The distribution map of *H. halys* in Zurich (Figure 3.) shows the first findings and the spread in detail. The Swiss map (Figure 4) demonstrates the dispersion to Basel in 2012, then to Bern, Geneva, Winterthur and the canton Ticino in 2013 with inquiries the following years.

Haye et al. (2014b) report complaints of people with damage to their fruits (apricots, nectarines, cherries) and berries (raspberries and blackberries) in their gardens. Only one incidence of economic damage in pepper culture under plastic has been reported by a vegetable producer in the Canton Zurich (Sauer, 2012; Haye et al., 2014b). The UPAS had one single case where privately grown apricots along the house wall showed damage. The first author found them occasionally in his garden on raspberry and blackberry fruits and few were marked with a buggy smell. Otherwise we have not had any reports of damage on fruit. In northern Switzerland *H. halys* is mainly a nuisance pest. The bugs shelter in roller shutter casings, behind facings with air space and under the roof. They are not only a nuisance when

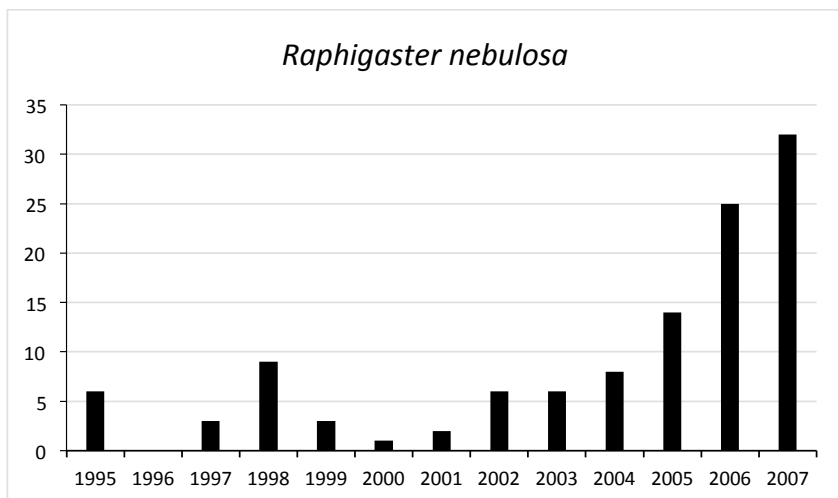
searching for their overwintering place in September and October. In their shelters they become active on warm winter days and in March when the temperatures rise.

Wermelinger (2008) suspects that *H. halys* was imported with ornamentals. Tim Haye (personal communication) has an explanation. Zurich is the partner city of Kunming, China, and in 1994 a Chinese garden was donated to Zurich by Kunming. In 1998, the roof tiles had to be replaced because they had cracked in the cold winter. The new tiles were imported to Zurich in large boxes directly from the imperial brickworks near Beijing. These boxes may have contained overwintering adults.

During the last two years, the population of *H. halys* in Zurich has not been perceived as a big nuisance and people seem to have got used to them. In the canton of Ticino, in Vienna, Austria and Italy there have been many complaints about mass invasions in 2016 (personal communication T. Haye). They seem to be at the point where Zurich stood in 2008. In southern Europe, where the Mediterranean climate is more suitable for *H. halys* and two generations can be expected (Haye et al., 2014a). The complaints might therefore not decline after some years like in Zurich and damage to fruit crops like in the USA (CABI Datasheet *Halyomorpha halys*) is already observed on pear cultures in northern Italy (Bariselli et al., 2016).



**Figure 1.** Frequency of *Halyomorpha halys* inquiries



**Figure 2.** Frequency of "*Raphigaster nebulosa*" inquiries in Zurich

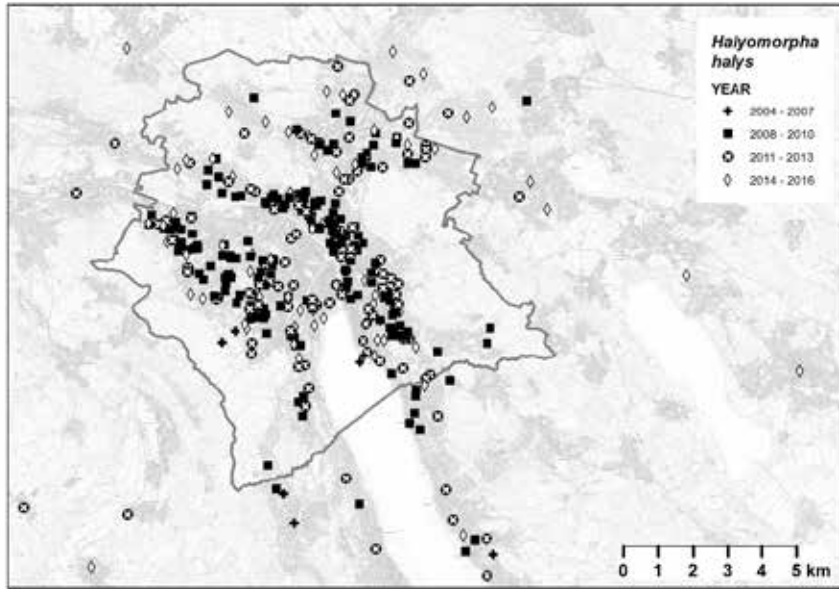


Figure 3. Distribution map of *Halyomorpha halys* in Zurich

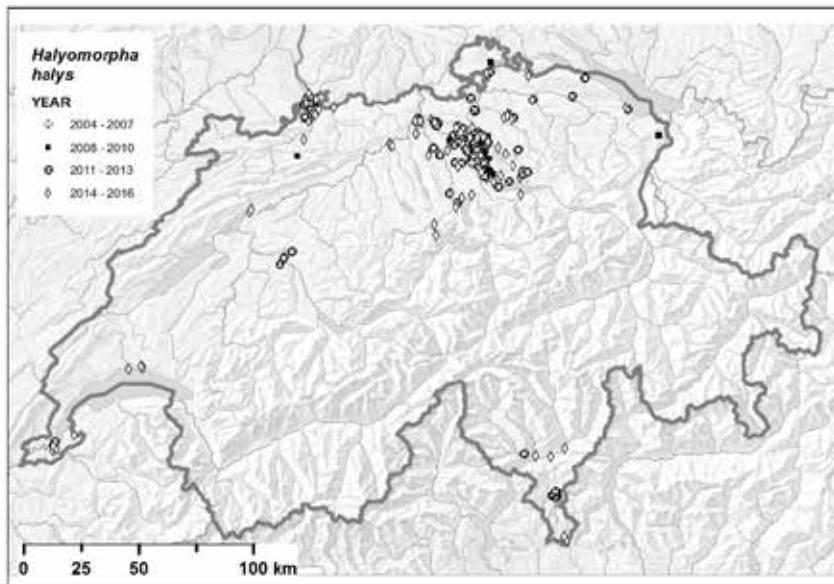


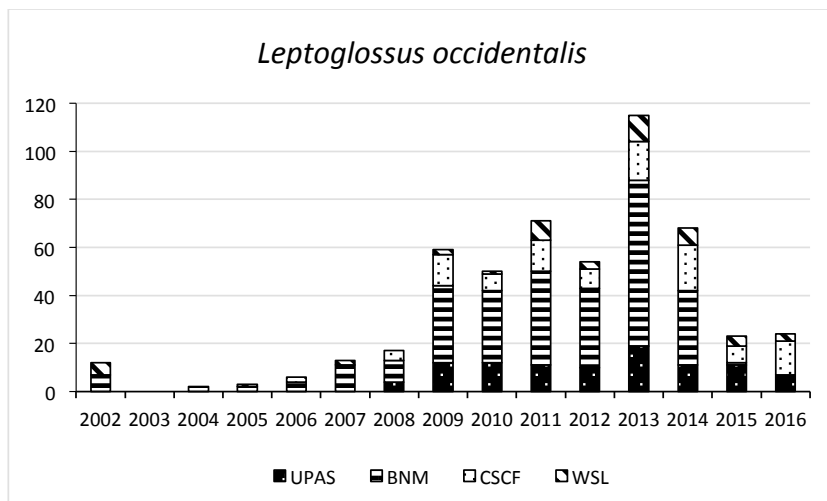
Figure 4. Distribution map of *Halyomorpha halys* in Switzerland

### The Western Conifer Seed Bug

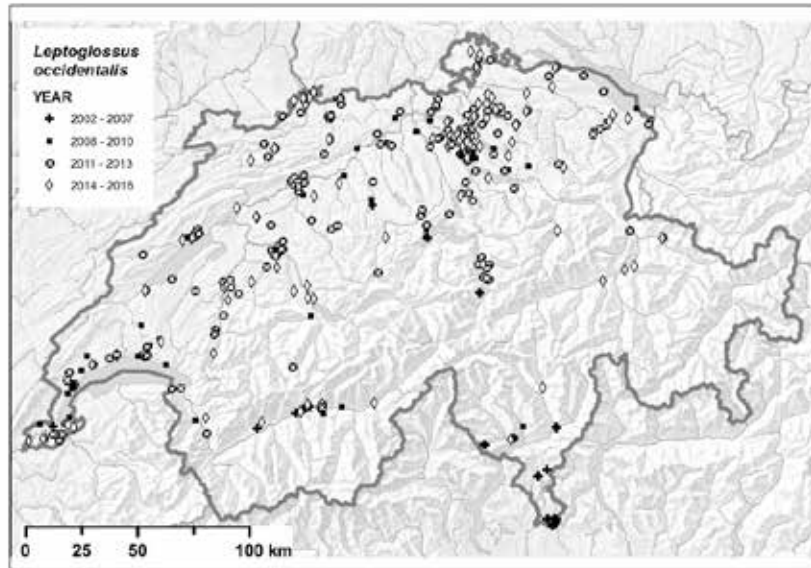
Even though first records of *L. occidentalis* are from northern Italy in 1999 (Bernardinelli and Zandigiacomo, 2001) there are pictures of *L. occidentalis* by the Swiss photographer Ernst Lienhard from the canton of Ticino in 1994 (archive of AGEO-Aargau, personal communication U. Schneppat). It seems to have been in southern Switzerland and northern Italy for quite a few years longer. The first specimens in the canton of Ticino were however found in 2002 (Colombi and Brunetti, 2002). In 2006 and 2007 the first sightings came from canton Valais and from central Switzerland near the main north-south traffic route (Figure 6). 2006 this species had spread northwards along the main trade

route in central Switzerland (Altdorf) and near Basel (Wyniger, 2007), close to the German border. In 2007 *L. occidentalis* spread eastwards to the canton of Valais and to the city of Geneva. In 2008 *L. occidentalis* was reported to the UPAS from the greater Zurich area. We received inquiries of single specimen in houses frequently in the late autumn of each year. In 2009 a total of around 60 incidences of *L. occidentalis* were compiled from all available sources. These stayed on a similar level until 2012 (Figure 5). 2013 is the peak year of the reports, after that the sightings declined to a lower level in 2015 and 2016. Already by 2010 the western conifer seed bug had spread through the Swiss midlands (Figure 6).

As far as we know, there are no reports of damage to conifer trees in Switzerland. Seeking hibernation sites in buildings *L. occidentalis* worries people by their appearance. When they are found indoors sitting on walls and people try to pick them off, they move away slowly emitting a smell of fresh green apple. Many people worried that this bug might be a cockroach or a wood pest capable of damaging their house. In one case a pest professional even offered expensive control measures for *Hylotrupes bajulus* in the roof, because a series of *L. occidentalis* were found in the nursery in the house. Once the people know that this bug is harmless, they do not worry about it anymore. We advise the people to collect the bugs and deposit them outdoors. The supplier of most data, U. Schneppat, confirms that although *L. occidentalis* is spreading in Europe, it is present in most of Switzerland but on a low level with no signs of damage.



**Figure 5.** Frequency of *Leptoglossus occidentalis* inquiries / findings

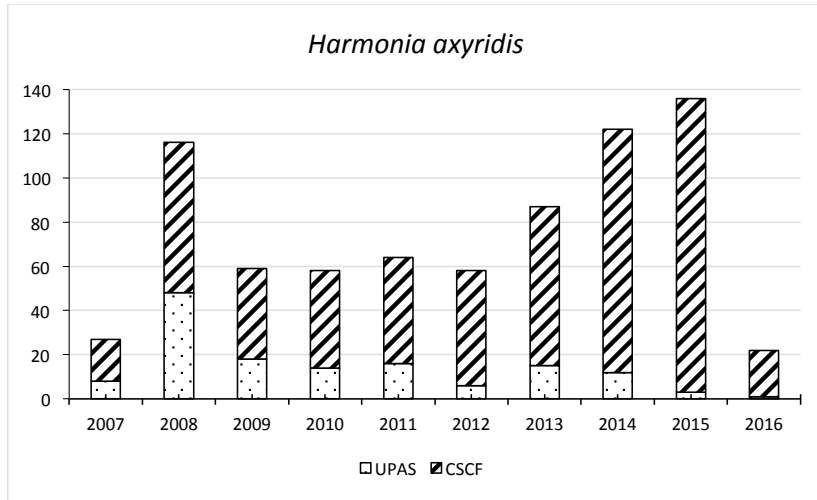


**Figure 6.** Distribution map of *Leptoglossus occidentalis* in Switzerland

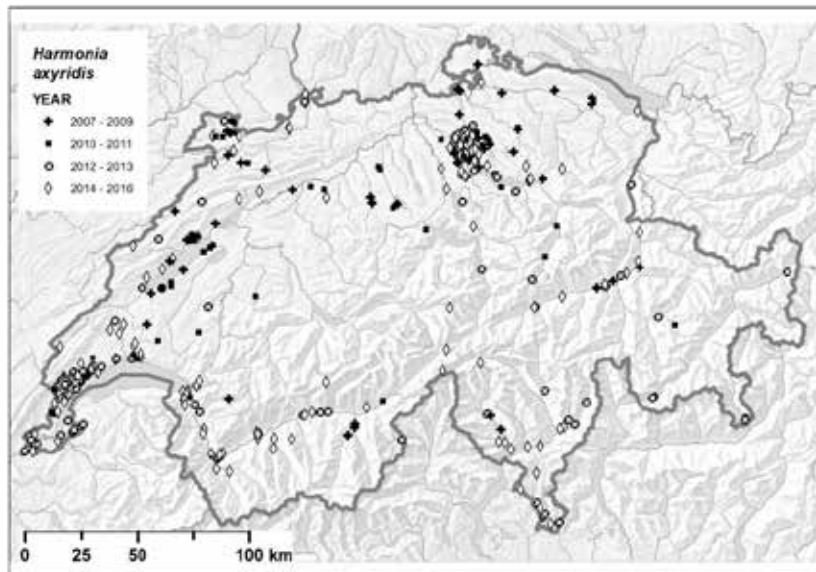
### Harlequin Ladybird

*Harmonia axyridis* was found in 2006 in high density in the canton Basel and in nine other cantons in northern Switzerland (Brown et al., 2008; Eschen et al., 2007). The UPAS in Zurich and the CSCF had first reports in autumn of 2007. In October 2008 the UPAS had almost 50 complaints about mass aggregations of the harlequin ladybird on outer walls and inside houses (Figure 7). This mainly occurred on sunny and rather warm days. It was not the ladybird itself but the large aggregations on and in their houses that worried people. In addition to this kind of nuisance the ladybirds produce a foul smelling yellow secretion, which is part of the hemolymph (Pospischil, 2008). Inside buildings this discolours wall covering and furnishings (Strand, 2009).

Our recommendations for complaints are to seal all obvious openings of the building, install insect nets on the windows used for aeration and then to vacuum-clean the ladybirds that enter the building as Kenis et al. (2007) recommend as well. We neither recommend inside nor outside insecticide applications. The first for toxic reasons, the latter because the pyrethroid insecticides available degrade in a couple of weeks and treatments would have to be repeated to be effective. While complaints to the UPAS have declined strongly, the CSCF, whose members collect data in the field, have found *H. axyridis* spread all over Switzerland at an increasing rate except for 2016 where findings dropped (Figure 7 and 8). One explanation is that the collectors didn't look for *H. axyridis* in 2016 as much as in the years before. The other is that in 2016 we had a very wet and cool June, which was bad for the aphid development and subsequently might have influenced the development of *H. axyridis*.



**Figure 7.** Frequency of *Harmonia axyridis* inquiries / findings



**Figure 8.** Distribution map of *Harmonia axyridis* in Switzerland

### Box Tree Moth

*Cydalima perspectalis* reached the canton of Zurich in 2009 and in 2010 the UPAS had its first inquiries (Figure 9). UPAS and GSZ had no enquiries in Zurich in 2011, but 2012 was a strong year of infestation with a peak of complaints (Figure 9). With optimal conditions the moth can develop up to 3 generations in a season (Leuthard et al., 2010; CABI Datasheet), which seemed to be the case in 2012. The inquiries dropped in the next years and stayed at a very low level during the following years (Figure 9). The data of WSL and CSCF show that *C. perspectalis* is continuously spreading over the Swiss midlands and the canton Ticino (Figure 10.) and can locally lead to strong infestations. The plant protection specialist Wolfgang Billen from southern Germany confirms that in the German area north of Basel and also around the city itself the box tree moth is only present on a low level (personal communication), because there are hardly any box elder trees left over. The same applies to Vorarlberg



in Austria (Klaus Zimmermann, personal communication). Many of the box elder trees have been removed, because they often had a shabby appearance and people did not want to apply insecticides all the time. The gardening stores and horticultural plant nurseries warn people about the box tree moth so they hardly plant these shrubs anymore. The box elder trees left over are often infested with the fungal pathogens *Cylindrocladium buxicola* (Henricot, 2002) and *Volutella buxi* (Corda, 1838) which hardly leave any edible leaves for the caterpillars and with strong infestations kills the box elder plants (personal communication W. Billen; Kenis et al., 2013). Still *C. perspectalis* is spreading northwards in the black forest and along the Rhine river valley. Once the box elder trees are defoliated, they take a long time to recover and the following generation of box tree caterpillars is left without any food resources.

In Zurich the UPAS and the gardening department advise the people to check plants early and hand-pick or shake the caterpillars from small, single trees (Stecher and Buckelmüller, 2012). With big trees or whole hedges we recommend the use of the environmentally compatible *Bacillus thuringiensis* var. israelensis product Delfin in the susceptible first and second larval stages for a successful treatment (Oelhafen et al., 2012; Stecher and Buckelmüller, 2012; Kenis et al., 2013). The gardening department in Zurich has treated their box elder trees in the public parks mainly with Delfin and most have survived the attacks and look healthy again. The box tree moth has not become a bigger problem since 2012. Natural enemies can also contribute to the decline of the box tree moth. Elph (2013) reports about house sparrows, *Passer domesticus* (Linnaeus, 1758) and wasps (Vespidae) eating the caterpillars. Further citations have appeared the following years (Vorarlberger Nachrichten, 2013 and 2014 and Elph, 2013) that confirm the sightings of birds feeding on the caterpillars. This adapted behaviour of passerine birds might contribute to contain the development of the box tree moth population.

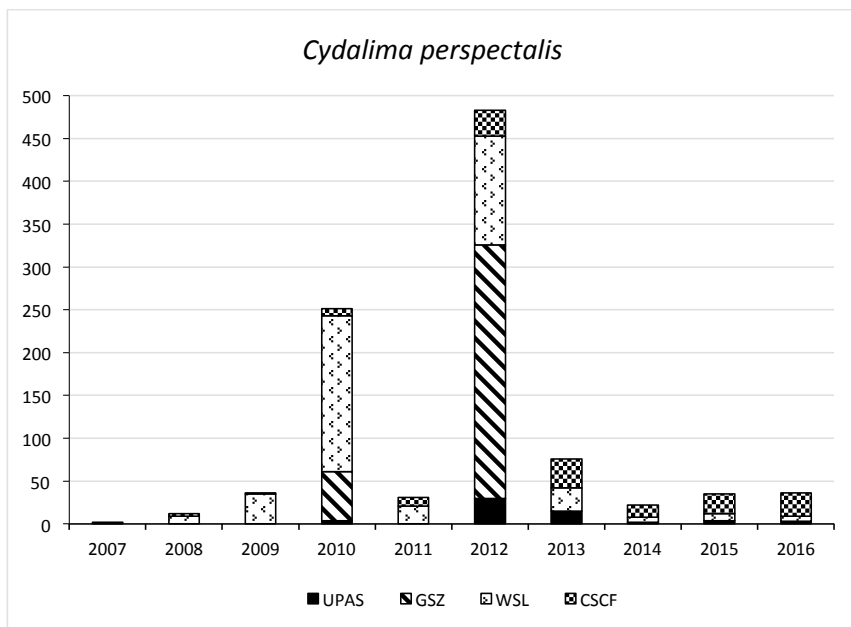
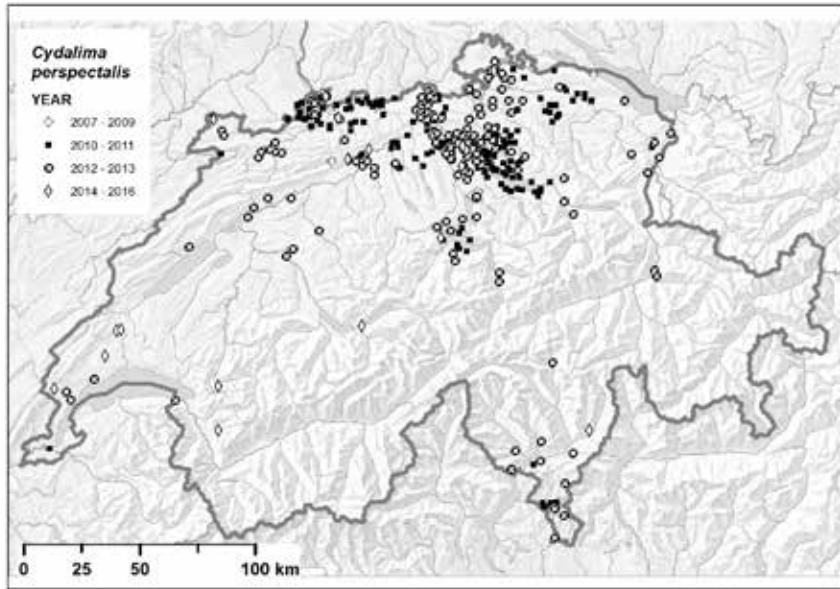


Figure 9. Frequency of *Cydalima perspectalis* inquiries / findings



**Figure 10.** Distribution of *Cydalima perspectalis* in Switzerland

## CONCLUSIONS

The declining inquiries to UPAS in the last years and the overall data show that all four invasive species are present in Switzerland, but mostly not causing much nuisance like at the early stage of their discovery. While the harlequin ladybird and the western conifer seed bug have spread over most parts of Switzerland and are present in low levels, the brown marmorated stink bug is spreading slower and seems to establish selectively in cities and in warmer regions. The box tree moth is expanding its range as well. After a few years of infestation the moth is present at a low level as there are no more box elder trees or as the remaining are monitored and treated consequently. Through expanding into new areas, new food sources are found for mass development and new damage is done. Box elder trees will become rare in private gardens of Europe and will mainly be cultivated in places where a professional pest control can be managed.

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