

REVIEW

# The potential impacts of the arrival of the harlequin ladybird, *Harmonia axyridis* (Pallas) (Coleoptera: Coccinellidae), in Britain

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**Abstract.** 1. The harlequin ladybird, *Harmonia axyridis*, has recently arrived in Britain.

2. This species has been introduced from Asia into many parts of the world for biological control purposes.

3. In many parts of North America it has become the predominant aphidophagous coccinellid in less than 20 years, and in north-western Europe it is spreading and increasing in number rapidly.

4. Since establishment in North America and continental Europe, reports of its effectiveness as a biological control agent of aphids and coccids have been accompanied by accounts of negative effects on other aphidophagous species and humans.

5. Here the potential impacts of the arrival of the harlequin ladybird in Britain are assessed.

**Key words.** Aphidophages, biological control, Coccinellidae, harlequin ladybird, *Harmonia axyridis*, invasive species.

## Introduction

On 19 September 2004, a male of the harlequin ladybird, *Harmonia axyridis* (Pallas), was found in Sible Hedingham, Essex, England. *Harmonia axyridis* is an aphidophagous coccinellid, native to central and eastern Asia (Yasumatsu & Watanabe, 1964; Hukusima & Kamei, 1970; Hukusima & Ohwaki, 1972; Kuznetsov, 1997). Since 1916, it has been repeatedly released in North America as a classical biological control agent (Gordon, 1985). This ladybird was favoured for biological control of aphids because of its size, diverse dietary range, efficiency as a predator, and wide niche colonisation ability. Despite numerous releases the species failed to become established in North America until 1988, when populations were found in Louisiana (Chapin & Brou, 1991). Whether these populations resulted from intentionally released beetles, or accidental migrants

is still a matter of debate (Teddars & Schaefer, 1994; Day *et al.*, 1994). However, since 1988, the species has spread across most of the U.S.A. and into Canada, becoming the most common aphidophagous coccinellid in many regions (Teddars & Schaefer, 1994; Dreistadt *et al.*, 1995; Smith *et al.*, 1996; Colunga-Garcia & Gage, 1998; Hesler *et al.*, 2001).

Since 1982, *H. axyridis* has been sold commercially as a classical biological control agent in Europe (Katsoyannos *et al.*, 1997; Ipert & Bertand, 2001). It was first used in Belgium in 1997 and since feral observations were reported in Ghent in 2001, numbers have increased exponentially (Adriaens *et al.*, 2003). It has also become established in northern France, Holland, Germany, and Luxembourg (Ipert & Bertand, 2001; P. Brakefield, pers. comm.; M. Majerus, pers. obs.). It was almost inevitable that *H. axyridis* would reach Britain, given the proximity of the French, Belgium, and Dutch coasts to England. Evidence suggests that *H. axyridis* arrived in Britain in 2004 by multiple routes (Majerus *et al.*, 2006).

In both North America and continental Europe, positive and negative effects of the establishment of *H. axyridis* have been reported. Using knowledge of the ecology and

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behaviour of *H. axyridis* from its native range, and its demographic increases since establishment in North America and continental Europe, here the potential impacts of its arrival in Britain are considered.

### Factors affecting the population demography of *Harmonia axyridis* in Britain

#### *Eurytopic nature*

*Harmonia axyridis* has the ability to exploit resources in a wide range of habitats, and so has the potential to survive and flourish in many parts of Britain. Colunga-Garcia and Gage (1998) studied the establishment of *H. axyridis* in south-western Michigan. The landscape is one of agricultural fields interspersed with deciduous and coniferous plantations (Burbank *et al.*, 1992). Although reported to be primarily a polyphagous arboreal species that inhabits orchards, forest stands, and old-field vegetation (Hodek, 1973; McClure, 1986; Chapin & Brou, 1991; Tedders & Schaefer, 1994; Coderre *et al.*, 1995; LaMana & Miller, 1996; Brown & Miller, 1998), *H. axyridis* was also found to thrive and breed in agricultural habitats, such as forage crops (LaMana & Miller, 1996; Buntin & Bouton, 1997), corn, soybean, and wheat (Colunga-Garcia & Gage, 1998) and conifer woodland (McClure, 1986). Within 4 years of its arrival in Michigan, *H. axyridis* had become a dominant coccinellid, found in all the habitats monitored (Colunga-Garcia & Gage, 1998). Further evidence to support the broad range of habitats in which *H. axyridis* is successfully able to survive and reproduce comes from its extensive native Asian range and its recent successful dispersal across North America and throughout Belgium (Adriaens *et al.*, 2003). This eurytopic ability suggests that now *H. axyridis* is established in south-east England, it will spread across the British mainland, invading a wide range of ecosystems.

#### *Climate*

The temperature-dependent development of aphidophagous coccinellids affects their establishment and subsequent predator-guild composition (Frazer & McGregor, 1992; Rosenheim *et al.*, 1993). The wide natural latitudinal and longitudinal range of *H. axyridis* in Asia, and its area of establishment from subtropical Florida in the south to cold temperate regions of Canada in the north, show that it can develop and breed in both warm and cool climates. In Oregon, LaMana and Miller (1998) demonstrated that *H. axyridis* is well adapted to winter temperatures below freezing and to summer temperatures of 30 °C. Such temperatures are similar to the range that *H. axyridis* will experience in Britain and so it is unlikely that climatic factors will prevent the spread of *H. axyridis* in Britain.

Natural or anthropogenically enhanced meteorological changes might also be important in determining the rate at which *H. axyridis* invades British ecosystems. The

escalating greenhouse effect and resulting global warming is already affecting the British climate. Whereas *H. axyridis* has been shown to reproduce successfully in a wide range of climates, many native British ladybirds tend to be more habitat- and niche-specific. If there is a significant shift in British weather patterns, the climatic adaptability of *H. axyridis* may give it a competitive advantage over some of the more niche-specific native ladybirds and other aphidophagous predators that are less climatically adaptable.

#### *Phenotypic adaptability*

*Harmonia axyridis* is a multivoltine species. Although considered bivoltine in much of Asia (Sakurai *et al.*, 1992; Osawa, 2000), North America (LaMana & Miller, 1996; Koch & Hutchison, 2003), and Europe (Ongagna *et al.*, 1993), up to four or five generations of *H. axyridis* per year have been observed (Wang, 1986; Katsoyannos *et al.*, 1997). Many British coccinellids, such as *Coccinella septempunctata*, *Anatis ocellata*, and *Exochomus quadripustulatus* require a dormancy period before becoming reproductively mature (Majerus & Kearns, 1989), but *H. axyridis* does not have such a requirement. Moreover, the maritime climate of Britain would allow *H. axyridis* to breed throughout the summer, with no requirement for a summer dormancy period as is seen in many parts of its range that experience very hot dry summers.

In south-central London in early November 2004, larvae of *H. axyridis* were found feeding and pupating long after all native British aphidophagous coccinellids had dispersed to overwintering sites. This late breeding attests to the continual breeding of the species if food is available and temperatures are not too low. Moreover, the wide dietary range of *H. axyridis* may increase survival of such larvae that develop so late in the year, when aphid populations have declined to very low levels. In the absence of aphids, *H. axyridis* larvae can successfully complete development on combinations of a range of other foods, including coccids, adelgids, psyllids, honeydew, and the eggs, larvae, and pupae of many insects, including conspecifics (Tedders & Schaefer, 1994; Hodek, 1996; Koch, 2003).

A further aid to this late development seen in *H. axyridis* may be its pupal and adult colour pattern plasticity. The pupal colour of *H. axyridis* ranges from almost completely orange to almost completely black; this variation being heavily affected by temperature. The lower the temperature experienced by a final-instar larva, the darker the pupa that is produced. This is adaptive, for the darker colour will absorb more heat, allowing faster adult development and earlier eclosion in cool conditions (Hodek, 1958; Majerus, 1994).

Adults of *H. axyridis* are highly polymorphic for the colour and pattern of their pronota and elytra. The ground colour may be orange, red, or black. Orange and red forms may be patterned with anything from zero to 21 black spots (the *f. succinea* complex), or may sport a grid-like black

pattern (f. *axyridis*). Black or melanic forms usually have two (f. *conspicua*) or four (f. *spectabilis*) large orange or red spots. Other forms with bars or stripes, or large patches of pale colour on a black ground colour (f. *aulica*) also occur in the native range of *H. axyridis*. This variation has been shown to have a genetic basis, controlled by a multi-allelic gene, with melanic forms generally being genetically dominant to non-melanic forms (Hosino, 1933, Tan & Li, 1934; 1936; Komai, 1956; Sasaji, 1971). To date, only f. *conspicua*, f. *spectabilis*, and forms of the *succinea* complex have been recorded in Britain: f. *axyridis*, which is the predominant form over large parts of central Russia, and the rarer Asian forms have not been found (Majerus *et al.*, 2006).

Despite genetic control of the main colour pattern morphs, environmental factors also influence some of the elytral pattern variation. Pupal exposure to low temperatures leads to slow imaginal development, resulting in forms of the *succinea* complex having more and larger spots, which are frequently fused one into another (Tan & Li, 1934). This increase in the deposition of melanic pigments is again likely to be adaptive through thermal melanism, for these adults will remain active at lower temperatures and have a longer opportunity to forage to store resources in their fat body for the winter than would less melanised individuals. The adults resulting from pupae collected in October and November in London in 2004 were very heavily spotted, and subsequent breeding experiments using these beetles showed that their large, fused spots were not inherited, indicating an environmental cause (Majerus & Roy, in press).

Grill *et al.* (1997) have shown that the natural genetic variation in *H. axyridis* provides considerable scope for adaptive changes in the developmental rate and size of this species. These observations support the contention that *H. axyridis* shows a high degree of phenotypic plasticity for a number of life-history traits, making it liable to colonise a wide range of British ecosystems and be highly competitive within them. Indeed, the maritime climate in Britain, coupled with the dietary range and phenotypic plasticity of *H. axyridis*, could allow this species to successfully and regularly extend its breeding season to September, October, and even into November. At this time, native coccinellids would not be breeding or competing for aphids and so population growth of *H. axyridis* in Britain might be even greater than seen in North America.

#### Dispersal potential

*Harmonia axyridis* is a highly dispersive species. During breeding periods it flies readily between host plants seeking high-density aphid populations. Furthermore, in both Asia and America it indulges in long migratory flights to and from dormancy sites (Nalepa *et al.*, 2000; I. Zakharov, pers. comm.). Flights to winter dormancy sites may start as early as late August in Siberia (M. Majerus, pers. obs.); however, most take place from late September through to late November (Liu & Qin, 1989; Sakurai *et al.*, 1993). The

winter is then passed in a state of dormancy in large aggregations, often on prominent, light-coloured objects (rocky outcrops of mountains, buildings, etc.) (Tanagishi, 1976; Obata, 1986). In the spring the beetles undertake another dispersal flight to seek food and suitable host plants on which to breed (LaMana & Miller, 1996). As yet, there are no data on the winter survival of *H. axyridis* in Britain. However, based on their survival in their native Siberian range (Dobzhansky, 1933), temperate climes in the northern U.S.A. and Canada (Coderre *et al.*, 1995; LaMana & Miller, 1996), and the continued reporting of live individuals in Britain, into February 2005, it is highly likely that *H. axyridis* will survive the winter in Britain and a spring dispersal may be seen here too. Such dispersal may result in a considerable increase in their distribution with the onset of warmer weather.

The history of rapid colonisation of North America by *H. axyridis* provides cause for concern. Just 2 years after their initial establishment in Georgia, *H. axyridis* had spread throughout the state (149 977 km<sup>2</sup>) and into the neighbouring states of Florida and South Carolina (Teddars & Schaefer, 1994). With such swift dispersal time-scales, coupled with their polyphagous diet and low habitat or host plant specificity, the authors predict that *H. axyridis* will spread across the entire British mainland by 2008.

#### Impacts

##### *Benefits as a pest control agent*

Since 1916, *H. axyridis* has been released as a classical biological control agent in North America and is now also commercially available in Europe. It has many attributes that contribute to its economic viability, including its polyphagous nature. *Harmonia axyridis* preys on a wide variety of tree-dwelling homopteran insects, such as aphids, psyllids, coccids, adelgids, and other insects (Teddars & Schaefer, 1994; Hodek, 1996; Koch, 2003). In North America, as well as offering effective control of target pests, such as aphids in pecans (Teddars & Schaefer, 1994), *H. axyridis* is also providing control of pests in other systems, e.g. *Aphis spiraecola* in apple orchards (Brown & Miller, 1998) and several citrus pests (Michaud, 1999, 2000, 2001a, 2002a; Stuart *et al.*, 2002). In both Asia and North America, *H. axyridis* has been reported to contribute to control of aphids on sweet corn (Musser & Shelton, 2003), alfalfa (Buntin & Bouton, 1997; Colunga-Garcia & Gage, 1998), cotton (Wells *et al.*, 2001), tobacco (Wells & McPherson, 1999), winter wheat (Colunga-Garcia & Gage, 1998), and soybean (Koch, 2003). The spread and increase of *H. axyridis* in Britain may therefore prove to be beneficial to crop systems by restricting aphid numbers below economically damaging levels and so reducing the use of chemical pesticides.

*Harmonia axyridis* has also been used as an augmentative biocontrol agent whereby control is achieved through

inundative or inoculative releases of natural enemies (Seo & Youn, 2000). In Asia, releases have successfully suppressed target pests, such as *Chaetosiphon fragaefolii* on strawberry (Sun *et al.*, 1996) and of coccids in pine forests (Wang, 1986). In America, releases into areas where *H. axyridis* has become established have reduced the detrimental impact of a variety of aphids on pecan (LaRock & Ellington, 1996).

The position of *H. axyridis* in integrated pest management schemes has also been considered. Both laboratory and field studies have investigated the impact of pesticides on *H. axyridis* (reviewed by Koch, 2003). General insecticides were found to be strongly lethal to *H. axyridis*. However, synthetic pyrethroids and some relatively new pesticides, such as spinosad, indoxacarb, and pyriproxyfen, showed minimal toxic effects or were less toxic to *H. axyridis* than to aphids (Cho *et al.*, 1997; Michaud, 2002b, 2003; Musser & Shelton, 2003). Biorational pesticides, including the fungus *Beauveria bassiana* and soap, were also shown to be less toxic than conventional pesticides (Smith & Krischik, 2000). Investigations considering the interaction between *H. axyridis* and insect-resistant transgenic crops have shown negative effects on *H. axyridis* to be negligible (Wold *et al.*, 2001; Musser & Shelton, 2003; Ferry *et al.*, 2003). Fungicides have little effect on *H. axyridis* (Michaud, 2001b; Wells *et al.*, 2001; Michaud & Grant, 2003). It thus appears that *H. axyridis* is compatible with many of the strategies employed in integrated pest management schemes (Koch, 2003).

#### Negative effects on non-target prey

The generalist diet of *H. axyridis* means that negative impacts on non-target prey species would appear to be inevitable. However, there is no empirical evidence on this subject: studies considering the effects of *H. axyridis* on the population demography of non-target aphids, coccids and other prey species away from crop systems have not been conducted. Such work is urgently needed. *Harmonia axyridis* is an accidental introduction into Britain and so lacks a specific target prey, thus making it more likely to adversely affect non-target prey species. The native guild of predators, parasitoids, and parasites that surround these prey will also be negatively affected.

Boettner *et al.* (2000) highlighted the need to examine the potential adverse effects of *H. axyridis* on non-pest flora and fauna due to a lack of existing information on this topic. Since then, Koch *et al.* (2003) have already identified *H. axyridis* as a potential predator of immature stages of the monarch butterfly, *Danaus plexippus*, an aposematic species that contains defensive chemicals. It is likely that many other species will be directly or indirectly affected by the arrival of *H. axyridis*.

#### Negative effects on other aphidophages

Since its establishment in America there has been a slow accumulation of data suggesting that *H. axyridis* is

adversely affecting other aphidophages. Brown and Miller (1998) found that the abundance of native coccinellids in apple orchards in West Virginia decreased over a 13-year period following the establishment of both *C. septempunctata* and *H. axyridis*. Colunga-Garcia and Gage (1998), reporting the results of a 9-year study in agricultural landscapes in Michigan, showed that populations of *Brachiacantha ursine*, *Cycloneda munda*, and *Chilocorus stigma* had all declined following the establishment of *H. axyridis*. A similar pattern was reported in a 5-year study in citrus groves, where the increase in *H. axyridis* was correlated to a decline in *Cycloneda sanguinea* (Michaud, 2002c). *Harmonia axyridis* is likely to have a negative effect on other aphidophages in three ways: resource competition, intra-guild predation, and intraspecific competition.

*Harmonia axyridis* is a voracious aphid predator and adults consume up to 65 aphids per day (Hukusima & Kamei, 1970; Lou, 1987; Hu *et al.*, 1989; Lucas *et al.*, 1997). Because adults are typically active for 30–120 days (He *et al.*, 1994; El-Sebaey & El-Gantiry, 1999; Soares *et al.*, 2001; M. Majerus, pers. obs.), they may consume in excess of 5000 aphids, or equivalents of other insect prey, during their lives. Michaud (2002c) demonstrated that *H. axyridis* was more voracious, fertile, and fecund than *C. sanguinea* and consequently directly out-competed *C. sanguinea*.

The wide dietary range of *H. axyridis*, coupled with its ability to disperse rapidly (and so forage widely) and its potential to breed continuously, gives this species the potential to significantly reduce British populations of its prey species. This may be considered beneficial in crop and horticultural systems, but not in other habitats where negative effects may manifest as a reduction in biodiversity and concomitant declines in native beneficial predators and parasitoids of aphids and coccids. Indeed, *H. axyridis* may impact directly on aphid parasitoids because both adult and larval *H. axyridis* feed on parasitised aphids that have not yet mummified (Nakata, 1995). Furthermore, Takizawa *et al.* (2000) showed that larvae that fed on parasitised aphids had similar survival, development rates, and adult weights as those fed on unparasitised aphids. It has also been suggested that the presence of *H. axyridis* larvae within an aphid colony may reduce the rate that parasitoids oviposit (Takizawa *et al.*, 2000) and thereby reduce their numbers.

Evidence suggests that *H. axyridis* is one of the top predators within the guilds of aphidophages and coccidophages, and can thrive on a varied diet, including other species of ladybird (Yasuda & Ohnuma, 1999). For instance, in Japan *H. axyridis* repeatedly arrived in alfalfa fields a short time after a number of other ladybirds allowing *H. axyridis* to feed on the pre-pupae and pupae of other coccinellids (Takahashi, 1989). Lucas *et al.* (1998) suggested that the position of *H. axyridis* as a dominant intra-guild predator might be attributable to its aggressive nature and the shape of its mandibles.

Reports of *H. axyridis* larvae and adults feeding on the immature stages of other aphidophagous insects are

common (reviewed in Koch, 2003). The outcome of interactions between *H. axyridis* larvae and those of other aphidophagous coccinellids tends to be in favour of the *H. axyridis* larvae (Snyder *et al.*, 2004; Yasuda *et al.*, 2004). Indeed, there are few reports of other coccinellids successfully attacking *H. axyridis*, and most evidence suggests that the immature stages of this ladybird are resistant to reciprocal attacks. In interactions between *H. axyridis* and *C. septempunctata*, Yasuda *et al.* (2001) attributed the greater success of the former to its higher attack rates and greater escape ability. The relatively large size of *H. axyridis* may also be important in this regard. Majerus (1994) reports that in predatory interactions between coccinellid larvae it is generally the larger that eats the smaller, as long as both are mobile. However, it is the defensive chemistry of *H. axyridis* that appears to be at the centre of this resistance to predation by other aphidophages, with various studies showing the unidirectional nature of intra-guild interactions between *H. axyridis* and other immature stages of coccinellid because larvae of these other species find *H. axyridis* unpalatable (Agarwala & Dixon, 1992; Agarwala *et al.*, 1998; Hemptinne *et al.*, 2000; Alam *et al.*, 2002). Levels of intra-guild predation by *H. axyridis* are inversely correlated to aphid or coccid density (Yasuda & Shinya, 1997; Burgio *et al.*, 2002). However, neonate *H. axyridis* larvae frequently attack and consume the eggs of other coccinellid species when they encounter them, even when aphids are plentiful (M. Majerus, pers. obs.). It is known that *H. axyridis* preys on immature stages of three of the most common generalist aphidophagous coccinellids in Britain, *C. septempunctata* (Hironori & Katsuhiko, 1997; Yasuda & Ohnuma, 1999; Yasuda *et al.*, 2001), *Adalia bipunctata* (Sakuratani *et al.*, 2000; Kajita *et al.*, 2000; Lynch *et al.*, 2001; Burgio *et al.*, 2002), and *Propylea quatuordecimpunctata* (Lynch *et al.*, 2001). It is likely that these species will all suffer from the arrival of *H. axyridis* in Britain. Since intra-guild predation is thought to be an important force in structuring aphidophagous ladybird guilds (Yasuda & Shinya, 1997; Yasuda & Ohnuma, 1999; Kajita *et al.*, 2000), *H. axyridis* has the potential to dramatically disrupt native guilds in Britain. North American evidence supports the contention that *H. axyridis* is an aggressive coccinellid with a tendency for intra-guild predation that could seriously affect the abundance of native coccinellids and dramatically reduce their available niches in the predator complex (Elliott *et al.*, 1996).

The negative effects of *H. axyridis* on other aphidophages are likely to be the result of a complex range of interactions, with *H. axyridis* in general having a competitive edge through resource competition, intra-guild predation and a more plastic phenotype. A more rapid development rate, continual breeding ability, and lack of diapause requirement, efficient chemical defence, and relatively large size would provide *H. axyridis* with a significant reproductive advantage over many native British species.

### Negative effects on humans

In addition to the adverse interactions between *H. axyridis* and other insects, in North America *H. axyridis* has also become a nuisance to humans. In the autumn, when the weather deteriorates, *H. axyridis* adults undertake long-range migrations from their feeding habitats to overwintering sites (Tanagishi, 1976; Obata, 1986; Obata *et al.*, 1986; Huelsman *et al.*, 2002). Their hypostatic behaviour results in a tendency to migrate towards prominent, light-coloured objects on the horizon (Obata, 1986), similar to the south-facing rocks they favour in their native range (Liu & Qin, 1989). In the U.S.A., houses, sheds, and garages have become the preferred, often inconvenient, overwintering sites for swarms of *H. axyridis* (Kidd *et al.*, 1995).

Increased heat, due either to central heating or the onset of warmer weather, causes *H. axyridis* to increase activity, crawling, and flying around inside homes (Huelsman *et al.*, 2002). Humans have also to contend with the defensive chemicals in their reflex blood, which is exuded from the femoro-tibial joints when the ladybirds are aggravated. The reflex blood has a foul odour and leaves yellow stains on soft furnishings. When aphid populations decline, *H. axyridis* are also known to bite people, probably to determine whether they would make a good food source. Such bites usually cause a slight stinging sensation as pre-digestive enzymes are injected into the skin, and a small bump thereafter develops. There have been a few reported cases of people showing a hyperallergic reaction to *H. axyridis*, manifesting as allergic rhinoconjunctivitis (Yarbrough *et al.*, 1999; Huelsman *et al.*, 2002; Magnan *et al.*, 2002).

The tendency of *H. axyridis* to swarm in late summer has also recently attained *H. axyridis* the status of a potential fruit production and processing pest in North America. As they build up energy reserves for the winter, they will feed on the sweet sap of ripe fruits, such as apples and pears, blemishing the fruits and reducing the value of the crop. In vineyards growing grapes for wineries, *H. axyridis* is attracted to the ripe grapes for the juice. When large numbers of *H. axyridis* among the grapes are harvested and crushed with the crop, their bitter-tasting, alkaloid defensive chemicals can seriously taint the vintage (Ratcliffe, 2002; Ejrich, 2003).

### Conclusion

*Harmonia axyridis* demonstrates the ability to spread very rapidly across new environments, colonising a wide range of habitats and phenotypically adapting to local conditions. It is a voracious, generalist predator that dominates in aggressive intra-guild interactions. Supported by the recent US decision to declare *H. axyridis* a potential fruit production and processing pest, the potential adverse impacts of *H. axyridis* significantly outweigh the benefits through pest control that it may bring to farming and gardening

communities. It is concluded that *H. axyridis* populations have the potential to rapidly grow and diversify to become seriously pestilent to the endemic British fauna including humans.

Because the spread of *H. axyridis* is currently limited to specific regions of Britain, time is of the essence. *Harmonia axyridis* provides a unique opportunity to carry out environmental impact assessments before, during, and after its establishment within all the habitats and communities it might potentially colonise in Britain. The probability of widespread spring dispersal flights coinciding with the onset of warmer weather in March further highlights the need for immediate action to monitor *H. axyridis*. Recognising this urgency, the Department for Environment, Food and Rural Affairs (Defra), in partnership with the National Biodiversity Network (NBN), has already awarded a grant to study the impact of *H. axyridis* in Britain (M. Majerus, pers. comm.). The direct and indirect effects of *H. axyridis* on British flora and fauna will be challenging to monitor, but will play a vital role in understanding the potential ecological predator–prey interactions of this aphidophagous ladybird in Britain. Research must be continued until the costs and benefits are sufficiently understood to create a detailed control plan for this invasive foreign species. Collaboration with Asian, North American, and European research projects is also recommended to maximise the information obtained and conclusions drawn. Although the different habitats, with their different prey ranges, may not provide a direct comparison with Britain, the similarities will be great and the contrasts may prove illuminating. The common lessons learnt should provide informative insights and avoid unnecessary duplication.

Finally, from a broader point of view, as global warming results in changes in the British climate, and with the general homogenisation of global ecology due to anthropogenic factors, there is an increasing risk of other insect invaders arriving to settle and become permanent residents in new environments. *Harmonia axyridis* therefore provides entomologists with a unique and exciting opportunity to monitor the spread and impacts of an invasive alien insect in British environments that might prove a timely model study for future ecological impact assessments.

Harris (1990) stated, 'most biological control agents that become extremely abundant are a nuisance'. *Harmonia axyridis* exemplifies this in North America and Belgium: as its population increases it is becoming progressively pestilent. It is therefore important that Britain seeks to control this new arrival and limit these adverse impacts as soon as possible.

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