

SCIENTIFIC DATA

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Data Descriptor: Spread of a model invasive alien species, the harlequin ladybird *Harmonia axyridis* in Britain and Ireland

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Received: 28 March 2018

Accepted: 21 August 2018

Published: 23 October 2018

Invasive alien species are widely recognized as one of the main threats to global biodiversity. Rapid flow of information on the occurrence of invasive alien species is critical to underpin effective action. Citizen science, i.e. the involvement of volunteers in science, provides an opportunity to improve the information available on invasive alien species. Here we describe the dataset created via a citizen science approach to track the spread of a well-studied invasive alien species, the harlequin ladybird *Harmonia axyridis* (Coleoptera: Coccinellidae) in Britain and Ireland. This dataset comprises 48 510 verified and validated spatio-temporal records of the occurrence of *H. axyridis* in Britain and Ireland, from first arrival in 2003, to the end of 2016. A clear and rapid spread of the species within Britain and Ireland is evident. A major reuse value of the dataset is in modelling the spread of an invasive species and applying this to other potential invasive alien species in order to predict and prevent their further spread.

Design Type(s)	database creation objective • citizen science design • biodiversity assessment objective
Measurement Type(s)	population data
Technology Type(s)	longitudinal data collection method
Factor Type(s)	temporal_interval • body marking • developmental stage
Sample Characteristic(s)	<i>Harmonia axyridis</i> • British Isles • habitat

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Background & Summary

The invasion process for an alien species involves various stages, notably introduction, establishment, increase in abundance and geographic spread¹. An alien species that spreads and has negative effects (which may be ecological, economic or social) is termed invasive^{2,3}. Invasive alien species are widely recognized as one of the main threats to global biodiversity^{4–6}. There are a number of international agreements which recognize the threat posed by invasive alien species, which are designated as a priority within the Convention on Biological Diversity Aichi biodiversity target 9 (<https://www.cbd.int/sp/targets/rationale/target-9/>) and are relevant to many of the Sustainable Development Goals (<http://www.un.org/sustainabledevelopment/sustainable-development-goals/>). An EU Regulation on invasive alien species came into force on 1 January 2015 (http://ec.europa.eu/environment/nature/invasivealien/index_en.htm) and subsequently a list of invasive alien species of EU concern was adopted for which member states are required to take action to eradicate, manage or prevent entry.

Rapid flow of information on the occurrence of invasive alien species is critical to underpin effective action. There have been few attempts to monitor the spread of invasive alien species systematically from the onset of the invasion process. Citizen science, i.e. the involvement of volunteers in science, provides an opportunity to improve the information available on invasive alien species⁷. Here we describe the dataset created via a citizen science approach to track the spread of a well-studied invasive alien species, the harlequin ladybird *Harmonia axyridis* (Coleoptera: Coccinellidae) in Britain and Ireland. This species was detected very early in the invasion process and a citizen science project was initiated and widely promoted to maximize the opportunity to gather data from the public across Britain and Ireland.

Harmonia axyridis was introduced between approximately 1982 and 2003 to at least 13 European countries⁸ as a biological control agent. It was mainly introduced to control aphids that are pests to a range of field and glasshouse crops. From the early 2000s it subsequently spread to many other European countries, including Britain and Ireland. It is native to Asia (including China, Japan, Mongolia and Russia)⁹ and was also introduced in North and South America and Africa¹⁰. *Harmonia axyridis* was introduced unintentionally to Britain from mainland Europe by a number of pathways: some were transported with produce such as cut flowers, fruit and vegetables; others arrived through natural dispersal (flight) from other invaded regions¹¹. To a lesser extent *H. axyridis* also arrived from North America¹². The major pathways of spread to Ireland were probably natural dispersal (from Britain) and arrival with produce. *Harmonia axyridis* is a eurytopic (generalist) species and may be found on deciduous or coniferous trees, arable and horticultural crops and herbaceous vegetation in a wide range of habitats. It is particularly prevalent in urban and suburban localities (e.g. parks, gardens, and in or on buildings)¹³.

Citizen science approaches to collecting species data are becoming increasingly popular and respected¹⁴. Advances in communication and digital technologies (e.g. online recording via websites and smartphone applications; digital photography) have increasingly enabled scientists to collect and verify large datasets of species information¹⁵. For a few species groups, including ladybirds, verification to species is possible if a reasonably good photograph of the animal is available. In late 2004, shortly after the first *H. axyridis* ladybird record was reported, funding was acquired from Defra and the National Biodiversity Network (NBN) to set up and trial an online recording scheme for ladybirds, and *H. axyridis* in particular. Thus, the online Harlequin Ladybird Survey and UK Ladybird Survey were launched in March 2005.

The surveys have been very successful in gaining records from the public since 2005. Innovations such as the launch of a free smartphone application (iRecord Ladybirds) in 2013 helped to maintain the supply of records. The dataset here comprises species records of *H. axyridis* in various life stages (larva, pupa or adult) from Britain and Ireland over the period 2003 to 2016.

A major reuse value of the dataset is in modelling the spread of an invasive species and applying this to other potential invasive alien species in order to predict and prevent their further spread. The time period of the study captures the initial fast spread of *H. axyridis* (principally from 2004 to 2009) plus a further substantial period (2010 to 2016) in which the distribution of the species altered relatively little, despite many further records being received.

Methods

This dataset (Data Citation 1) comprises 48 510 spatio-temporal records of the occurrence of *H. axyridis* in Britain and Ireland, from first arrival in 2003, to the end of 2016. For its type it is thus an unusually substantial dataset. Whilst the records were collated and verified by the survey organizers, the records themselves were provided by members of the public in Britain and Ireland. Uptake to the Harlequin Ladybird Survey was undoubtedly assisted by the pre-existence of the Coccinellidae Recording Scheme (now the UK Ladybird Survey), supported by the Biological Records Centre (within NERC Centre for Ecology & Hydrology)¹⁶.

Reflecting the general diversification of citizen science through innovative use of technology¹⁷, high levels of public access to the internet and digital photography enabled an online survey form to be established for *H. axyridis* in Britain and Ireland. The Harlequin Ladybird Survey (www.harlequin-survey.org) was one of the first online wildlife surveys in Britain and Ireland. It was launched in March 2005 in response to the first report of *H. axyridis* in Britain, in September 2004¹⁸. The Harlequin Ladybird Survey benefited from high levels of media interest, and members of the public showed great willingness to look for *H. axyridis*, and to register their sightings with the survey¹³. There are only three

Field	Descriptor
STARTDATE	Start data for the record (DD/MM/YYYY).
ENDDATE	End date for the record (DD/MM/YYYY).
GRIDREF	The grid reference specifying the location of the observation at the fullest precision available. The grid reference is either Ordnance Survey British (OSGB), Ordnance Survey of Ireland (OSI), or a truncated version of the Military Grid Reference System (MGRS) depending on the location of the record. Records from Britain use OSGB, from Ireland use OSI, and from the Channel Islands use MGRS. OSI grid references are distinguished by having a single letter at the start (e.g. N48), while OSGB and truncated MGRS grid references both start with 2 letters (e.g. SP30), those that start WA or WV belonging to the truncated MGRS and the rest to OSGB. The truncated MGRS grid references used here for the Channel Islands simply omit the zone number and 100 km square code from the start of the grid references as all squares within the Channel Islands are within the same zone and 100 km square 30U (e.g. WV6548 in this dataset refers to MGRS 1 km grid reference 30UWV6548).
PRECISION	The precision of the grid reference (in metres) given in GRIDREF field.
VC	The Watsonian vice county code (https://en.wikipedia.org/wiki/Vice-county). Codes 1 to 112 represent the vice counties of Britain, 113 represents the Channel Islands, and codes 201 to 240 represent Irish vice counties (where 201 = vice county H1, 202 = H2, etc).
LATITUDE	Latitude (WGS 84) for the centre of the grid reference supplied in the GRIDREF field.
LONGITUDE	Longitude (WGS 84) for the centre of the grid reference supplied in the GRIDREF field.
GR_1KM	The grid reference of the 1 km grid square in which the occurrence record lies (only populated if the original grid reference is at 1000 m precision or finer).
LATITUDE_1KM	Latitude (WGS 84) for the centre of the 1 km grid square in which the record occurs.
LONGITUDE_1KM	Longitude (WGS 84) for the centre of the 1 km grid square in which the record occurs.
GR_10KM	The grid reference of the 10 km grid square in which the occurrence record lies.
LATITUDE_10KM	Latitude (WGS 84) for the centre of the 10 km grid square in which the record occurs.
LONGITUDE_10KM	Longitude (WGS 84) for the centre of the 10 km grid square in which the record occurs.
ABUNDANCE	A text field containing any abundance information that was supplied with the record.
FORM_ABUNDANCE	Abundance information relating to color forms, if available
FORM	Color form of the ladybird, if available: <i>conspicua</i> , <i>spectabilis</i> , <i>succinea</i> .
STAGE_ABUNDANCE	Abundance information of different life stages, if available.
STAGE	Ladybird life stage: larva, pupa, adult.
RECORDER	ID(s) for recorder name(s) that submitted the record. In the BRC database recorder information is standardized to Surname followed by initials (e.g. Smith, J.). For this reason, the recorder ID relates to a unique standardized name and not an individual. A single ID can refer to multiple individuals and a single individual can also be associated with multiple recorder IDs.

Table 1. The fields contained in each *Harmonia axyridis* species record in the database, with a descriptor for each.

records from 2003 and no earlier records have been received, supporting the case that the earliest records in the dataset represent the onset of the invasion process for this species. Indeed *H. axyridis* has a relatively high detectability (e.g.¹⁹) and rapid reproductive rate, so is unlikely to have arrived unnoticed.

Each record represents a verified sighting of *H. axyridis* on a given date (or range of dates) and comprises one or more individual ladybirds observed from one or more life stages (larva, pupa, adult). Records are from Britain (England, Wales and Scotland, including offshore islands), Ireland (both Northern Ireland and the Republic of Ireland), the Isle of Man and the Channel Islands (primarily Guernsey and Jersey) and are mainly from the period 2004 to 2016. The earliest record of *H. axyridis* in Britain was initially thought to be from 3 July 2004, but three earlier records (from 2003) were received retrospectively. The data records represent species presence and there are no absence data available.

The majority of the records were received from members of the public via online recording forms (at www.harlequin-survey.org or www.ladybird-survey.org) (Supplementary Figure 1) or via smartphone apps (iRecord Ladybirds or iRecord - www.brc.ac.uk/iRecord) (Supplementary Figure 2), with some records (especially in earlier years) received by post. Other records, particularly from amateur expert¹⁶ coleopterists and other naturalists, were received in spreadsheets.

The spatial resolution of the records is variable. Many include an Ordnance Survey grid reference (converted to latitude and longitude), enabling resolution to 100 metres or less, but many others were derived at 1 km resolution from a UK postal code (UK Government Schemas and Standards, <http://webarchive.nationalarchives.gov.uk/20101126012154/http://www.cabinetoffice.gov.uk/govtalk/schemasstandards/e-gif/datastandards/address/postcode.aspx>). The option on the online recording form to enter the location via a UK postal code was provided to make the entry of records easier for members of the public unfamiliar with grid referencing systems. Whilst the resolution is thus reduced for these records, the reduction in user error (e.g. the problem of grid reference eastings and northings being transposed) is an advantage²⁰. The postal code method was applicable for sightings of *H. axyridis* made within 200 metres of a specified postal code, so could not be used for a minority of records where the ladybird was seen in a remote semi-natural habitat. The spatial resolution of the records tended to increase over time, as the number of records received via the smartphone apps increased, and these records generally have GPS-generated latitudes and longitudes.

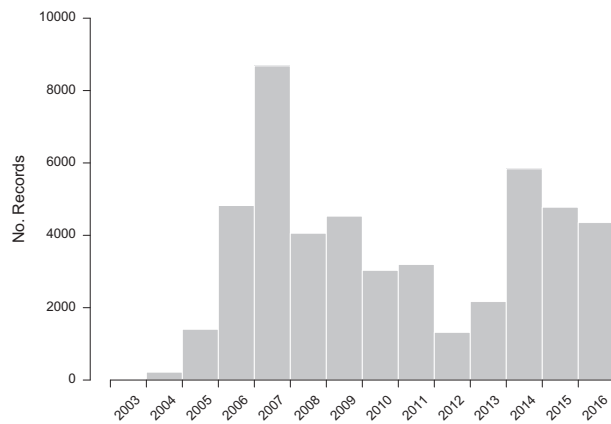


Figure 1. The number of verified *Harmonia axyridis* records received for Britain, the Channel Islands and Ireland by year, from 2003 to 2016.

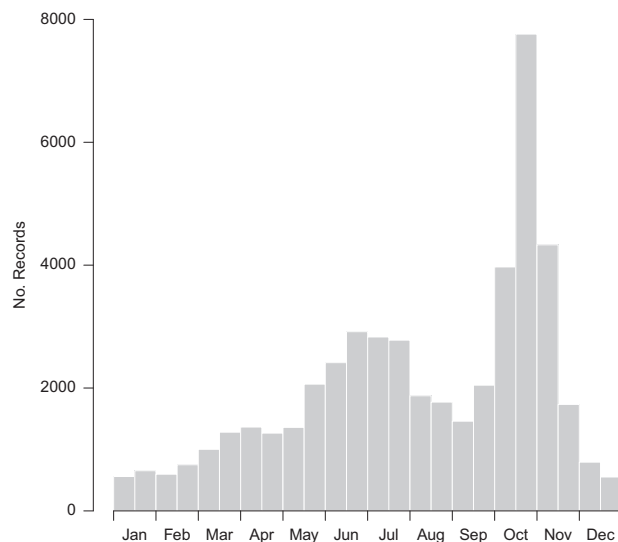


Figure 2. The number of verified *Harmonia axyridis* records received for Britain, the Channel Islands and Ireland by month, from 2003 to 2016.

Data Records Repository

The dataset is freely available for download from the Environmental Information Data Centre (EIDC) catalogue (Data Citation 1). The dataset is provided as a single tab-delimited text file, with each line representing a single record.

Constituents of Species Records

Each species record includes 19 fields (Table 1).

Figures and Tables

The figures and tables here show a summary of the dataset, notably the number of verified *H. axyridis* records received by year (Fig. 1), by month (Fig. 2), by vice county (Fig. 3 and Table 2 (available online only)) and the spread of *H. axyridis* in Britain, the Channel Islands and Ireland from 2003 to 2016 (Fig. 4).

Technical Validation

Record Verification

Verification of the records was made by the survey organizers (led by HER and PMJB but also including others) on receipt of either a photograph or ladybird specimen. The records received from amateur expert

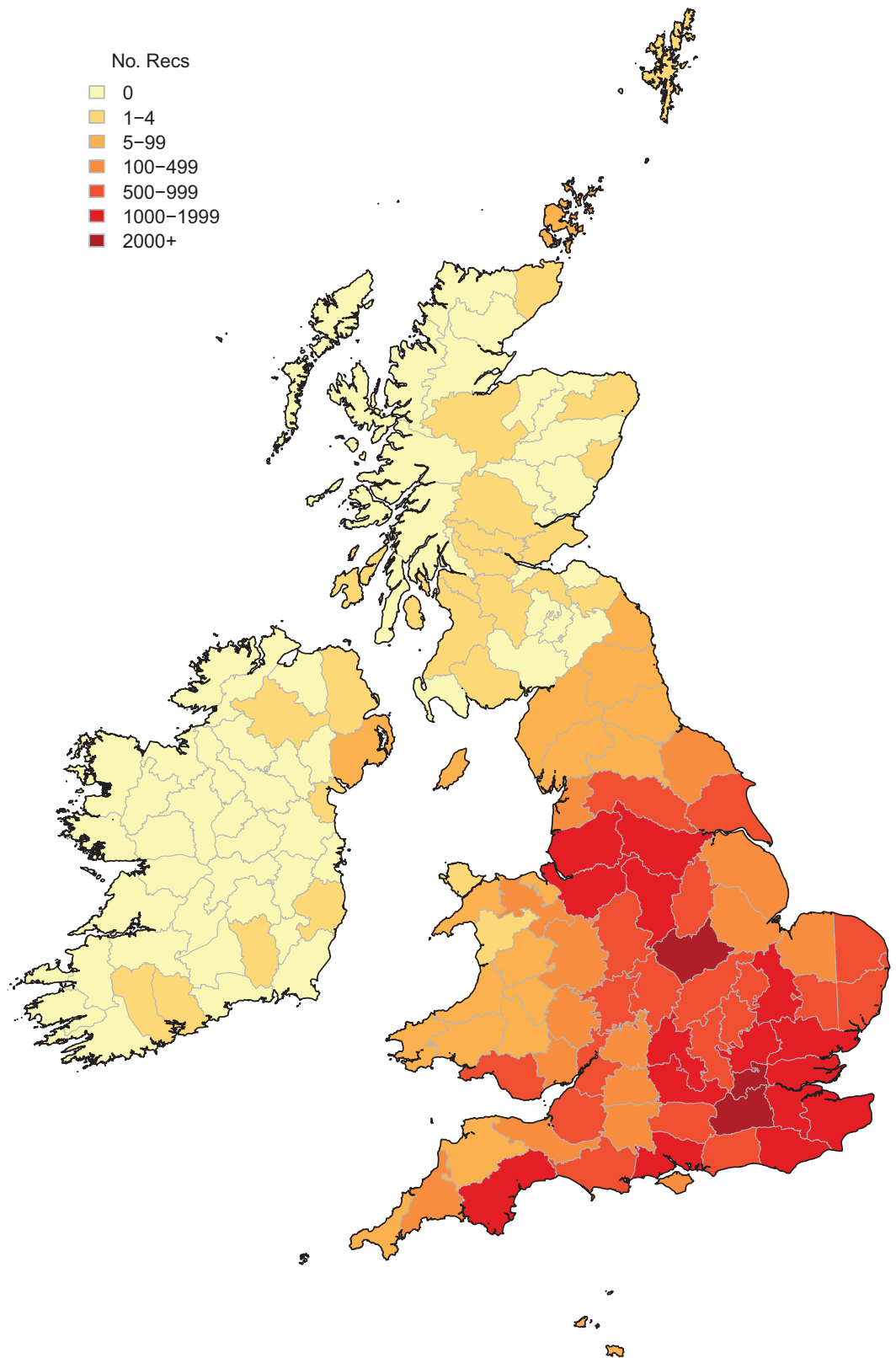


Figure 3. The number of verified *Harmonia axyridis* records received for Britain, the Channel Islands and Ireland, split by Vice County, from 2003 to 2016.

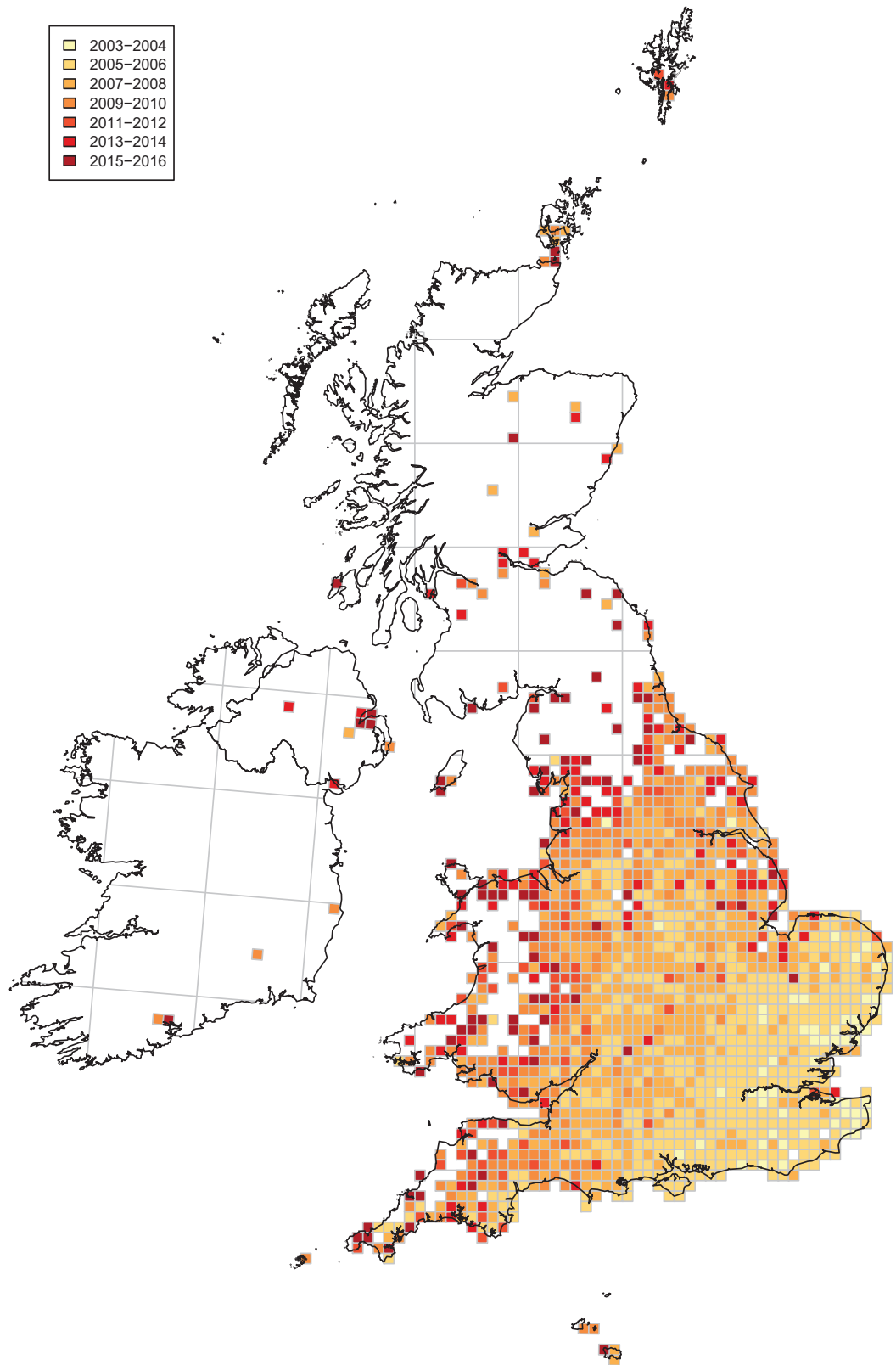


Figure 4. The spread and distribution in 10 km squares in Britain, the Channel Islands and Ireland of *Harmonia axyridis* from 2003 to 2016. NB where *H. axyridis* was recorded in a square in multiple time periods, the older time period overlays the newer one(s).

coleopterists and other naturalists are regarded as accurate (i.e. without the survey organizers seeing a photograph or specimen) and have been included in the dataset. Many further online records were received that remain unverified (i.e. no photograph or specimen was sent, or the photograph was of insufficient quality to enable identification) or were verified as another species. All such unverified or inaccurate records are excluded from this dataset. For discussion of these issues (partly relating to our dataset) see²¹. Verified records were regularly uploaded to the NBN Gateway (now the NBN Atlas - <https://nbnatlas.org/>). There the records could be viewed via online maps, which helped to encourage further recording.

Recording Intensity

Recording intensity by the public was not consistent over time and was influenced by media coverage, publicity events by the survey organizers, and other factors. The number of records in a period is also influenced by weather conditions and seasonality: the main peak in record numbers each year tended to be from late October to early November, the period in which *H. axyridis* generally moves to indoor overwintering sites (hence this is when many people first notice the species in their homes).

There is also spatial variability in recording intensity: more records come from areas with high densities of people (Fig. 3). Across Britain and Ireland there were a number of particularly active local groups or individuals which contributed hotspots of recorder activity, e.g. London. To many recorders, juvenile stages (especially pupae and early instar larvae) were less noticeable and more difficult to identify than the adult stage, thus limiting their recording. The possibility of a reporting bias towards sightings early in the season also exists (i.e. some recorders may have reported their first sighting of *H. axyridis*, but not subsequent sightings). In order to minimize this effect, the importance of recording multiple sightings was stressed to recorders. The peaks in record numbers observed late in each year also suggest that any effect of this potential bias was minor. There is probably a further minor temporal bias towards recording on some days of the week (e.g. weekend days) more than others.

Technical Validation

In addition to the expert verification detailed above, each record has also undergone a series of validation checks that are designed to highlight other potential issues with the data. Checks were performed on the date information supplied with the record to ensure that both the start and/or end dates supplied are in recognized formats, are valid dates, are in the past or present (e.g. no future dates), and where both supplied that the start date is prior or equal to the end date. The location information is also checked to ensure that the supplied grid reference is in a recognized format and is a valid grid reference and that the supplied grid reference is from a 10 km and/or 1 km square that contains land. If other location fields were supplied with the grid reference (such as 10 km grid reference, vice county, tetrad or quadrant codes, etc) they were cross-checked to ensure consistency.

References

- Blackburn, T. M. *et al.* A proposed unified framework for biological invasions. *Trends in Ecology & Evolution* **26**, 333–339 (2011).
- Roy, H. E. *et al.* The contribution of volunteer recorders to our understanding of biological invasions. *Biol. J. Linn. Soc.* **115**, 678–689 (2015).
- Russell, J. C. & Blackburn, T. M. Invasive Alien Species: Denialism, Disagreement, Definitions, and Dialogue. *Trends in Ecology & Evolution* **32**, 312–314 (2017).
- Reid, W. V. *et al.* Ecosystems and human well-being: synthesis. *Millennium Ecosystem Assessment*. (Island Press, 2005).
- Butchart, S. H. *et al.* Global biodiversity: indicators of recent declines. *Science* **328**, 1164–1168 (2010).
- Seebens, H. *et al.* No saturation in the accumulation of alien species worldwide. *Nature Communications* **8**, 14435 (2017).
- Latombe, G. *et al.* A vision for global monitoring of biological invasions. *Biol. Conserv.* **321**, 295–308 (2017).
- Brown, P. M. J. *et al.* The global spread of *Harmonia axyridis* (Coleoptera: Coccinellidae): distribution, dispersal and routes of invasion. *BioControl* **56**, 623–641 (2011).
- Orlova-Bienkowskaja, M. J., Ukrainsky, A. S. & Brown, P. M. J. *Harmonia axyridis* (Coleoptera: Coccinellidae) in Asia: a re-examination of the native range and invasion to southeastern Kazakhstan and Kyrgyzstan. *Biol. Invasions* **17**, 1941–1948 (2015).
- Roy, H. E. *et al.* The harlequin ladybird, *Harmonia axyridis*: global perspectives on invasion history and ecology. *Biol. Invasions* **18**, 997–1044 (2016).
- Jeffries, D. L. *et al.* Characteristics and drivers of high-altitude ladybird flight: Insights from vertical-looking entomological radar. *PLoS One* **8**, e82278 (2013).
- Majerus, M., Strawson, V. & Roy, H. The potential impacts of the arrival of the harlequin ladybird, *Harmonia axyridis* (Pallas) (Coleoptera: Coccinellidae), in Britain. *Ecol. Entomol.* **31**, 207–215 (2006).
- Brown, P. M. J. *et al.* *Harmonia axyridis* in Great Britain: analysis of the spread and distribution of a non-native coccinellid. *BioControl* **53**, 55–67 (2008).
- Silvertown, J. A new dawn for citizen science. *Trends in Ecology & Evolution* **24**, 467–471 (2009).
- August, T. *et al.* Emerging technologies for biological recording. *Biol. J. Linn. Soc.* **115**, 731–749 (2015).
- Pocock, M. J., Roy, H. E., Preston, C. D. & Roy, D. B. The Biological Records Centre: a pioneer of citizen science. *Biol. J. Linn. Soc.* **115**, 475–493 (2015).
- Pocock, M. J., Tweddle, J. C., Savage, J., Robinson, L. D. & Roy, H. E. The diversity and evolution of ecological and environmental citizen science. *PLoS One* **12**, e0172579 (2017).
- Majerus, M. *The ladybird has landed*. (University of Cambridge Press, 2004).
- Pocock, M. J., Roy, H. E., Fox, R., Ellis, W. N. & Botham, M. Citizen science and invasive alien species: Predicting the detection of the oak processionary moth *Thaumetopoea processionea* by moth recorders. *Biol. Conserv.* **208**, 146–154 (2017).
- Majerus, M., Forge, H. & Walker, L. The geographical distributions of ladybirds in Britain (1984–1989). *Br. J. Entomol. Nat. Hist.* **3**, 153–165 (1990).
- Gardiner, M., Allee, L., Brown, P.M.J., Losey, J., Roy, H.E. & Smyth, R. Lessons from lady beetles: Accuracy of monitoring data from US and UK citizen science programs. *Front. Ecol. Environ.* **10**, 471–476 (2012).

Data Citation

I. Roy, H. E. *et al.* NERC Environmental Information Data Centre <https://doi.org/10.5285/70ee24a5-d19c-4ca8-a1ce-ca4b51e54933> (2017).

Acknowledgements

We are immensely grateful to the thousands of people across Britain and Ireland who have so generously and enthusiastically contributed records to the UK Ladybird Survey and so collaboratively furthered understanding of the ecology of *Harmonia axyridis*. We thank the National Biodiversity Data Centre of Ireland for their collaboration and sharing of data. We are very grateful to the following organizations for funding and support over the years: Department for Environment Food and Rural Affairs, National Biodiversity Network Trust, Joint Nature Conservation Committee, Natural Environment Research Council Centre for Ecology & Hydrology, Anglia Ruskin University and University of Cambridge.

Author Contributions

H.E.R. and P.M.J.B. co-lead the UK Ladybird Survey and in doing this verified the majority of the ladybird records within this dataset, though a minority of records were verified by others. P.M.J.B. wrote the initial draft of the paper and all authors contributed additions and revisions. C.H., H.J.D., S.L.R. and D.B.R. validated the data and provided technical expertise. C.H. generated the figures.

Additional Information

Table 2 is only available in the online version of this paper.

Supplementary information accompanies this paper at <http://www.nature.com/sdata>

Competing interests: The authors declare no competing interests.

How to cite this article: Brown, P. M. J. *et al.* Spread of a model invasive alien species, the harlequin ladybird *Harmonia axyridis* in Britain and Ireland. *Sci. Data*. 5:180239 doi: 10.1038/sdata.2018.239 (2018).

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