Received: 15 May 2022 | Accepted: 24 March 2023
DOI: 10.1111/afe.12570

ORIGINAL ARTICLE

Agricultural and Forest Entomology
Royal Entomological Society

Exploring the range expansion of the yellow-spotted longhorn beetle *Psacothea hilaris hilaris* in northern Italy

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Funding information
New emergences in cultural heritage management (ALERT), University of Milan

Abstract

1. *Psacothea hilaris hilaris* is an exotic cerambycid detected in Lombardy (northern Italy) in 2005 and now established and undergoing an expansion phase. The species constitutes a serious pest for *Ficus* spp. and *Morus* spp.
2. The aim of this work is to update the distribution area of the species in Italy, investigating its expansion over 16 years. Data were acquired through the authors' direct field records and community science, by data mining on national and international web platforms and social networks. Reports were analysed and GPS points plotted in ArcMap 10.8.1 to obtain distribution maps.
3. Of the records collected, 34% were acquired during field surveys, 22% via e-mail and 44% through on-line forums and social networks.
4. Adults of *P. h. hilaris* showed a long period of activity, from April to the beginning of December, with a peak of presence from June to September. The presence of the pest has been ascertained over six provinces in Lombardy covering an area estimated at more than 1750 km^2 in 2021. New detections occurred within 2 km of a known infestation from the previous year in 41.6% of cases, and between 2 and 4 km away in 37.7% of cases. The mean rate of range expansion estimated from reported records was 3.17 ± 0.33 km/year from 2010 to 2021. After an initial phase of settlement, the insect is now spreading southward.
5. Given the relevant phytosanitary interest that the species may have for fig plants in Italy and in the Mediterranean Basin, it is fundamental to deepen the knowledge about its flight biology, dynamics and active dispersal capabilities in order to estimate the future range expansion.

KEYWORDS
bioinvasion, Cerambycidae, community science, exotic species, fig plants, xylophagous

INTRODUCTION

The yellow-spotted longhorn beetle *Psacothea hilaris hilaris* (Pascoe, 1858) (Coleoptera, Cerambycidae, Lamiinae) represents one of the multiple cases of exotic wood boring beetles introduced into the Mediterranean Basin during recent decades (Cocquempot & Lindelöw, 2010; Eyre & Haack, 2017; Jucker et al., 2006; Marchioro et al., 2022; Ruzzier et al., 2022; Ruzzier & Colla, 2019; Ruzzier, Morin, et al., 2020). Rassati et al. (2016) reported 34 exotic species detected in this area, belonging to Buprestidae (1 species), Cerambycidae (14 species) and individuals in 2 subfamilies of Curculionidae, Scolytinae (18 species) and Platypodinae (1 species). Due to international trade, climate, variety of plant species and ecosystem diversity, the Mediterranean area, and Italy in particular, represents a favourable area for the arrival and settlement of exotic species (Domina, 2021; Ruzzier et al., 2021; Ruzzier, Tomasi, et al., 2020). As a consequence, some of the most worldwide harmful xylophagous Cerambycidae have settled in Italy [e.g. *Anoplophora glabripennis* (Motschulsky, 1853), *Anoplophora chinensis* (Forster, 1771) and *Aromia bungii* (Faldermann, 1835) (Hérard & Maspero, 2019; Rassati et al., 2016; Rassati et al., 2018)]. Therefore, the list of newly introduced exotic species is certainly destined to grow in the years to come (Hulme, 2021).

P. h. hilaris is native to Japan but it is also present in China, Republic of Korea, Vietnam and Taiwan (Danilevsky, 2020; Lamiines of World, 2022). It is 1 of the 13 subspecies of *Psacothea hilaris* easily recognizable by its colorimetric pattern (von Breuning, 1943). In detail, it is characterized by 10 larger spots in a row on the outer side of each elytron and by numerous lesser spots (Kusama & Tatakuwa, 1984; Lupi, Jucker, Rocco, Harrison, & Colombo, 2015). The life cycle of all subspecies of *P. hilaris* is almost exclusively associated with Moraceae, *Ficus* spp. (fig plants) and *Morus* spp. (mulberry plants) in particular (Iba, 1980). Adult beetles can colonize both healthy and stressed plants, feeding on leaves and on the soft bark of small branches, but their damage is negligible. The females oviposit under the bark of trunks and branches larger than 1 cm, and the larvae, after an initial feeding period in the phloem, move to the xylem to complete their development. Larvae cause serious damage to the plant, often leading to decay and death of the host after a few years (Lupi et al., 2013). The usage of insecticides is poorly effective in controlling the beetle because, to reach the larvae protected within the trunk, there would be a need to use systemic insecticides. However, these are not recommended, as fig fruits are an edible crop and mulberry leaves can feed *Bombyx mori* L. larvae. In addition, few natural enemies are known and are still under study (Abdi et al., 2021).

The biology of *P. h. hilaris* was studied in Asia and in Italy, where it was introduced (Iba, 1980; Iba et al., 1976; Jucker et al., 2006; Lupi et al., 2013; Lupi, Jucker, Rocco, Harrison, & Colombo, 2015; Watari et al., 2002). In Italy, previous studies found evidence that the species is mainly associated with *Ficus carica* L. and, more rarely, with *Morus nigra* L. and *Morus alba* L. (Lupi, Jucker, Rocco, Cappellozza, & Colombo, 2015). According to Lupi et al. (2013), the Italian population of *P. h. hilaris* is monovoltine and it is able to overwinter under the bark at the egg or larval stage, with adults in activity from mid-June until the end of October.

As with several other Lamiinae, *P. h. hilaris* has been the object of passive introduction by humans via international trade. In 1997, the species was intercepted in Canada in warehouses on wood and wooden spools imported from China (Allen & Humble, 2002). In Europe, the beetle was first detected in 1997 in Derbyshire (East Midlands, UK; EPPO, 2008) and thereafter, in 2008 in the East Midlands (EPPO 2008/201), when a living adult was found in a private garden. Apparently, the species is present in UK with few occurrences and no substantial damage to the local flora has ever been recorded (EPPO, 2022). In 2007, *P. h. hilaris* was recorded in France in the Rhône Department, but no further interceptions followed (INPN, 2021). In Germany, in Northern Bayern (Bavaria), the beetle was detected in 2012 in a freight station, but there, also, few occurrences followed (EPPO, 2013). In Italy, the species was first reported in Lombardy (Northern Italy) in 2005 (Jucker et al., 2006) and it is now established. Since its detection, *P. h. hilaris* has continued to spread throughout the whole region and the most recent updated information on the area of distribution of the species was provided by Lupi et al. (2013) with an estimated presence on about 60 km^2.

Invasive insects represent one of the greatest causes for the loss of biodiversity worldwide, as well as causing high economic damage due to the loss of production (Jucker & Lupi, 2011; Kenis et al., 2009). Thus, early detection and knowledge of the distribution of invasive species are fundamental to rapidly undertake management and eradication strategies (Brockerhoff et al., 2010; Büyüktahtakin & Haight, 2018; Reaser et al., 2020). Detecting and monitoring exotic and invasive species is crucial for the implementation of containment plans, but is generally complex to perform on a large scale (e.g. regionally or nationally; Caley et al., 2020). At present, there are no available specific pheromone traps for the capture of the yellow-spotted longicorn beetle. Fukaya et al. (1996) reported the isolation and identification of a *P. hilaris* contact sex pheromone and He et al. (2021) improved the method for its synthesis; unfortunately, this pheromone has a short range of attraction and is of very little use for monitoring and control. For these reasons, community science represents a valuable support to institutional surveillance, allowing the collection of relevant series of data on a large geographic scale (Chandler et al., 2017; Ruzzier, Menchetti, et al., 2020; Streito et al., 2021; Thomas et al., 2017) which are difficult to acquire in other ways. In recent years, multiple cases have shown the importance of involving community members not only for updating species distribution, but also for acquiring ecological and biological data (Froud et al., 2008; Maistrello et al., 2016; Thomas et al., 2017).

P. h. hilaris is a species that is suitable for monitoring through community science thanks to its easily recognizable appearance and colourful chromatic pattern (von Breuning, 1943; Lupi, Jucker, Rocco, Harrison, & Colombo, 2015). This paper, through authors' personal records and community science contributions, updates information on its current distribution and provides some considerations on the range expansion of *P. h. hilaris* in Italy and also highlights its altitudinal preferences and period of adult activity. Understanding the current

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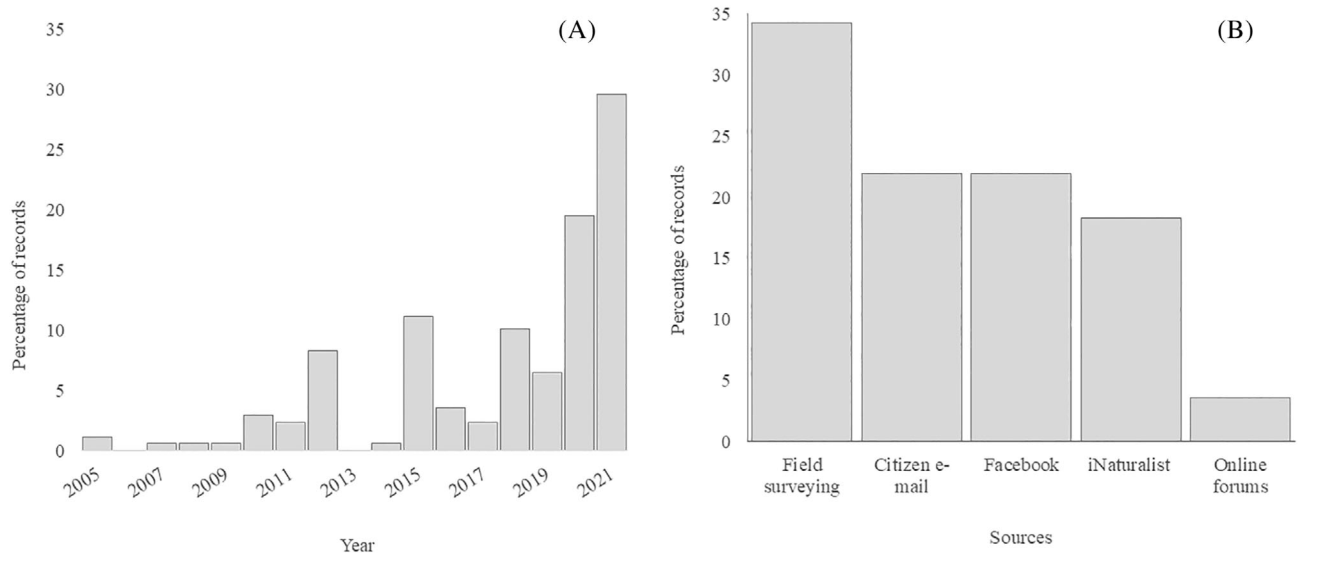

FIGURE 1 Percentage of records of *Psacothea hilaris hilaris* (a) and of sources of records notified (b) in the years 2005–2021.

distribution pattern could be an important key factor in reconsidering the pest categorization of the species for the Italian and circum-Mediterranean zone.

MATERIALS AND METHODS

Data collection

To assess the actual distribution and estimate the spreading dynamics of *P. h. hilaris* in Italy, data were gathered through direct field surveys in combination with extensive data mining on national and international web platforms and social networks. The time interval considered comprised from the first detection in Italy (2005) until December 2021.

Field monitoring was based upon both direct observations of wandering specimens and indirect signs of its presence such as oviposition scars on host plants and the perfectly circular emergence holes (mean diameter 7.86 ± 1.30 mm according to Lupi et al., 2013) which AR typical of this species, as other woodborers associated with *Ficus* in Italy have smaller emergence holes and attack decaying plants. Surveys were made at fortnightly intervals within a 5 km radius from the previous observation area; and additional points outside these areas were added if information about the presence of the yellow-spotted longhorn beetle from more distant areas was provided.

The data mining was based on websites and online forums such as iNaturalist.org, naturamediterraneo.org, entomologiitaliani.net, floraitaliae.actaplantarum.org, and facebook.it. The following search terms (both in English and Italian) were used in the research (alone or in combination): '*Psacothea hilaris hilaris*', '*Psacothea*', 'Italy', 'yellow-spotted longhorn beetle', 'longhorn', 'longicorn', 'exotic insect', 'invasive insect', 'fig pest', 'mulberry pest'. Accesses were possible through authors' private accounts. To improve *P. h. hilaris* records directly through community science, in 2015 the authors started an information campaign in the municipalities located in the infested areas through local journals, workshops, and flyers for distribution. Moreover, a specifically dedicated email site for the collection of records was created and periodically checked (at least fortnightly). Every time a record was given, detailed information about the insect (photos) and the locality were required.

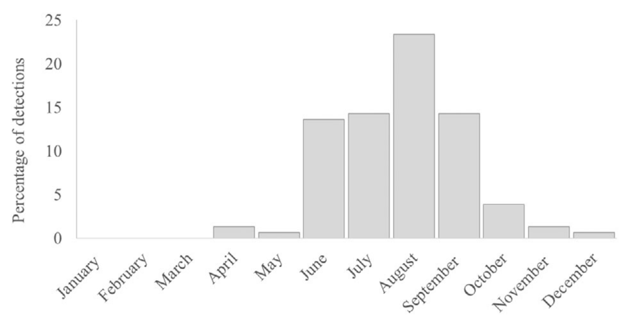

FIGURE 2 Percentage of detection of *Psacothea hilaris hilaris* in the different months across all years.

All the occurrence records were used to build a dataset which includes collection date, locality, coordinates (WGS 1984 UTM Zone 32 N; uncertainty less than 2500 m), altitude and source of the record.

Data analysis

Period of adult activity

The period of *P. h. hilaris* adult activity was obtained by summarizing the occurrences per month during the entire sampled time interval. This information does not take into account climate variability due to years or to the microclimatic differences across occurrence site but gives an overview of the main period for detection in northern Italy.

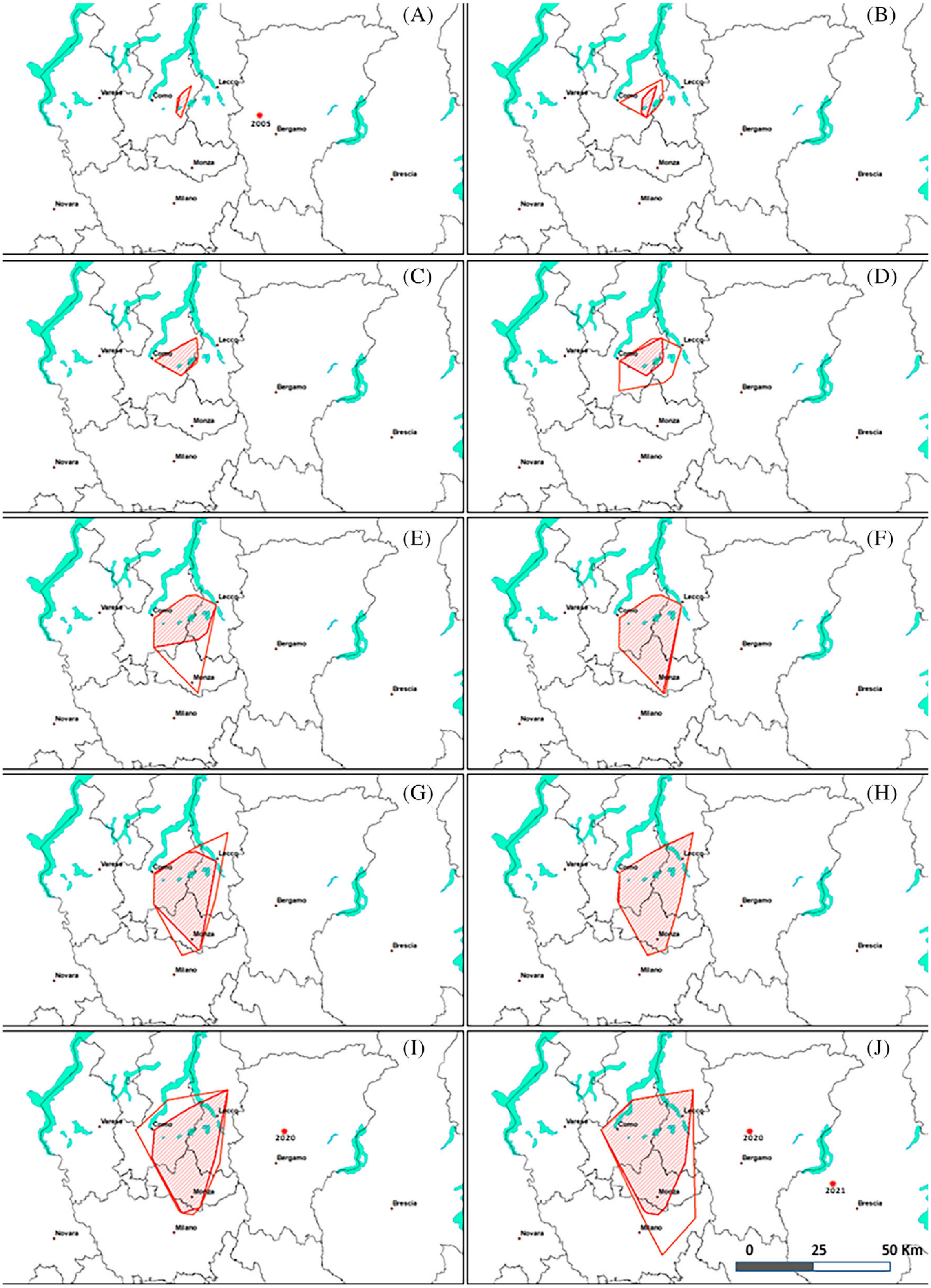

FIGURE 3 Areas of spread in the years: 2010–2011 (a); 2011–2012 (b); 2012–2014 (c); 2014–2015 (d); 2015–2016 (e); 2016–2017 (f); 2017–2018 (g); 2018–2019 (h); 2019–2020 (i) 2020–2021 (j). In each image the comparison with the previous year (dashed area) is highlighted (the grey lines delimit the division between the provinces; the cities named are the provincial capitals). Asterisks indicate points far from the main area and excluded from the calculation of the area.

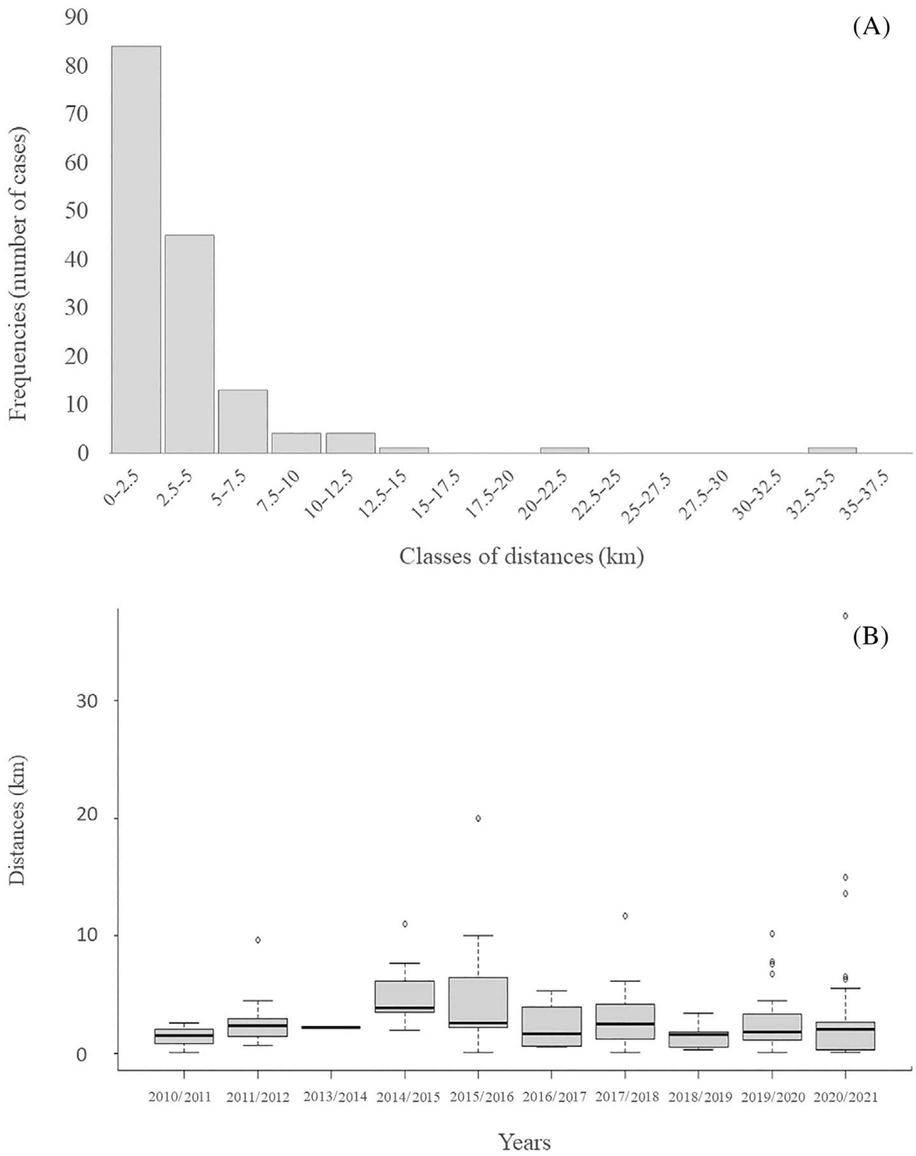

FIGURE 4 Frequency distribution of the distances of interannual range of expansion per year (a), and box plots of distances (solid black line represents the median, boxes the interquartile range) in kilometres per year with evidence of outliers (circles) in the period 2010–2021 (b).

Range expansion and altitudinal distribution occurrences

The species range for each year was assessed using the Minimum Convex Polygon (MCP), the smallest polygon around points with all interior angles less than 180°, a standardized method internationally accepted for estimating species dispersal (IUCN, 1994).

Because occurrence records in the early phase of establishment of *P. h. hilaris* in Lombardy were scarce, and MCP requires at least five occurrences, we grouped all data collected between 2005 and 2009 to determine the initial species range. We assumed that each specimen recorded established a local population generating propagules capable of colonizing new areas; thus, each occurrence was treated as permanent over years. Only one of the points reported in 2005, which resulted in no other detection in the years following the first finding, and which was about 30 km from the zone of invasion, was excluded from the estimation of the present distribution of the species. For the years 2010–2021, the yearly species range was assessed using the occurrences of the year and those pertaining to all the previous years. MCPs were calculated using the *adehabitatHR* R package (Calenge, 2006) in R version 4.2.2 (R Core Team 2022).

Given the fact that occurrence data are temporally autocorrelated, the rate of range expansion was estimated using a geometric growth model (Gotelli, 2008) using the *nls* function in R, according to the formula:

$$A_t = A_0\,(1+R)^t.$$

where A_t is the area of the species range at the time t, A_0 is the initial range and R is the geometric annual increase of the species range.

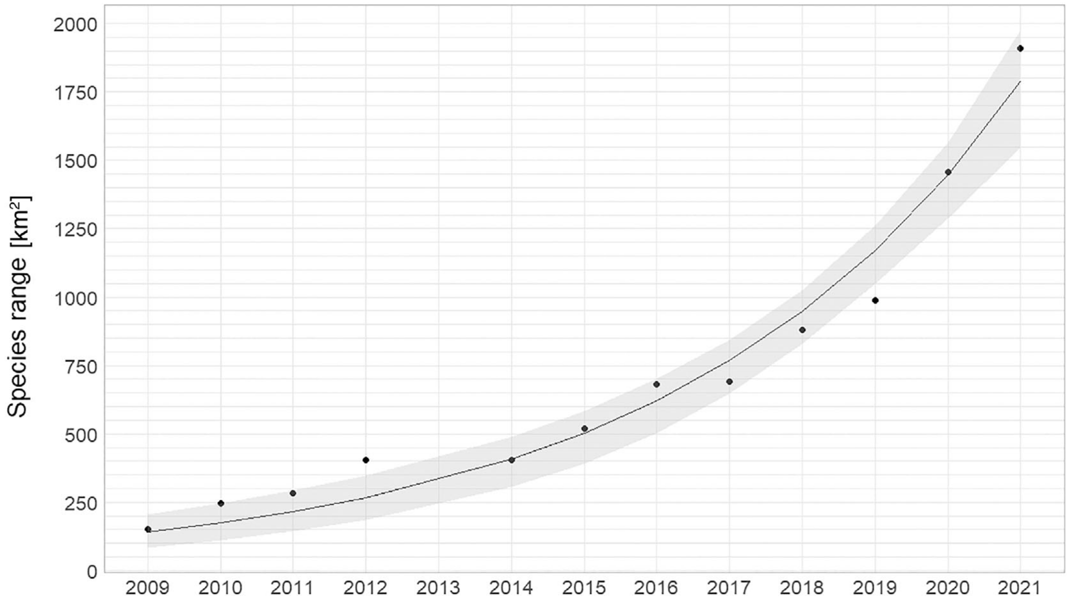

FIGURE 5 Range expansion of *Psacothea hilaris hilaris* in squared kilometres in Lombardy (Northern Italy) according to geometric growth function; $R = 0.235$ [95% CI: 0.194–0.276] ($A_0 = 142.0$ km^2 [95% CI: 92.5–191.5], $R^2_{\text{Nagelkerke}} = 0.970$). Points represent the Minimum Convex Polygon calculated for each year.

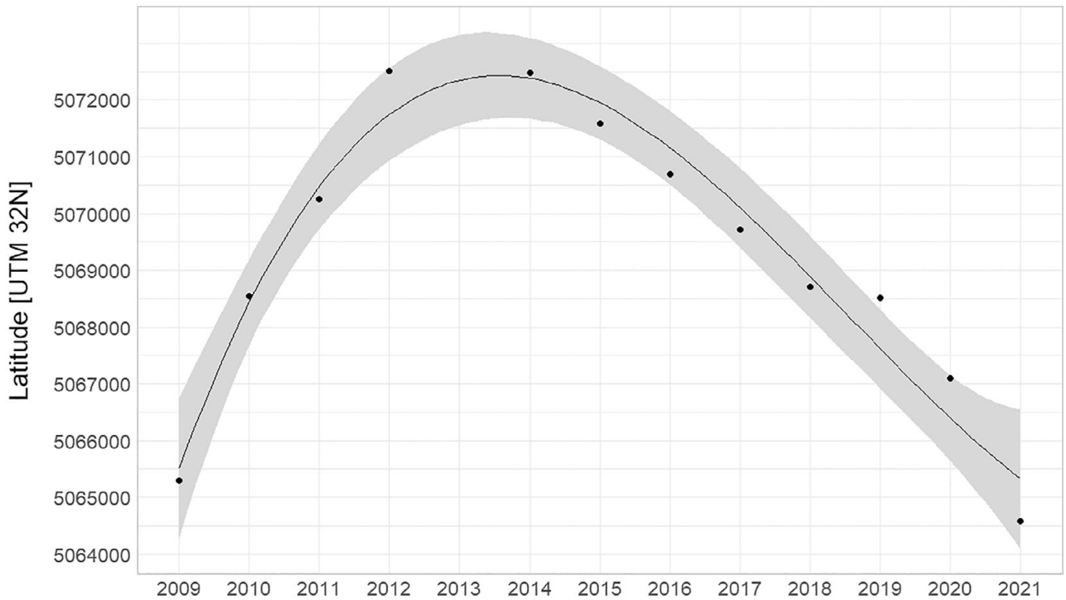

FIGURE 6 Displacement of the Minimum Convex Polygon centroid along latitude over time, interpolated according to a polynomial function of third degree ($R^2 = 0.941$). Points represent the latitude of the Minimum Convex Polygon calculated for each year.

Moreover, to evaluate a possible directionality in the species range expansion, we assessed MCPs centroid displacement over the years. The centroids were obtained using the *Momocs* package (Bonhomme et al., 2014); the centroid shift was evaluated for latitude and longitude separately, using a linear model in which geographical coordinates were used as dependent variables and the year as independent variable according with a polynomial function with a degree not superior to the third. To evaluate the reliability of the linear models in explaining the centroid shift over time, we used the corrected Akaike Information Criterion (AICc) (Burnham & Anderson, 2002) to compare the performance of the single model for latitude and longitude with the corresponding null model.

The altitude of each detection point was acquired from Google Earth Pro (ver 7.3.4.8342 12 May 2022). Altitudinal ranges were combined independently from the year and frequency; from these data, a distribution table of the altitudes was obtained.

Linear dispersal and area were considered to assess the spreading capability of *P. h. hilaris*. To evaluate annual linear dispersal in

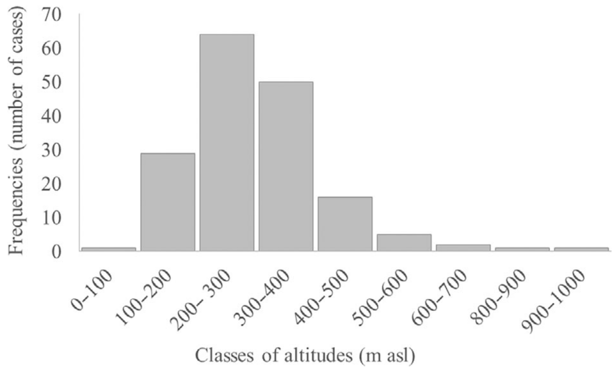

FIGURE 7 Frequency distribution of detection points at assigned altitude classes.

kilometres, the distance of new detection points was calculated as the linear distance in kilometres from the closest locality documented in the previous year. Distances were calculated from the beginning of the invasion (2005) and were kept separated for each year to calculate mean annual dispersal.

RESULTS

Data collection

The survey allowed the collection of 171 records of *P. h. hilaris* in Lombardy, all within the period 2005–2021. Two data points were discarded as they were clearly erroneous: one misidentification of an adult on a direct report and one larva on iNaturalist incorrectly attributed to *P. h. hilaris*. Only 17.15% of the detections ($n = 29$) were reported from the years between 2005 (first detection) and 2014, while 82.8% of the records ($n = 140$) were made in the years 2015–2021; the last 2 years accounted for nearly the half of all detections (49.1%; Figure 1a).

Original field observations contributed 34% (216) of detections, and community science acquired the remaining 66% through direct reports via e-mail (22%), Facebook (22%), iNaturalist (18.4%) and online forums (3.6%; Figure 1b). Field monitoring produced 58 records of *P. h. hilaris*, even though these data were mostly acquired between 2005 and 2015. Starting from 2016, community science became the primary source of data. As a consequence, starting from this year the number of detections through citizen observations has increased, with a total of 37 reports by e-mail. The reports via social networks contributed, overall, 44% to the detections of new pest occurrences.

Period of adult activity

The data show that *P. h. hilaris* has a long period of activity, ranging from April until the beginning of December (Figure 2); however, the peak of detection was in summer, with the records collected between June and September accounting for 65.6% of the total. Note that in 2021, a few adults were observed on December 11 in a private garden.

Range expansion and altitudinal distribution occurrences

A total of six neighbouring provinces (Bergamo, Como, Lecco, Monza Brianza, Milano, and Brescia) have been invaded by *P. h. hilaris*. In Bergamo province, two dead adults were collected in the proximity of a private woodshed in 2005 (Jucker et al., 2006); since then, no infested plants or further specimens were found in the area until 2020, when another isolated specimen was recorded 10.6 km away from the previously cited locality (Figure 3). The largest number of reports of distances of interannual ranges of expansion were found in the range between 0 and 2 km (41.6%) and 2 and 4 km (37.7%) from previous records (Figure 4a). Distances over 10 km accounted for only 5.2% of total detections. The total mean annual rate of dispersal in the period 2010–2021 was 3.17 ± 0.33 km (mean ± SE). Few outliers were detected in 6 years, mainly localized in the range 10–20 km, and with a maximum of 37.20 km in 2021 (Figure 4b).

The analyses showed that *P. h. hilaris* is in a clear expansion phase with an estimated annual rate of range expansion $R = 0.235$ [95% CI: 0.194–0.276] ($A_0 = 142.0$ km^2 [95% CI: 92.5–191.5], $R^2_{\text{Nagelkerke}} = 0.970$). *P. h. hilaris* has been able to increase its range by approximately 10-fold in slightly more than 10 years, reaching an occupying area of more than 1,750 km^2 in 2021 (Figure 5).

In specific regard to the range expansion directionality over time, the species did not show any significant longitudinal shift because all the polynomial functions tested were not better than the null model on the basis of the AICc (AICc; results not shown); conversely, *P. h. hilaris* showed a clear latitudinal shift according to a polynomial function of third degree ($R^2 = 0.941$; Figure 6).

The altitude at which *P. h. hilaris* was recorded ranged between 97 and 956 m asl, with a major frequency of detection points at altitudes comprised between 100 and 400 m asl (64.46% of the total; Figure 7) and the highest location was at 956 m asl in 2020 in Bergamo province. No detection was reported in 2021 for the same area.

DISCUSSION AND CONCLUSION

This research provides evidence of the spread of *Psacothea h. hilaris* over a period of 16 years in terms of dispersal capability. Although *Ficus* spp. and *Morus* spp. are genera not native to Italy, they are historically part of the Italian flora and they can be found in private and public areas, both managed and unmanaged (Mellano & Beccaro, 2015; Piccirillo, 2015). Thus, *P. h. hilaris* can easily find suitable hosts on which to feed, oviposit and develop.

Community science has greatly contributed to the present research. The year 2020–2021 has substantially made use of the data originated on social networks (almost 50% of the total detections), showing the importance of large-scale data mining of online resources.

The high number of records in 2020–2021 could be possibly attributed to COVID-19 restrictions that forced citizens to remain at home or in its proximity, thus increasing the possibility of encountering the species. In fact, *P. h. hilaris* attacks fig and mulberry, plants which are generally common in private gardens all over the infested area (Mellano & Beccaro, 2015; Piccirillo, 2015). Similar effects of pandemic lockdown on species recording in anthropic areas were also shown by authors in other parts of the world (Sánchez-Clavijo et al., 2021). In addition, we also have to underline the importance of a correct species identification; in our research, the erroneous records, if not verified, would have led to an overestimation of the area of settlement of the species.

The present distribution of *P. h. hilaris* in Northern Italy is the typical example of range expansion by neighbourhood areas (Shigesada et al., 1995). This process, tending to be slow, is associated with the intrinsic diffusion capabilities of the species. However, the detection in 2021 at 37.2 km from the nearest record in the previous year, suggests that this may be an example of passive transport or an independent introduction of the species. It cannot be excluded that in the near future the diffusion of this species may undergo a further acceleration thanks to the increase role of passive transport mediated by people; this trend has been already observed for other invasive insects in Europe (Lanner et al., 2022; Robinet et al., 2017).

Given the relevant phytosanitary interest that *P. h. hilaris* may have for ornamental and cultivated Moraceae all over Italy, *F. carica* especially, it is fundamental to deepen knowledge about its flight biology, population dynamics, and active dispersal capabilities in order to estimate, or if possible, to define, the future range of expansion of the species. As with other invasive species, the understanding of its ecological traits would help towards undertaking more efficient management strategies. At the moment no information is available about the flight ability of *P. h. hilaris*, but the distances estimated in the present work can be considered explicative, or a good approximation, of the active dispersal of this species.

The vagility of longhorn beetles varies substantially both at intra-specific and interspecific level and it is influenced by insect population dynamics (Javal et al., 2018; Smith et al., 2004; Zhang et al., 2020). The availability of host plants in the neighbouring areas, the health status of the host plant, the landscape heterogeneity, and climatic factors (including climate change) can greatly influence the diffusion of the species. Although there is no information in the literature concerning the flying ability of *P. h. hilaris* and either of its congeners, the intrinsic flight capability of different cerambycids has been studied in other species, under laboratory conditions. El-Shafie et al. (2022) observed in *Jebusaea hammerschmidtii* (Reiche) the potential to cover a cumulative distance of 11.5 km/day; the authors also noted that the species' flight ability was greatly dependent upon air temperature. *Anoplophora glabripennis* (Motschulsky) is reported to fly up to a maximum distance of 14 km/day, with an average of 2.3 km/day; for this species also, the vagility depends on individual age and nutrition status (fed vs. starved specimens; Lopez et al., 2017). In natural conditions, longhorn beetles have shown sedentary behaviour, a low dispersal range and the tendency to remain in the proximity of the host plants (Drag & Cizek, 2018; Smith et al., 2004). According to these findings, the mean distance of 3.17 ± 0.33 km per year detected in *P. h. hilaris* seems to be reasonably coherent.

The area of dispersal started from the southern part of Lake Como, and in the first year the species expanded northwards and subsequently directed exclusively southward in the Po Plain. Considering the orography, after an initial northward dispersal, the subsequent expansion of the species towards the north was limited by the presence of mountain chains which possess adverse bioclimatic conditions for the development of the host plants. In fact, 1000 m is the altitudinal limit of *F. carica*, *M. alba*, and *M. nigra* (Pignatti, 1982).

Based on our records, *P. h. hilaris* seems to find the best conditions in which to proliferate between 100 and 400 m; the isolated specimen recorded at 956 m asl in 2020 in Bergamo province might represent a single, causal introduction rather than the representative of an adventive population. However, data are too limited to currently evaluate the real capability of the species in establishing at higher altitudes.

Moreover, it will be necessary to evaluate whether the insect could adapt to the warmer climates that characterize the Mediterranean areas where the fig is cultivated intensively, and whether it is likely to become a pest. This last scenario would seem the least likely, since various studies on *P. h. hilaris* have shown that the temperature of 30°C is considered beyond the range of temperatures optimal for this insect's development (Lupi, Jucker, Rocco, Cappellozza, & Colombo, 2015; Watari et al., 2002). However, the high genetic differentiation among the subspecies and the existence of metapopulations even in the same subspecies (Saeb & Grewal, 2014) together with the phenotypic plasticity of this species (Lupi, Jucker, Rocco, Harrison, & Colombo, 2015) do not exclude that *P. h. hilaris* could adapt to new bioclimatic contexts in future.

The specimens found in late autumn (late November/December) provide further evidence of the capability of the insect to survive at low temperatures and also confirm for Northern Italy the possibility of oviposition in late autumn, as found in Japan (Watari et al., 2002).

In conclusion, the definition of the beetles' spreading area described in the paper was largely possible thanks to the contribution of citizens. Community science constitutes a fundamental resource in detecting exotic species on their first arrival, but it plays an even more important role in monitoring changes in the species distribution over time, particularly for those pests of phytosanitary importance, but which are not included among the quarantine species list and thus not subject to institutional monitoring. The data generated have important implications for understanding the establishment phases and the dynamics of diffusion of a species and can contribute to reduce the economic costs linked to monitoring and increase the efficiency of Phytosanitary service general surveillance. A rigorous information and awareness campaign is mandatory and the quality and quantity of the data are direct results of how easily a species is detectable and identifiable; *P. h. hilaris* is one of those cases that worked the best.

Based on the results produced in this survey, *P. h. hilaris* is still restricted to Lombardy; however, given its constant dispersal over the years, it is only a matter of time before the species will spread to neighbouring regions. In particular, human-mediated introduction could play a key role in accelerating the spreading, especially in the absence of controls on the movement of goods on a regional and national scale. Considering that *P. h. hilaris* may pose a serious threat in fig nurseries and orchards (along with other emerging insect pests, e.g., *Aclees taiwanensis* Kôno and *Cryphalus dilutus* Eichhoff; Faccoli et al., 2016; Farina et al., 2020), the overall risk of its spread within the Mediterranean basin should be taken into special consideration. Furthermore, it will be important to monitor the natural spread of this species more efficiently, given the relative abundance that its host plants have on Italian territory. However, it is difficult to predict the impact that the species could have if it were able to colonize those areas devoted to fig production. In addition, *P. h. hilaris* could constitute a potential limiting factor for sericulture, a productive sector undergoing a revitalization in Italy and totally dependent upon *M. alba* availability.

AUTHOR CONTRIBUTIONS

Daniela Lupi: Conceptualization; investigation; methodology; project administration; resources; supervision; validation; writing – original draft. **Serena Malabusini:** Data curation; investigation; writing – review and editing. **Silvia de Milato:** Investigation; writing – review and editing. **Alessandro Luigi Heinzl:** Investigation; writing – review and editing. **Enrico Ruzzier:** Data curation; formal analysis; methodology; writing – review and editing. **Luciano Bani:** Formal analysis; writing – review and editing. **Sara Savoldelli:** Investigation; writing – review and editing. **Costanza Jucker:** Conceptualization; funding acquisition; investigation; methodology; writing – review and editing.

ACKNOWLEDGEMENTS

The research was supported by the grant from the University of Milan 'New emergences in cultural heritage management (ALERT)'. The authors thank all the people who shared their observations on *P. h. hilaris*, substantially contributing in the improvement of the dataset used in this paper. The authors also acknowledge the support of NBFC to University of Roma Tre- Department of Science and University of Milano-Bicocca—Department of Earth and Environmental Sciences, funded by the Italian Ministry of University and Research, PNRR, Missione 4 Componente 2, 'Dalla ricerca all' impresa', Investimento 1.4, Project CN00000033. Open Access Funding provided by Universita degli Studi di Milano within the CRUI-CARE Agreement.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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How to cite this article: Lupi, D., Malabusini, S., de Milato, S., Heinzl, A.L., Ruzzier, E., Bani, L. et al. (2023) Exploring the range expansion of the yellow-spotted longhorn beetle *Psacothea hilaris hilaris* in northern Italy. *Agricultural and Forest Entomology*, 1–11. Available from: https://doi.org/10.1111/afe.12570