Summer raids of *Arocatus melanocephalus* (Heteroptera, Lygaeidae) in urban buildings in Northern Italy: Is climate change to blame?

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Abstract

Starting in 1999, repeated massive intrusions of the bug *Arocatus melanocephalus* inside urban buildings have been reported every summer in different locations in Northern Italy.

This investigation, performed in the town of Modena, where the problem was particularly intense, by means of a survey and meteorological data series, showed a significant positive correlation between the intensity of insect outbreaks and the daily mean temperature increase.

These findings suggest that current climatic warming might have affected the behaviour and/or population dynamics of *A. melanocephalus* and that building intrusions might represent an attempt to escape exceptionally high summer temperatures.

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1. Introduction

Instrumental recordings and experimental data agree that climate is changing with a trend towards global warming and that, in particular, recent years have been much warmer than average (Jones et al., 1999; Houghton et al., 2001; Jones and Moberg, 2003; Schar et al., 2004). Living systems (organisms, populations and communities) respond to regional changes rather than global averages (Walther et al., 2002), however many studies from all over the world have revealed similar phenological shifts that very likely reflect the common trend in reaction to recent climate warming (Easterling et al., 2000; Penuelas and Filella, 2001; Parmesan and Yohe, 2003). Focusing on insects, alterations in climate can affect abundance (Bale, 2002; McLaughlin et al., 2002), species distribution (Warren et al., 2001; Thomas et al., 2001; Hill et al., 2002; Hughes et al., 2003; Roy and Asher, 2003), physiology (Bradshaw and Holzapfel, 2001; Musolin and Numata, 2003, 2004), synchrony and relationships with hosts (Visser and Holleman, 2001; Kamata et al., 2002), ultimately impacting the structure of the whole communities (Harrington et al., 1999; Wuehrich, 2000; Walther et al., 2002; Stenseth et al., 2002; Thomas et al., 2004).

Starting in 1999, seasonal bug infestations inside urban buildings have been reported in different locations in Northern Italy, especially in the regions Emilia Romagna, Veneto and Friuli-Venezia Giulia (Nicoli Aldini and Peretti, 2002; Santi et al., 2002; Santi and Baronio, 2002; Zandigiacomo, 2003). These invasions occurred during summer, when large numbers of insects gather on external walls and balconies and penetrate through doors and windows to get inside houses, hospitals, theatres and other buildings. An aggravating factor is that the bugs emanate a pungent smell, similar to bitter almonds, which is considered unpleasant by people. The intruders are adults of the elm seed bug *Arocatus melanocephalus* (Fabricius 1798) (Lygaeidae), a univoltine heteropteran completing its...

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life cycle on elms *Ulmus* spp. (Péricart, 1998; Zandigiacomo, 2003). The species had never represented a problem until very recently, when summer urban raids of *A. melanocephalus* caused significant alarm and distress to people, especially those with houses close to elm trees.

In order to get a better understanding of the phenomenon of *A. melanocephalus* summer raids we undertook an investigation to test the hypothesis that intrusions correlate with increase of summer temperature. We performed a survey to obtain the features and trend of the intensity of the infestations and compared the results with historical series of meteorological data.

### 2. Materials and methods

*A. melanocephalus* biology is poorly known and a first detailed study of its phenology and physiology is currently being performed with both field observations and laboratory experiments. Winged adults (6.5–7 mm length) are mainly red and black. The head and scutellum are black, the prothorax, antennae, legs and hemelytra are a blend of black and red, whereas the abdominal sternites are red. Nymphs have black head and thorax and red abdomen. This lygaeid overwinters as adult, mating occurs during spring, eggs are laid on elms’ fruits and nymphs go through five instars before appearance of adults in late May–June (Péricart, 1998; Santi et al., 2002). The post-embryonic development is very short (4–6 weeks) and there is a pronounced overlap of different stages, especially in May.

The presence of *A. melanocephalus* has been reported in Italy since the last quarter of the 19th century (De Carlini, 1878), eliciting some complaints from the owners of houses close to elm rows. Closeness to *Ulmus* spp. trees was also reported in our survey: all the infested buildings were located less than 100 m from parks or gardens with at least one elm tree.

A special survey was prepared and distributed among competent personnel of the Environment Sector of the municipality of Modena (Northern Italy; 44°39′24″N, 10°55′12″E) and to the staff of the local company designated by the town council to control *A. melanocephalus* urban infestations. Eighty questionnaires were distributed in the most infested city areas and 45 were returned, completely or partially filled. The 10 questions aimed to assess the years, the periods of occurrence and the meteorological situation during the urban infestations, the intensity and features of the raids, the distance of infested areas from elm trees. To understand the extent and temporal dynamics of the phenomenon, we tried to quantify the intensity of infestation for each year, from 1975 to 2004, using a scale from 0 to 10, asking to estimate the mean number of bugs observed daily in buildings between June and September (Table 1).

Historical temperature data were obtained from the Geophysical Observatory of Modena University. For the purpose of this study, the considered parameter was daily mean temperature (DMT), calculated as follows: 

\[
DMT = \frac{T_{\text{min}} + T_{\text{max}} + T_{\text{8.00 AM}} + T_{\text{7.00 PM}}}{4};
\]

relative humidity, affected by some lack of homogeneity in recording, was not considered.

Spearman rank correlation between the intensity of *A. melanocephalus* raids and the mean temperatures calculated for each month, season and for the whole year was performed by using the statistical package Statistica 7.1 (2005, Statsoft Italia srl).

### 3. Results and discussion

Summer raids of the *A. melanocephalus* inside urban buildings have represented a serious nuisance during the last 5 years when the phenomenon amplified its intensity and extension, as witnessed by the increased number of reports of affected locations. Results from the survey in Modena showed that similar infestations had never been reported in this city before summer 1998, although *A. melanocephalus* was not a completely unknown insect. It had never been reported as a nuisance for urban infestations, with the only exception of an old note saying that this bug was relatively common in the town of Turin (Piemonte, Northern Italy), at least in 1863–1878 (Lessona, 1878), eliciting some complaints from the owners of houses close to elm rows. Closeness to *Ulmus* spp. trees was also reported in our survey: all the infested buildings were located between 40 °N and 50 °N (Péricart, 1998).

<table>
<thead>
<tr>
<th>No. of individuals</th>
<th>Intensity level</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤5</td>
<td>0</td>
</tr>
<tr>
<td>6–10</td>
<td>1</td>
</tr>
<tr>
<td>11–15</td>
<td>2</td>
</tr>
<tr>
<td>16–20</td>
<td>3</td>
</tr>
<tr>
<td>21–25</td>
<td>4</td>
</tr>
<tr>
<td>26–30</td>
<td>5</td>
</tr>
<tr>
<td>31–35</td>
<td>6</td>
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<tr>
<td>36–40</td>
<td>7</td>
</tr>
<tr>
<td>41–45</td>
<td>8</td>
</tr>
<tr>
<td>46–50</td>
<td>9</td>
</tr>
<tr>
<td>&gt;50</td>
<td>10</td>
</tr>
</tbody>
</table>

Intrusions of *A. melanocephalus* inside urban buildings always occurred between late May or the first days of June and the last days of September. The largest outbreaks occurred in 2003, followed by 2002 and 2001 (Fig. 1). The same trend was detected in other locations affected by the elm seed bug invasions in Northern Italy (Nicoli Aldini and Peretti, 2002; Santi and Baronio, 2002; Zandigiacomo, 2003) and could be inferred also by the number of articles dedicated to the bug invasions in the local press.

Temperature time series for Modena are shown in Fig. 2. A marked variability due to year-to-year weather change is smoothed by using the moving average over 10 years. Annual temperature showed a gradual increase, which is of
1.1 °C over the last 100 years (calculated by means of a linear regression on the series). These data are consistent with the trends reported in many European areas and with worldwide climate change pattern (Houghton et al., 2001). The moving average temperature shows a steeper increase starting from 2000 (all the data are above the 95th percentile), indicating that in Modena the greatest rise in temperatures is very recent. Summer temperatures show an even a more pronounced trend towards a progressive warming with a peak in 2003, when the average value was 28.6 °C (Fig. 1). Since the mean (± SD) of summer temperatures for the preceding period of 1860–2002 was 23.4 ± 0.9 °C, the temperature of summer 2003 exceeded this mean level by 5 °C. This anomaly was due not only to the occasional presence of extremely hot peaks, but also to the persistence of highly torrid days. In fact, during 2003 there were 78 days with the maximum temperature above 30 °C, in contrast to the mean of 26 days/year for the period of 1860–2002. Summer 2003 was the warmest summer season ever recorded in most of northern Italy and Europe (Cegnar, 2004; Luterbacher et al., 2004). Even taking into account climate warming, a mathematical model suggests that an event like summer 2003 should be regarded as statistically extremely unlikely (Schar et al., 2004).

Overall, meteorological data for Modena show that the biggest increase in temperature was recorded during the last 6 years (1999–2004). This period coincided with the years when the most intense summer raids of A. melanocephalus occurred. Massive invasions of this bug reached their maximum in Modena during summer 2003, the hottest season ever recorded (Fig. 1).

When data were analyzed for the period of 1975–2004, a significant positive correlation was found between the intensity of A. melanocephalus raids in urban buildings and (i) the mean temperature of the months April, May, June and August, (ii) the mean temperature of spring, summer and autumn, and (iii) the mean annual temperature (Table 2). No data are available on the real natural abundance or population density of this bug during the previous years; thus it is not possible to assess if the present invasions are results of population outbreaks. Moreover, too little is known about biology, seasonal adaptations and their control in this lygaeid. The on-going experiments in this direction seem to indicate that both nymphs and adults of this species are intolerant of temperatures higher than 30 °C and are negatively affected by low relative humidity. It is possible that beside winter diapause, which is spent by adults usually aggregated under tree bark or leaf litter (Pe´ricart, 1998), A. melanocephalus has a period of summer dormancy. During summer, newly emerged adults can be occasionally observed gathered in small groups on the lower surface of leaves and under bark crevices of elm and plane trees (Platanus spp.). Apparently they do not feed...
and their activity appears to be reduced, that is typical of aestivation (personal observations). Whether or not the population of *A. melanocephalus* experiences an outbreak, it is possible that the movement to urban buildings represents a behavioural strategy to escape from extremely hot, thus, unfavourable, environmental conditions. It is likely that the temperatures recorded during the recent summers (either very high short-term peaks or rather high temperatures for long periods of time) move beyond the tolerance limits of this species. This triggered massive shifts away from the usual summer shelters on trees to the closest buildings in search of better conditions for aestivation. This is further supported by the data from our survey: 60% of intrusion events were recorded during the hottest days/weeks, whereas intrusions were less numerous during the periods of lower temperature or on rainy days. Moreover, it may be speculated that higher spring temperatures may increase fecundity of overwintered adults and/or survival of newly generated nymphs, leading to increase in population density. Also, mild winters with strong increase in minimum temperatures and decreased number of frost days may have increased adult survival as known for other insects (*Bale et al., 2002*). Meteorological observations show increases in both minimum and maximum daily temperatures for every month in Italy, especially in the last 20 years (*Brunetti et al., 2000*). The winter temperatures in Modena show a gradual increase of 1.1 °C over the last 100 years, with many cases of winter mean temperatures above 5 °C during the last 15 years (Fig. 2).

Association of population outbreaks and climate is reported also for other Heteropterans. In the USA, outbreaks of boxelder and red-shouldered bugs (*Boisea trivittatus* and *Jadera haematoloma*) are associated with a succession of hot and dry years (*Bauernfeind, 2003*). Numbers of overwintering adults are maximized in mild winters, and hot weather accelerates the development of nymphs. Dry years favour these Rhopalids because fewer individuals perish due to fungal pathogens or to drowning during rainy periods. Drought years have been shown to cause drastic crashes in some insect species and outbreaks in others (*Mattson and Haack, 1987*).

Results from mathematical models indicate that yearly temperature variation alone can account for the synchronization of life cycles of poikilothermic organisms with multiple life stages such as the mountain pine beetle *Dendroctonus ponderosae* (*Powell et al., 2000; Jenkins et al., 2001*), and that if there is climate warming, some aphid populations might become more abundant and less stable in some circumstances (*Zhou et al., 1997*). It has been shown that in the pitcher-plant mosquito *Wyeomyia smithii*, the shift in genetically controlled photoperiodic response is consistent with an adaptive evolutionary response to recent global warming (*Bradshaw and Holzapfel, 2001*). Although the physiological adaptations to the seasonal climatic conditions of *A. melanocephalus* have not yet been investigated, field observations indicate that there might be a direct relation between climate warming and population size.

Evidence from experimental research and mathematical models has suggested that global warming is seriously affecting insect seasonal development, distribution and population dynamics (*Logan et al., 2003*). In this context, special attention should be focused on insect pests of agriculture or public health. The modelled climate change scenarios (*Houghton et al., 2001*) and suggestions from other studies (*Patz and Reisen, 2001; Harvell et al., 2002*) predict possible increase of insect populations, including vectors of infectious diseases (malaria, dengue, Chagas disease, etc.). These considerations reinforce the need for more detailed monitoring and evaluations of current and expected climate change.

Our study, although preliminary, suggests that summer raids of the elm seed bug *A. melanocephalus* in urban buildings might be caused or promoted by the recent temperature increase and could represent a behavioural, rarely reported, response of insects to climate warming. This species might be a good candidate to study the effects of climate change on insects.

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