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Using citizen science to monitor non-native species: the case of *Lethocerus patruelis* (Stål, 1855) (Hemiptera: Belostomatidae) in Italy

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SUMMARY

Findings of *Lethocerus patruelis* (Stål, 1855) in Southern Italy have become frequent in the last decades. We collected records of *Lethocerus patruelis* observations in Italy using scientific literature, citizen science programs, and social networks as data sources to create a complete and up-to-date dataset. This dataset is made of 59 *Lethocerus patruelis* observations from the Apulia, Basilicata, Calabria, and Abruzzi regions, 32 of which were previously unpublished, spanning from 1997 to 2020. Half of these records comes from biodiversity dedicated Facebook groups, citizen science programs and online forums, underlining the usefulness of unconventional data sources to gather data on species with poorly known distributions. The existence of *Lethocerus patruelis* viable populations in Italy remains unclear.

INTRODUCTION

Non-academic online sources are becoming increasingly important for academics. Some of these sources are citizen science projects, i.e., projects in which volunteers participate and cooperate in scientific research, usually by collecting and/or processing data as part of a scientific inquiry (Silvertown 2009). Nowadays the use of internet and tool such as smartphones, which are able to record geographical coordinates with a good degree of precision and collect medium to high quality

pictures and audio records, have made possible to use citizen science projects to collect data on broad geographic scale: thanks to citizen scientists, professional scientists are able to get access to great amount of data in places where they do not have easy access to, such as private properties or developing countries, where the internet user populations is continuously increasing (Vercayie and Herremans 2015, Supraytino et al. 2017). Because of this, citizen science has been successfully applied to many different fields, such as taxonomy, biogeography and conservation biology (Silvertown 2009, Bonardi et al. 2011, Vercayie and Herremans 2015, Supraytino et al. 2017). Concerning conservation biology and biogeography, citizen science data have been proved to be complementary, less clustered, and gathered faster than traditionally collected presence-only data stored in traditional official data repositories, particularly for insect species, thus improving species distribution mapping and consequent conservation measures (van der Wal et al. 2015, Zapponi et al. 2017).

Data can also be collected by unconventional online sources, such as widely used social networks like Facebook. The number of wildlife enthusiasts reporting wildlife observations on social networks and other websites is exponentially increasing, as well as the amount of publicly available potential data (Mori et al. 2017). Social media have been used to collect different kind of biodiversity related information (Heard et al. 2019). For instance, they have been used to assess illegal introductions of alien species and their spreading (Panzeri et al. 2014, Miyazaki et al. 2016, Faraone et al. 2017, Lo Parrino et al. 2019), to identify undescribed species (Gonella et al. 2015, Skejo and Caballero 2016), to obtain information about interspecific interactions (Mori et al. 2017), to get new data about the distributions of a species (Heard et al. 2019) and, more recently, to assess the impacts of lockdown measures on biodiversity conservation (Manenti et al. 2020). Facebook groups in particular have been proved to be effective data sources in some cases (e.g. Skejo and Caballero 2016, Mori et al. 2017, Heard et al. 2019), while online forums have been proved to be very accurate and reliable when it comes to species identification (De Felici et al. 2021), thus their usefulness as potential data sources should be also taken into account. Despite their evident usefulness, data collected through citizen science projects or unconventional online sources have some limitations, such as the lack of standardized protocols for data collection, uneven search efforts, and geographic and reporting biases, which must be taken into account when dealing with these data (van Strien 2013, Vercayie and Herremans 2015, Uyeda et al. 2020).

Species of the Belostomatidae family, commonly called “giant water bugs”, “electric light bugs” or “toe-biters”, are large, aquatic predators distributed in the Americas, Europe, Asia, Africa, and Oceania (Ohba 2019, Sareein et al. 2019). The subfamily Lethocerinae includes three genera (*Lethocerus*, *Kirkaldyia*, and *Benacus*) (Goodwyn 2006) that are known to feed mainly upon vertebrates (Ohba 2018). Species belonging to this subfamily usually eat fishes and amphibian larvae (Ohba 2011a, Nesemann and Sharma 2013), but they were also observed attacking and eating birds, snakes and turtles (Mori and Ohba 2004, Ohba 2011b, Ohba 2012, Ohba 2019).

Lethocerus patruelis (Stål, 1855) (Hemiptera: Heteroptera: Nepomorpha: Belostomatidae) is the only Belostomatidae species present in Europe (Grozeva et al. 2013, Sareein et al. 2019) and it is the largest European true bug. Its distribution includes south-eastern Europe, Turkey, the Arabian Peninsula, the Middle East, Mesopotamia, Pakistan, India, and part of south-eastern Asia (Perez Goodwyn 2006, Sareein 2019). Concerning Europe, this species is known to be found in Albania, Bosnia, Bulgaria, Crete, Croatia, Greece, Italy, Macedonia, Montenegro, Romania, Serbia, and Turkey, and there are some unconfirmed records for Hungary (Aukema and Rieger 1995, Perez Goodwyn

2006, Bacchi and Rizzotti Vlach 2007, Grozeva et al. 2013, Cianferoni and Nardi 2013, Dulcic et al. 2015, Stoianova and Simov 2016, Corsini-Foka et al. 2019, Davranoglou and Karaouzas 2021). Some of the most recent records suggest that *Lethocerus patruelis* range is expanding, particulary northwards (Grozeva et al. 2013, Stoianova and Simov 2016) and westwards (Cianferoni and Nardi 2013, Lo Parrino 2019, Castiglione et al. 2021).

Concerning Italy, individuals of *Lethocerus patruelis* have been found in the Abruzzi, Apulia, Basilicata, and Calabria regions, in the southern portion of the peninsula (Cianferoni and Nardi 2013, Lo Parrino 2019, Castiglione et al. 2021). It was suggested that *Lethocerus patruelis* might have reached Italy from the Balkan countries due to the ship traffic in the Adriatic Sea, and this claim was supported by the proximity of the earliest records to the major Italian Adriatic ports and by offshore observation of flying individuals attracted by ship lights (Cianferoni and Nardi 2013).

Since no evidence of naturalization of *Lethocerus patruelis* (e.g., the presence of eggs or nymphs) has yet been observed in Italy, possibly because of the lack of focused searches, it is not possible to exclude the possibility that all the recorded individuals came from the Balkanic countries, possibly through naval traffic.

The aim of this work is to collect the available data of *Lethocerus patruelis* observations in Italy, scattered between published scientific papers and publicly available online sources such as Facebook groups, citizen science platforms, and forums, in order to increase our knowledge about its presence in Italy.

METHODS

Most Italian records of *Lethocerus patruelis* prior to 2014 have already been reported in Cianferoni and Nardi (2013). The first record of the species in the Basilicata region is reported by Lo Parrino (2019), and the first records from Calabria are reported by Castiglione et al. (2020). The other records reported in this paper are unpublished and come from personal communications, from the iNaturalist (https://www.inaturalist.org/) citizen science platform, and from six different biodiversity-dedicated Italian Facebook groups and pages: 'Scienze Naturali' (https://www.facebook.com/ScienzeNaturali),'Società Italiana di Scienze Naturali - Il gruppo' (https://www.facebook.com/groups/scienzenaturali), 'Riconoscimento Insetti' (https://www.facebook.com/groups/ricoin/), 'Insetti e altri artropodi- un fantastico mondo da scoprire.' (https://www.facebook.com/groups/96614526499/), 'Entomologia' (https://www.facebook.com/groups/157858384240686/), 'Fra le "SCRASCE" con Wilma' (https://www.facebook.com/groups/fralescrasce/). These web sources were consulted multiple times between November 2019 and April 2021.

In most cases the specimens were not collected, so it was not possible to identify the exact *Lethocerus* species from the available pictures alone. Despite that, since *Lethocerus patruelis* is the only confirmed taxon of the Belostomatidae family reported in Europe, we treated photographic records as *Lethocerus* cfr. *patruelis*. For collected individuals and where ventral, detailed pictures were available, the sex of the specimens was determined from the shape of the 'genital plate' (Fig. 1).

All these data were used to obtain a complete, up-to-date list and a map of *Lethocerus patruelis* records in Italy.

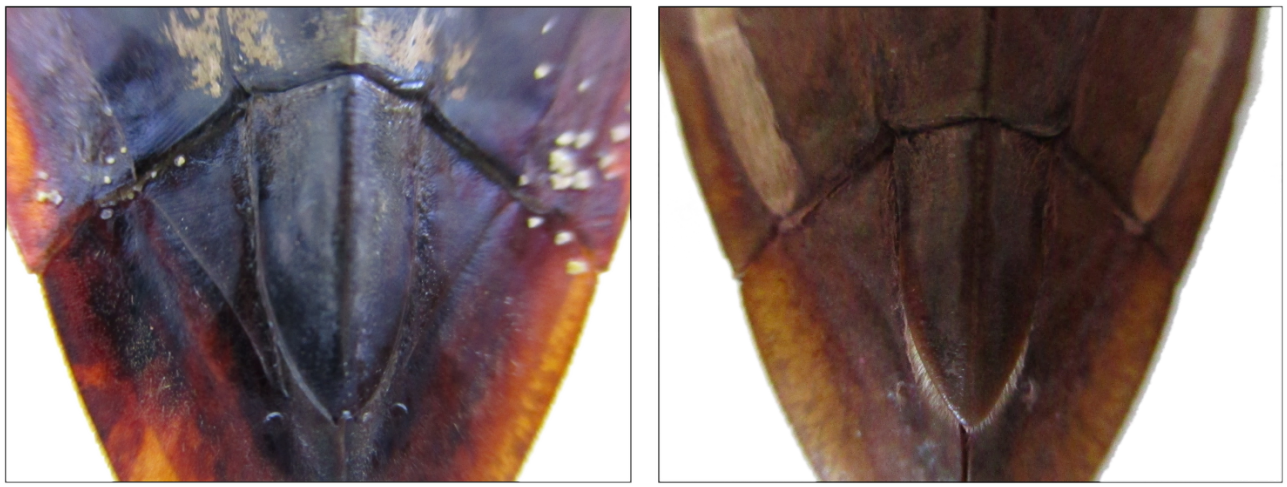

Figure 1: Differences in the shape of the genital plate between ♀ (on the left) and ♂ (on the right) *Lethocerus patruelis*.

RESULTS

A total of 59 records were collected (Table 1), 23 of which were already reported in Cianferoni and Nardi (2013), one was reported in Lo Parrino (2019), two were reported in Castiglione et al. (2020). The 33 remaining records are published for the first time in this paper. The data range from 1997 to 2020 (Fig. 2). The year with the highest number of records was 2019 (14 findings), while September (21 records), was the month with more records followed by August (12 findings). Most of the observations where the month was reported (48 out of 59) have been made during late spring-summer (from May to September), with only 2 records made in October and 1 in November. The region with the highest number of records is Apulia (52 findings), followed by Basilicata (3 findings), Calabria (2 findings) and Abruzzi (1 record) (Fig. 2).

Only for 15 out of 58 records it was possible to determine the sex of individuals: 9 females were already reported in Cianferoni and Nardi (2013); 1 male was reported in Lo Parrino (2019); 1 female was reported in Castiglione et al. (2020); 2 females and 2 males were not reported before. More extensive details are reported in Appendix 1.

DISCUSSION

The high number of *Lethocerus patruelis* observations in the last years, even in localities far from the Adriatic Sea, seems to suggest that the species is indeed expanding westward. Since *Lethocerus patruelis* range includes areas climatically comparable to Southern Italy and given the abundance of wetlands in the surroundings of many Italian observations of the species, we cannot exclude that dispersing individuals may find suitable habitats, and establish viable populations. However, only the evidence of successful reproductions will give a definitive answer to the breeding status of *Lethocerus patruelis* in Italy. It must be remarked that at least 6 individuals were observed in freshwater habitats, while other 4 were observed on land near water bodies. It is interesting to note that the oldest known records of *Lethocerus patruelis* in Italy came from the Bari and Brindisi provinces, near the main Apulian Adriatic ports, hence supporting the possibility of an accidental introduction of this species. The high number of records in August and September seems to confirm the seasonal dispersal behaviour of this species, meaning that its presence in Italy is still a seasonal presence of dispersing individuals. Closely related species are known to migrate following seasonal patterns by flying or drifting (DuBois 1992, Macías-Ordóñez 2003, Yoon et al. 2010,

Nagaba and Takeda 2013, Ohba 2019), so it is possible that *Lethocerus patruelis* put in practice similar behaviours. The records published by Grozeva et al. (2013) seem to support this view, with most of the individuals being collected by light traps between August and October. Davranoglou and Karaouzas (2021) report the same pattern, with a peak in September-October, not dissimilarly to the observations reported in this work.

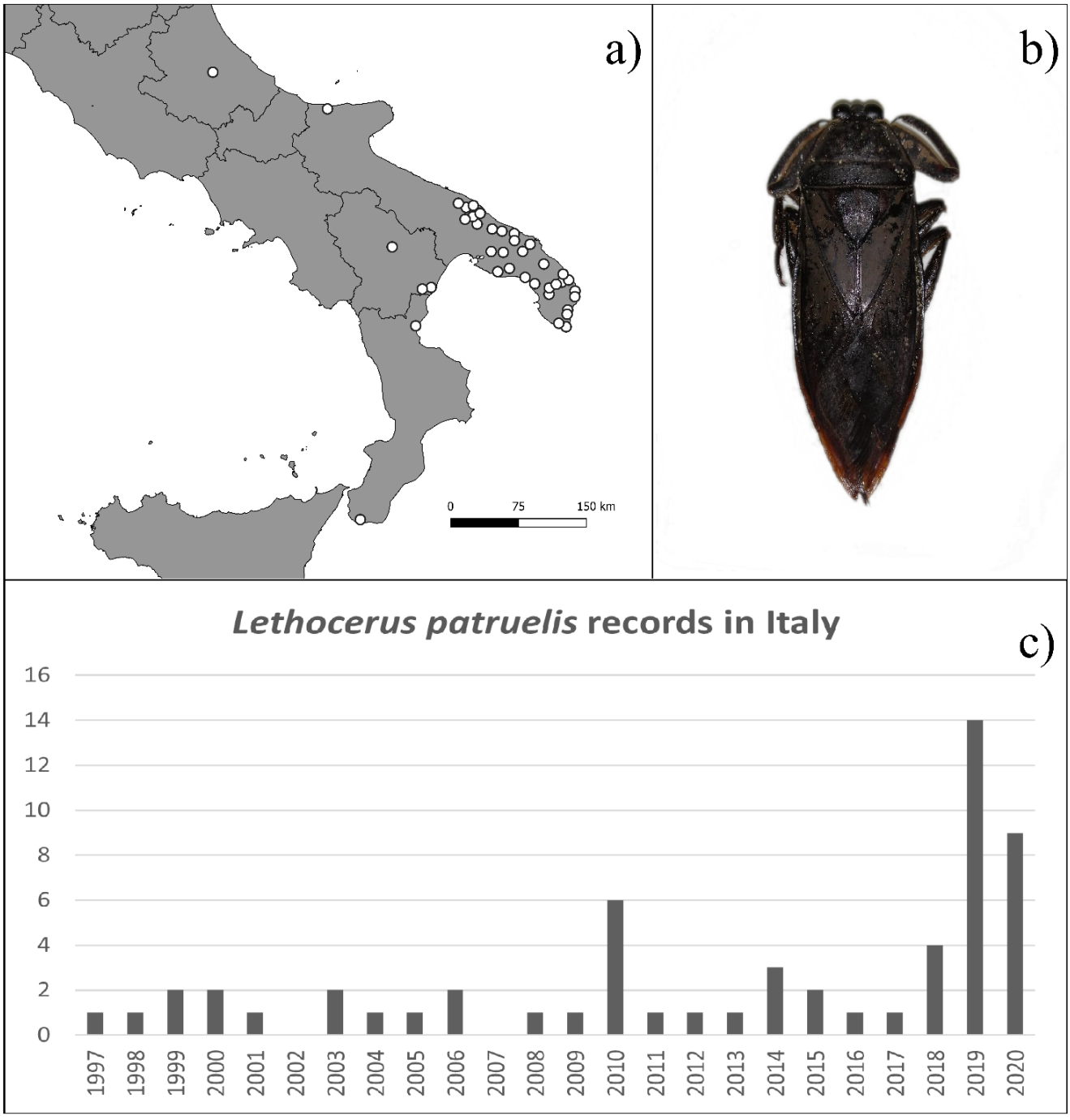

Figure 2: a) *Lethocerus patruelis* observations in Italy; b) ♀ specimen from Salve, Apulia; c) annual frequency of *L. patruelis* findings in Italy.

Since 12 out of 15 sexed individuals were females, it seems plausible that the male parental care typical of the *Lethocerus* genus may lead to a less efficient dispersal of male individuals, as it was suggested by Cianferoni and Nardi (2013), but data are still too scarce to assess whether that is the case.

It should be noticed that 26 of the new records here reported comes from iNaturalist and Facebook groups and pages, as well as 1 record from Castiglione et al. (2020), while 5 of the records from Cianferoni and Nardi (2013) come from entomology dedicated websites: "Forum Entomologi Italiani" (http://www.entomologiitaliani.net), "Forum Natura Mediterraneo" (http://www.naturamediterraneo.com), "Forum Tropicamente" (http://www.tropicamente.it), meaning that more than half (32 out of 59) of *Lethocerus patruelis* Italian records come from publicly available online data sources, while only one record, also reported in Cianferoni and Nardi (2013) comes from a traditional data depository (Bacchi and Rizzotti Vlach 2007). Davranoglou and Karaouzas (2021) report a similar situation, with 30 records coming from Facebook groups, 4 coming from iNaturalist, and only 2 coming from traditional data depositories. Interestingly, there are many more records coming from Facebook groups than from iNaturalist in both Italy and Greece, despite the latter has been specifically designed to collect organisms' observations from citizens. This may be due to the much wider audience hosted on Facebook than on iNaturalist and similar platforms, which are only used by the minority of people with a great interest in collecting biodiversity data. Moreover, at least in Italy, Facebook groups often refers to local areas, spanning from national to regional or sub-regional scales; group members and administrators usually possess a deep knowledge of the focus territories (Marcenò et al. 2020).

Since these unconventional online sources have been proved to be reliable sources of information about the distribution of certain taxa, particularly insect species, it could be very useful to improve the quality of the collected data. Despite it is not possible to uniform search effort by non-scientist citizens on these platforms, it is however possible to add other useful information. For instance, Facebook group and forum admins should encourage members to always include as detailed as possible observation date and location, emphasizing at the same time the importance of explaining the circumstances of the observation (e.g., casual encounter versus targeted search). Concerning scientists, it would be useful for conservationists and biogeographers to become part of these communities, for at least four different reasons: 1) to improve species identifications, in order to avoid accidental misidentifications by amateurs; 2) to monitor possible observations of rare, invasive, or poorly-known taxa, as in the case of this work; 3) to spread awareness about conservation issues, good practices, and the importance of their researches; 4) to "recruit" volunteers to collect presence data on particularly interesting species. These actions by admins and scientists may help reducing data quality differences between actual citizen-science platforms and these unconventional online data sources and increasing the latter's usefulness in scientific research, exploiting their wide user communities.

CONCLUSIONS

This work provides an up-to-date overview of *Lethocerus patruelis* westernmost observations. The collected data suggest that *Lethocerus patruelis* might establish in certain areas of Southern Italy, or it might already have, but definitive proofs of its naturalisation have yet to be found. Remarkably, this work shows the potentiality of unconventional sources, such as social networks and forums as a source of publicly available online data, particularly to monitor elusive species, alien species, and, more generally, species with poorly known distributions.

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