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Research Article

Realtime Social Networking Service rapidly reveals distributions of non-indigenous land snails in a European capital

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Abstract

We utilized a social media website (Facebook) to gather information from citizen scientists on their observations of the introduced large land snail species *Cornu aspersum*, and *Helix lucorum* in Budapest, Hungary. In a Facebook post we presented the project to reveal where the two species occur in Budapest, together with an identification guide which included images. In this study we compiled information received in the two months following the Facebook post. We obtained 44, 92 and 105 locality observations of *H. lucorum*, the native *H. pomatia* and C. *aspersum*, respectively in the city, mostly within five days after the post. Our Realtime Social Networking Service (RSNS) method, which included intensive communication with citizen scientists, revealed that *C. aspersum* was spread in most areas across Budapest, except for the Buda region west of the Danube where *H. lucorum* dominates. Their distributions overlapped with each other only in small ranges. We found that no specimens of these non-indigenous species were present in the collection of L. Drimmer, who extensively collected land snails in the city in the early 1990s. Accordingly, the two non-indigenous species most probably established their current distributions in Budapest in the last 30 years. Our study demonstrates that RSNS method efficiently and rapidly reveals distributions of relatively large animal species in city areas and provides a dependable basis for further research.

Key words: introduced species, *Cornu aspersum*, *Helix lucorum*, *H. pomatia*, Helicidae, Pulmonata, Gastropoda

Introduction

Helix pomatia Linnaeus, 1758 is an indigenous snail species throughout Hungary, whereas the other native species, *Helix lutescens* Rossmässler, 1837, inhabits only the eastern region (Pintér and Suara 2004). Similar large, helicid snails, *Cornu aspersum* (O.F. Müller, 1774) (also known as

Cryptomphalus aspersus, *Helix aspersa* and *Cantareus aspersus*) and *Helix lucorum* Linnaeus, 1758 are native to southern Europe (Welter-Schultes 2012; Neubert 2014) and do not occur naturally in the country. However, *C. aspersum* is known from Hungary since the 1970s (Pintér et al. 1979), and is reported from four sites in the capital city, Budapest (Varga et al. 2010). *Helix lucorum* has been known from Hungary since 1995 (Varga 1995) and Varga et al. (2010) reported one population in Budapest.

Unpublished observations of the presence of the latter two non-indigenous species suggest that both occur more widely in Budapest than previously thought. Therefore, we hoped to survey their current distributions in the Budapest area. Surveying the entire city by a few professional scientists would have taken too long to complete. Furthermore, these snails commonly inhabit private gardens, which are not easily accessible to researchers. Technical development increasingly allows citizen scientists to contribute to monitoring invasive pest species (Bonney et al. 2009; Adriaens et al. 2015); methods using citizen scientists are more suitable for long-term monitoring projects instead of obtaining a snapshot of the current distribution.

To overcome these shortcomings, we utilized social network service (SNS) to gather information from citizen scientists. We obtained a sufficient amount of data within a week to reveal the current approximate distributions of both non-indigenous species in Budapest. Thus, the aim of this study is to show the actual distribution of the invasive *C. aspersum* and *H. lucorum*, and to introduce the Realtime Social Network Service (RSNS) method, which has proved to be useful to rapidly assimilate distribution ranges of relatively large-bodied snail species and present information on their dispersal. As a by-product of our survey, locality data of the native *H. pomatia* were also reported.

Materials and methods

On 8 July 2018 one of us (BPG) posted to Budapest inhabitants in Hungarian on his own Facebook profile explaining the project and asking readers for localities and photographs where they observe snails in Budapest. An identification guide including images of the native Roman snail, *H. pomatia* and the two non-indigenous helicid species was also provided (Figure 1).

Reports arrived as comments to the Facebook post or as messages to the posting author. When the reported locality was not precise, clarification was subsequently requested by correspondence with the reporter. In multiple cases citizen scientists had difficulty distinguishing between *H. lucorum* and *H. pomatia* that have prominent colour bands on their shells. Therefore, we only accepted reports of *H. lucorum* verified with photographs. Citizen scientists had no problem identifying *C. aspersum* and we accepted all records for that species even without photographs. We compiled the present data from responses received by 7 September 2018. Additional reports

Figure 1. Identification guide accompanying the Facebook post. All photos were originally downloaded from the internet, and can freely be used without permission. 1. Photographer: anbalemans (https://www.inaturalist.org/observations/22278061); 2: Wikimedia commons; 3. Photographer: Cheryl McCleary-Catalano https://www.inaturalist.org/observations/22848748; 4: Wikimedia commons; 5: Photographer: Enrico Bisenzi https://www.inaturalist.org/observations/23041376; 6: Photographer: Anne https://www.inaturalist.org/observations/27742764. Hungarian text indicates vernacular names of each species.

came from biologist colleagues, which are listed in the Supplementary material Table S1, but not counted as an outcome of the RSNS method. Furthermore, we have not listed duplicates, i.e. multiple reports of the same species from exactly the same locality. Range sizes were estimates by drawing the smallest possible convex polygon around the localities using Google Earth Professional.

To compare the distributional data gathered via RSNS method to those gathered previously, we used locality data of specimens collected by László Drimmer (1925–2009). He volunteered at the Hungarian Natural History Museum (HNHM) and collected snails in Budapest between 1978 and 2001, most intensively between 1992 and 1993. Most of his specimens were deposited in the HNHM. The specimen labels provide the locality according to streets without house numbers. We entered those street names in Google Earth and marked the locations where this software placed the pin (Google's exact method to place the pin is unknown to us). In some areas where Drimmer collected specimens in the early 1990s, we received very little data via the RSNS method. For these areas, we designed an A5-size flyer that like the Facebook post requested occurrence data for the three species. On 14 and 17 August 2018, one thousand copies of the flyer were distributed to mailboxes along streets of the II., XI., and XII. districts of Budapest (all Buda side) listed in the Table S2.

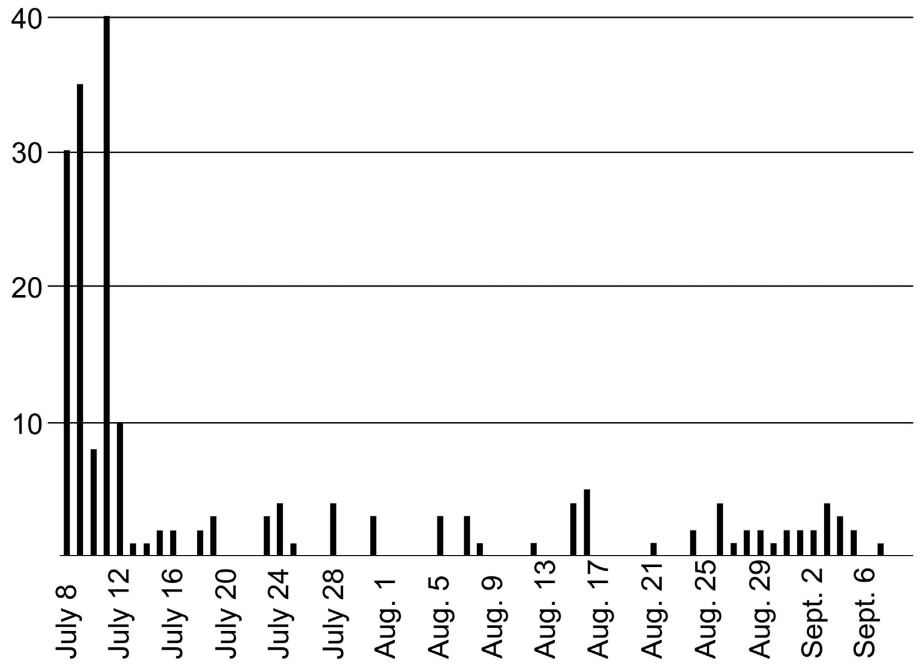

Figure 2. Dynamics in the number of reporting people per day. Facebook post was released on the 8th of July and flyer distributions on the 14th and 17th of August, 2018.

The Roman snail has been split into two species (*H. pomatia* and *H. thessalica* O. Boettger, 1886, see Korábek et al. 2015). Due to the difficulties in distinguishing these two species, we do not distinguish them in this study.

Results

The Facebook post was shared 600–610 times within the first 5 days and 670 times during the two months deadline. Throughout this period, we received locality information for *C. aspersum*, *H. pomatia* and *H. lucorum* from 195 reporters, mostly from Budapest and its vicinity (Figure 2). Within the first 5 days of the post, we received reports from 123 people, but the number of reporters per day greatly decreased. We occasionally received several reports in a day, especially after rain until early September. From the areas where flyers were distributed, we received 13 reports.

Photographs accompanied 182 of the 241 reports of one of three species, *C. aspersum*, *H. pomatia* and *H. lucorum*. In the two months following the Facebook post we received 37 and 101 locality reports for *H. lucorum* and *C. aspersum* in Budapest, respectively (Figure 3, Table S1, Figure S1). These reports revealed that *C. aspersum* occurs throughout Budapest, except for the Buda region, west of the Danube River where *H. lucorum* is most common. The range of *C. aspersum* is 508 km^2 in Budapest and its immediate vicinity, whereas that of *H. lucorum* is 95 km^2. Mapping reported localities revealed that the distributions of these two species do not greatly overlap in Budapest. Only two locality records confirmed their syntopic occurrence. We also received two reports of *H. lucorum* and 23 of *C. aspersum* from places outside Budapest city limits (Figures 3 and 4, Table S1). The occurrence of

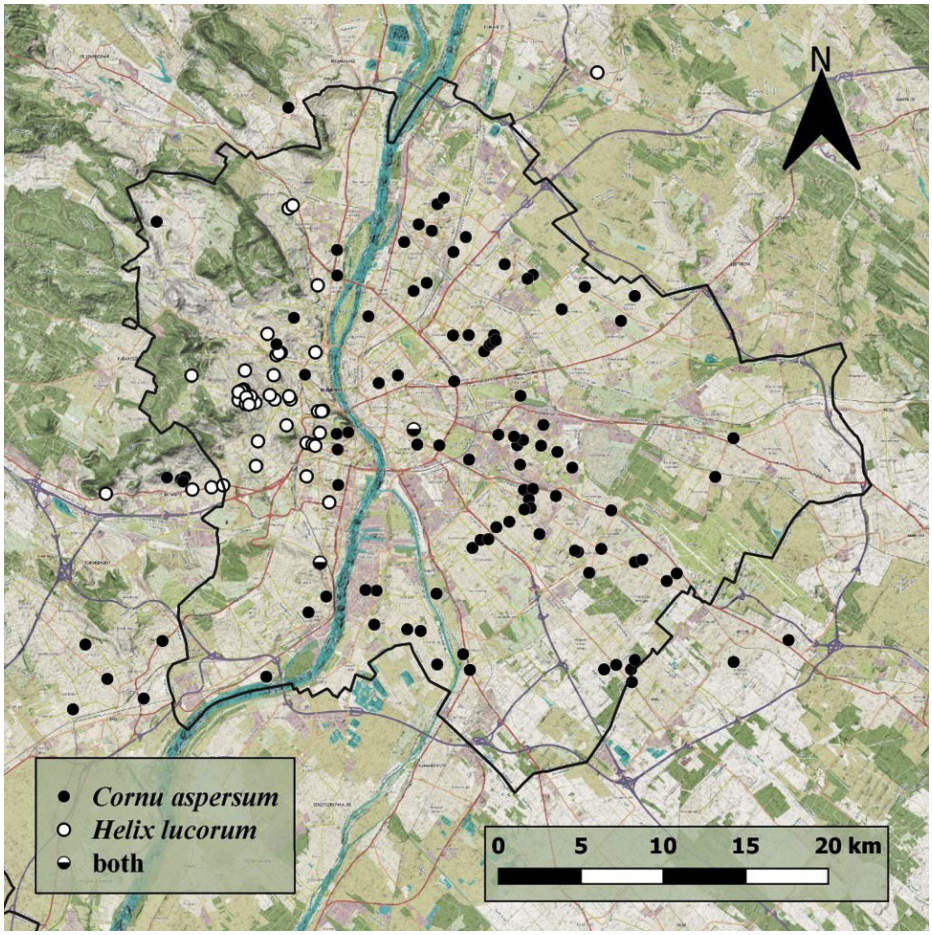

Figure 3. Distributions of *Cornu aspersum* (filled) and *Helix lucorum* (open) in Budapest and its vicinity, based on reports from citizen scientists.

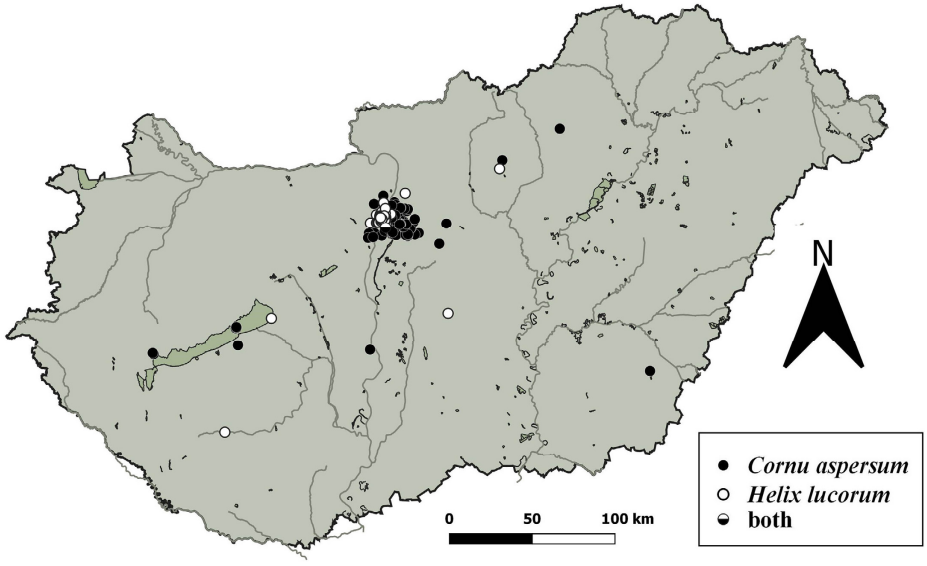

Figure 4. Distributions of *Cornu aspersum* and *Helix lucorum* in Hungary.

H. pomatia was confirmed by reports from 96 sites within Budapest, and from 10 sites in the close vicinity of the city. The distribution of the native species do not show any notable geographical patterns. By compiling information from L. Drimmer's collection in the early 1990s, we found that

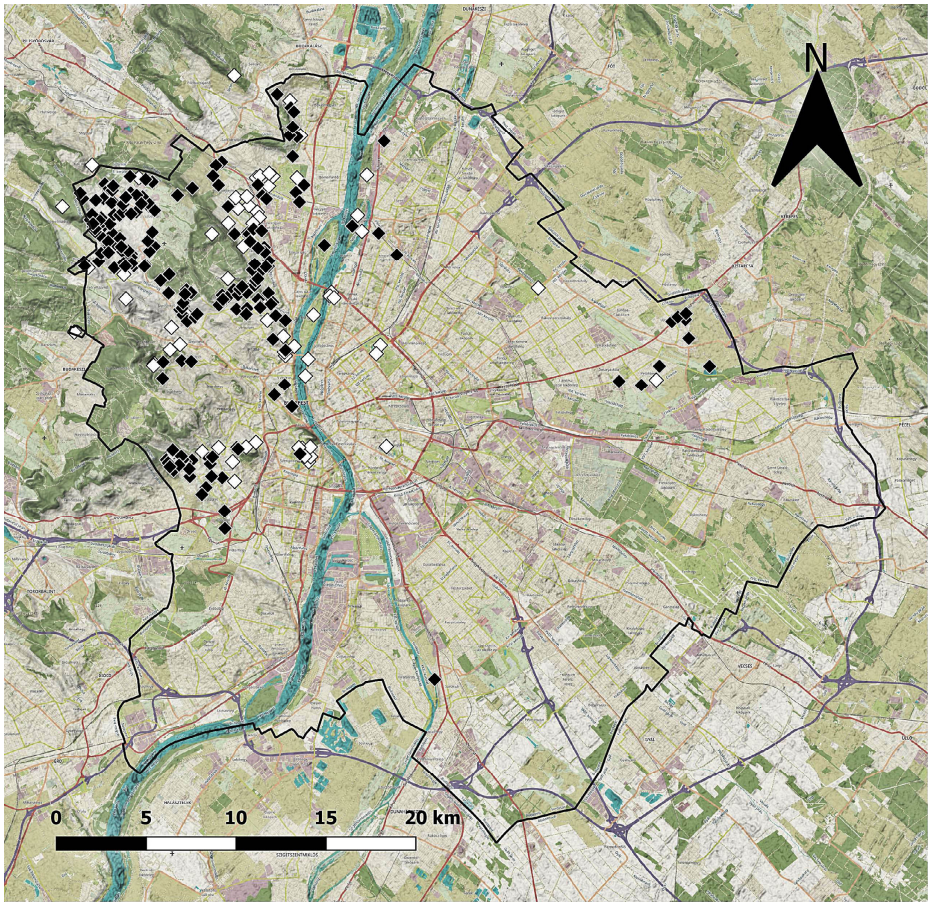

Figure 5. Sites where László Drimmer collected land snails with (filled) and without the native Roman snails (*Helix pomatia*) (open) in the early 1990s.

he collected land snails frequently in the Buda area, west of the Danube River. He collected *H. pomatia* from most of those collecting sites (Figure 5), but we found no specimens of *H. lucorum* and *C. aspersum* in his collection.

Discussion

Distribution and spread of the invasive species

The present results show that *C. aspersum* and *H. lucorum* are now common in Budapest. However, the distribution ranges of these two non-indigenous species do not greatly overlap. The former occurs throughout the city, although much less common in the hilly Buda area, where the latter mainly occurs (Figure 3). *Cornu aspersum* and *H. lucorum* were reported occurring together at only two sites. The infrequency of these reports may have resulted from a possible tendency that each participant responded only for one species at a time, even if the other species was present nearby. This might be the case for the relatively narrow overlapping distributional ranges. However, in our own observations at 16 sites in Budapest, we found only *C. aspersum* at eight sites and *H. lucorum* at the other 8 sites but did not find them together. These results imply possible exclusive interaction between these species.

The present mapping of localities from Drimmer's collection showed that he collected land snails in those areas. We found, however, no specimens of these non-indigenous species in his collection despite their large adult shell sizes. This demonstrates that the two species' distributions in Budapest were established in the last 30 years.

RSNS method

Thousands of citizen science projects have been successfully launched during the last two decades in various fields, especially in biology and conservation (Bonney et al. 2015; Kullenberg and Kasperowski 2016). Citizen scientists are mostly effective in data collection and data processing, and these programs are also useful in increasing public awareness (Bonney et al. 2015). Data collection on invasive species with the help of citizen scientists is becoming more popular. So far approximately 20 such studies have been published, targeting invasive plants (e.g. Crall et al. 2015; Dehnen-Schmutz and Conroy 2018) and animals (e.g. Falk et al. 2016; Maistrello et al. 2016; Grason et al. 2018). Only a minority of those investigations have used SNS, such as Facebook (Davis et al. 2018; Dehnen-Schmutz and Conroy 2018), and even their study period was long, such as several months. On the other hand, our study collected most data that revealed the general distribution of the targeted invasive species within less than a week. This was possible by intensive personal communication with reporting citizen scientists. We refer to this method as RSNS (Realtime Social Network Service) method. We showed that collecting information through social media, such as Facebook, can be efficiently used as a rapid method to determine distributions of land snail species, and probably other conspicuous invasive species as well.

Our Facebook post was immediately and frequently shared and generated many messages. The first author had ca. 760 Hungarian Facebook friends, many of whom were interested in or were working with nature. Most shares were not, however, through his own Facebook connections but by Facebook members not directly linked to him. He also shared his post in Facebook groups that specialize in invertebrate identification with 3,000–4,000 members, and this could have greatly increased the visibility of the post.

The large number of responses that arrived within a short time, may suggest that the targeted non-indigenous snails were known by the citizens who responded to the post, according to the incoming data quality. Many of them reported that they had already recognized the occurrence of snails which look different from *H. pomatia*. Since large land snails and slugs are well-known, and even popular animals among both children and adults (Silvertown et al. 2011; Dörler et al. 2018), citizen scientists may already have had valuable unpublished information on the presence of those snails and even photos of specimens. This type of citizen knowledge resource has

been documented elsewhere too (Dehnen-Schmutz and Conroy 2018), and could be efficiently harvested by RSNS method. Biodiversity monitoring websites may have been considered as modern advanced forums for citizen science due to smart phone applications. Our study, however, demonstrates that the RSNS method could more strongly encourage citizen scientists to present their observations, probably because it requires a minimum investment of time and energy; they do not have to register or log in to any websites other than their social media account, which they typically use on a daily basis. They can simply post or send photos at the moment when they notice the targeted research item. Furthermore, they receive direct feedback from researchers, which we identify as a key element in the success of our data collection project.

Using help of citizen scientists via social media to gather locality data on relatively large land snails has three major advantages. Firstly, urban areas such as gardens are typically not be easily accessible to researchers, but information can be acquired with the help of citizen scientists (Maistrello et al. 2016; Spear et al. 2017; Dörler et al. 2018). The land snails targeted by us also typically inhabit in gardens. Secondly, as our research showed, the RSNS method can gather information more rapidly than most citizen science websites. Speed in data collection would be crucial for management planning against introduced species' spread through nowadays transportations. Thirdly, in addition to the locality data, citizens can also verbally report information about damage in their gardens ascribed to the introduced snails. This information could be further analysed and used for designing research and action plans.

Our study, therefore, shows that a survey by the RSNS method provides a useful basis, which would otherwise be costly to obtain, for further studies, especially in the present case to elucidate causes underlying their barely overlapping distributions. Our method will also allow for testing how stably the current difference of distribution patterns between the two species remains over time.

Origin and dispersal of introduced helicids in Budapest

Cornu aspersum could not only be a garden pest and threat for native vegetation, but also monopolise food resources which would perhaps be critical to indigenous molluscs and transmit parasites and pathogens to the indigenous fauna (Barker and Watts 2002). This species has been introduced to Greece, New Caledonia, Australia, and New Zealand as a human food resource (Gargominy et al. 1996; Barker and Watts 2002; Welter-Schultes 2012). This activity dates back to ancient times (Yıldırım et al. 2004). Successful dispersal of this species may result from its tolerance of diverse climatic conditions (Capinha et al. 2014). For example, it can survive the freezing of up to 60% of its body water (Ansart et al. 2001). *Helix lucorum*

has been introduced to Ukraine, Czech Republic, France, Slovakia, Austria, Spain, Russia, and England (Fischer et al. 2008; Mienis and Rittner 2010; Quiñonero Salgado et al. 2010; Palmer 2010; Peltanová et al. 2012; Balashov et al. 2013; Čejka and Čačaný 2014; Egorov 2017). It survives much colder winters than those in its original range unlike previously thought (Capinha et al. 2014).

The present study found that these species are not present in Drimmer's collection. While *C. aspersum* has occurred in Tihany (city north of the Balaton Lake) in Hungary since the 1970s, the first known specimens in Budapest were collected in 1999 by András Hunyadi (Table S1). *Helix lucorum* has lived in Budapest, Költő Street, since the late 1990s (Domokos 2014). This suggests that the two species were introduced after the early 1990s. Both species may have been transported with on cargo vehicles (Peltanová et al. 2012).

No studies have investigated how these two non-indigenous species were introduced to Hungary. A possible theory for their introduction is suggested by the second author. After the political transition in Hungary in 1989, the breeding, selling and export of helicid land snails became a somewhat popular business opportunity, particularly for the French market. Hungarian business people attempted to operate snail-farming enterprises based on preceding Italian and French examples. They persuaded others to invest in equipment and "breeding snails" of various species for snail farming. Publications, written originally in Italian (e.g. Avagnina 2005), were translated to Hungarian and distributed among potential snail breeders. As a consequence, a large number of live *C. aspersum* were imported from North Africa, Southern and Western Europe, and Chile. At some time snails escaped or were released, leading to the establishment of the species in the wild in Hungary. The introduction of *H. lucorum* probably happened because the native snail *H. pomatia* became protected from collection for commercial purposes in Hungary. Thus, breeding stocks of *H. lucorum* were legally imported and this species eventually became established in the wild. The restricted range of *H. lucorum* in the western part of Budapest implies that it has spread from one or a few sources only. However, populations outside of Budapest could be the results of the introduction pathways outlined above.

The rapid spread of these species could also partly be explained by their active dispersals. *C. aspersum* is able to move up to 50 m per day (Jørgensen and Sørensen 2008) and thus could theoretically disperse across the city of Budapest within a few years. Furthermore, the general public might speed the spread of non-indigenous snails. For example, three citizen scientists reported in the present survey that they recognized these snails including *H. pomatia* were damaging their gardens but did not want to kill them. They instead collected and released them in nearby small forested areas.

Conclusions

We used a Facebook post to gather information from citizen scientists on the distributions of the native Roman snail (*H. pomatia*), and two similar, invasive species (*H. lucorum* and *C. aspersum*). Although gathering data with the help of citizen scientists has been a common practice in conservation biology and pest species monitoring, this is typically done in long-term projects, and does not allow for an immediate survey of real-time distribution. Our Facebook post provided us with enough data to reveal the distributions of the native and introduced species within a week, which opens new perspectives for the Realtime Social Networking Service (RSNS) method to monitor biological invasions.

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Supplementary material

The following supplementary material is available for this article:

Table S1. List of localities of *Helix pomatia* (native), *H. lucorum* (invasive) and *Cornu aspersum* (invasive).
Table S2. List of streets where flyers were distributed.
Figure S1. kmz file (compatible with Google Earth) of *Cornu aspersum*, *Helix lucorum* and *Helix pomatia* in Hungary.

This material is available as part of online article from:
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