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Ophraella communa, the ragweed leaf beetle, has successfully landed in Europe: fortunate coincidence or threat?

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Summary

We report the occurrence of the North American ragweed leaf beetle *Ophraella communa* in Europe. During our surveys to monitor populations of the invasive alien plant *Ambrosia artemisiifolia* in Europe, we found the beetle south of the Alps, in more than 130 sites in southern Switzerland (Ticino) and northern Italy (Lombardia, Piemonte and Emilia-Romagna). At sites where *O. communa* was present, up to 100% of the plants were attacked with damage levels high enough to completely defoliate and prevent flowering and seed set of most ragweed plants. That in its first year of discovery, *O. communa* was already found over a large area of c. 20 000 km^2 and in all habitat types occupied by *A. artemisiifolia* reflects its great dispersal potential and wide habitat suitability. This oligophagous beetle is a successful biological control agent against *A. artemisiifolia* in China, but despite extensive host specificity tests, the risk of attack and the level of damage of sunflower under field conditions remain unclear. The recently launched COST Action on 'Sustainable management of *Ambrosia artemisiifolia* in Europe (SMARTER)' offers an ideal framework to respond quickly to the recent establishment of *O. communa* in Europe and to collect data that can help determine whether this event should be considered a troublesome introduction or whether it is likely to become the first case of a successful biological control of an invasive weed in continental Europe.

Keywords: biological control, leaf feeder, weed management, invasive alien species, *Ambrosia artemisiifolia*.

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Introduction

Ambrosia artemisiifolia L. (Asteraceae; common ragweed) has uniquely raised the awareness of invasive alien plants in Europe (Shine *et al*., 2010). This plant originates from North America but has become widespread in other continents, including Asia, Australia and Europe (Cunze *et al*., 2013; GISD, 2013). In

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Europe, it is most abundant in the Pannonian Plains, the Lyon area in France, the Milano area in Italy, Ukraine and southern Russia (Prank *et al*., 2013). The main problem with this plant is its production of highly allergenic pollen, generating huge medical costs and reduced quality of life among the allergic population (Fumanal *et al*., 2007). *Ambrosia artemisiifolia* also has become a major weed in European agriculture, especially in spring-sown crops such as sunflower, maize, sugar beet and soybean (Komives *et al*., 2006). The spread and impact of *A. artemisiifolia* is likely to increase with changing climate, posing a significant risk to society, even in countries presently not yet affected, as evidenced by both ecological niche models (Hyvönen *et al*., 2011; Bullock, 2012; Cunze *et al*., 2013) and process-based (or mechanistic) distribution models (Chapman *et al*., 2014). Chemical and mechanical control methods have been developed and partially implemented to control *A. artemisiifolia* (Buttenschøn *et al*., 2010), but they are not a solution for all invaded habitats and often do not result in the eradication of populations. To mitigate *A. artemisiifolia*'s further spread and to reduce its abundance in badly infested areas in Europe, sustainable control strategies need to be based on a combination of methods.

While classical biological control of *A. artemisiifolia* has been successfully implemented in other continents (Australia, China: Palmer *et al*., 2010; Zhou *et al*., 2010), this long-term management tool is not yet implemented in Europe. Biological control attempts in China started in the mid-1960s and up to the 1980s, five insects species were sequentially introduced (Wan *et al*., 2009). Presently, the most efficient and successful species are the stem-galling moth *Epiblema strenuana* (Walker) (Lepidoptera: Tortricidae; first released in 1993) and the leaf beetle *Ophraella communa* LeSage (Coleoptera: Chrysomelidae; accidental introduction, discovered in 2001), both with up to six generations per year in southern China (Chen *et al*., 2013).

The recently started EU-COST Action 'Sustainable management of *Ambrosia artemisiifolia* in Europe (SMARTER)' aims to develop a sustainable management strategy for *A. artemisiifolia* in Europe, with a focus on biological control (cf. www.ragweed.eu). In this framework, a recent literature survey to explore prospects for biological control in Europe prioritised six insect herbivores and one rust pathogen from the native North American range of the plant; the few natural enemies that have colonised *A. artemisiifolia* in Europe are polyphagous and cause little damage, rendering them unsuitable for an augmentative approach (Gerber *et al*., 2011). However, to our surprise, we found large infestations of a leaf beetle in southern Switzerland and northern Italy in the summer and autumn of 2013. The beetle was discovered and then surveyed independently by different teams in different regions. During regular surveys of the Swiss cantonal phytosanitary service of Ticino, we found for the first time an infestation by a leaf beetle in Switzerland (Balerna, 12 July; Appendix 1). A quick scan of the area in Ticino and Varese (Lombardia, Italy) within the next 2 weeks revealed that many other *A. artemisiifolia* sites were infested. Morphological identification of specimens collected at three of these sites (1x Ticino, 2x Varese, cf. Appendix 1) confirmed that the specimens collected were *O. communa*. This corroborated morphological and molecular analyses of beetles collected in a parallel survey in Lombardia from another site in Varese (Castellanza, 30 July) (Appendix 1, Boriani *et al*., 2013). In hindsight, the beetle had also already been seen in the Milano area (Lombardia, Italy: Abbiategrasso, 10 July) by the local health service authority, but had not been recognised at the time. In Piemonte, the beetle was first observed by the local phytosanitary service (Galliate, 7 Aug.).

Ophraella communa is presently regarded in China as the most successful weed biological control agent, killing *A. artemisiifolia* plants over large areas before seed set (FH Wan and ZS Zhou, personal communication 2013). This effect could not only be achieved through inundative releases (after mass rearing and field releases on a given population), but also through migration of the beetles following rapid local population build-up (Guo *et al*., 2011; Chen *et al*., 2013). The three larval stages and the adults of the beetle all feed on leaves of *A. artemisiifolia* (Wan *et al*., 2009).

Here, we present results on the occurrence of *O. communa* in Europe in 2013 and the phenology of attack at sites in northern Italy and southern Switzerland. We briefly discuss the type of data that need to be collected to allow a thorough assessment of whether the establishment of *O. communa* in Europe should be considered as a fortunate coincidence in the campaign against the highly invasive *A. artemisiifolia*, or whether it should be considered as a threat to closely related wild or crop species.

Materials and methods

After discoveries of the beetle in early summer 2013 in both Switzerland and Italy, several teams independently performed a preliminary survey of *O. communa* occurrences in adjacent areas. As the different teams had no prior knowledge of each other's activities, surveying methods had not been standardised. As soon as the different teams knew of the others' work, they immediately decided to homogenise the data as far as possible. Finally, a handful of beetle occurrences reported by others that we had instructed were included in the data set. From mid-July to mid-October 2013, more than 150 *A. artemisiifolia* sites in Italy (121), Switzerland (30) and France (4) were surveyed. Surveys were generally limited to the area where the conducting authority is active (Swiss cantons, Italian regions or provinces, French departments) and was sometimes extended somewhat beyond these borders. In the most severely infested areas (Swiss cantons Ticino and Geneva, Italian province Milano), the surveys were part of the regular *A. artemisiifolia* monitoring by local authorities and previously known *A. artemisiifolia* sites were visited. In other parts of Lombardia and in Piemonte, where exact location records of *A. artemisiifolia* populations do not always exist, researchers surveyed suitable areas (construction sites, road sides, cultivated fields, ruderal sites) to find populations that were then inspected for the presence of the beetle. In France, four known *A. artemisiifolia* sites were visited in the departments of Cote d'Or and Saône-et-Loire.

Generally, we recorded the presence of the beetle, looking for all developmental stages and if possible, we estimated the incidence of attack (% of plants with leaf beetles and/or leaf beetle damage) and described the phenology of the beetles and of the attacked plants. The level of damage was later standardised by categorising the median level of damage at the site (by visually inspecting a variable number of plants) as very low (very few leaves slightly damaged), low (some leaves damaged), medium (many leaves damaged, damage as in Fig. 1A), medium-high (partly defoliated) or high (extensive defoliation, flowers not developed or dried, Fig. 1B–D). Time spent at sites varied from 10 to 90 min. Some of the sites were visited several times throughout the season. Occasionally, neighbouring Asteraceae plants were also inspected for the presence of the beetle. As sites were not selected in a stratified and random way, we only report sites where the beetle was found, and not those where the beetle was absent.

Results

Ophraella communa occurrences

So far, *O. communa* has only been observed south of the Alps (Fig. 2), where we found it in more than 80% of sites surveyed, covering an area of c. 20 000 km^2 (112/121 sites in Italy, 20/30 in Switzerland, 0/4 in France, details of occurrences in Appendix 1, including habitat types occupied by *A. artemisiifolia*). The beetle occurs frequently in southern Switzerland throughout the canton of Ticino (both Sottoceneri and Sopraceneri), and in the Italian regions Lombardia (provinces Bergamo, Como, Cremona, Lecco, Lodi, Milano, Pavia, Varese) and Piemonte (provinces Alessandria, Biella, Novara, Torino, Verbano-Cusio-Ossola, Vercelli), and at a single site in Emilia-Romagna. Overall, we observed higher incidence of attack by *O. communa* at sites near to Milano Malpensa International Airport (province of Varese, and adjacent provinces of Novara and Como), and lower levels towards the north, west and south (Fig. 2). The beetle was neither observed in Swiss *A. artemisiifolia* sites north (Thun) or west of the Alps (Geneva), nor in France (Cote d'Or, Saône-et-Loire). Although no specific surveys were performed in other European countries, SMARTER members involved in ragweed surveys have not reported the presence of the beetle in their countries after its occurrence in Italy and Switzerland had been communicated to them.

Phenology of attack

Details of incidence and level of attack of *A. artemisiifolia* by *O. communa* are given in Appendix 1.

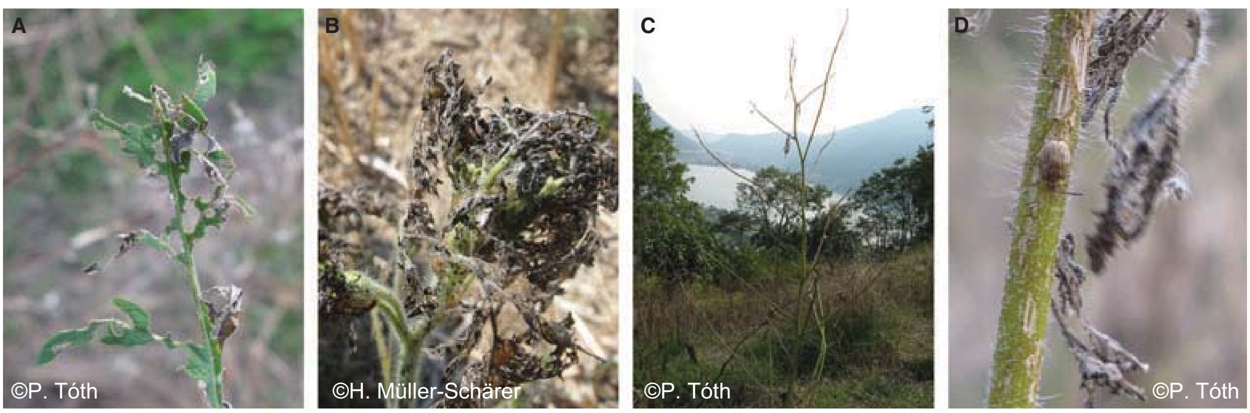

Fig. 1 Impact of *Ophraella communa* on *Ambrosia artemisiifolia*. Different types and levels of plant damage: A. Partial leaf damage; B. All leaf tissue damaged or dried out, plant full of pupae; C. Complete defoliation, no reproductive structures present; D. Male flowers dead, stem tissue damaged.

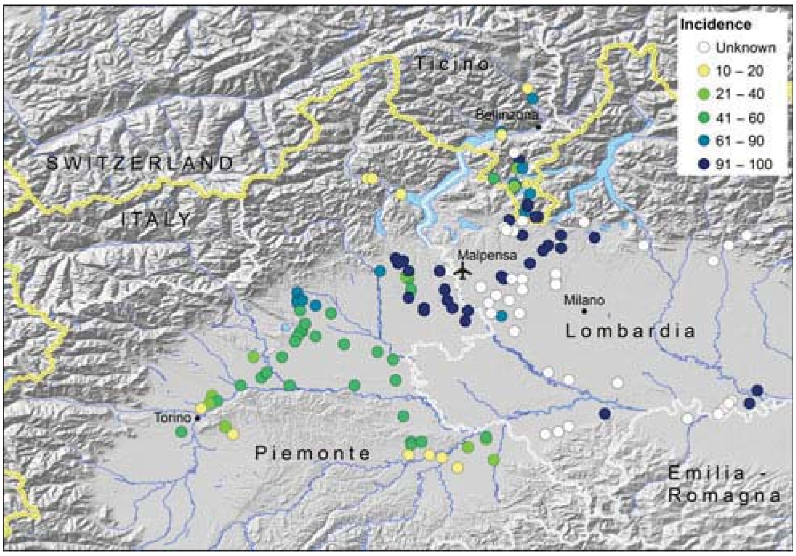

Fig. 2 Occurrence of *Ophraella communa* in Europe in 2013. Dots indicate sites where *O. communa* was found on *Ambrosia artemisiifolia*, colours represent the incidence of attack (% of plants attacked) at the time of observation.

Fig. 3 *Ophraella communa* on *Ambrosia artemisiifolia*. Different developmental stages: A. Eggs; B. Larva; C. Pupa; D. Adult; and E. Thousands of *O. communa* in a sweeping net after 10 sweeps in a field full of *A. artemisiifolia* near Milano (Corbetta, 24 Sept. 2013). Adults and the three larval stages of the beetle all feed on the leaves. Based on extensive laboratory studies (Zhou *et al*., 2010) and field observations (Chen *et al*., 2013) on temperature dependent developmental time in China, we expect 3–4 beetle generations per year in the areas, where it is presently occurring in Europe.

Generally, the level of attack rapidly increased over time. In Switzerland, *A. artemisiifolia* plants with leaf beetles and leaf beetle feeding damage were first observed in mid-July 2013 in Balerna, canton Ticino. At that moment, plants were still in the vegetative or bolting phase. The damage consisted of perforated and desiccated, dead leaves (Fig. 1A). All developmental stages of the leaf beetle (Fig. 3A–D) were found to co-occur on single plants. Larvae were usually found on young leaves at the top of the plants, whereas eggs, pupae and adults were encountered throughout the plants. Incidence and level of attack strongly varied within and between sites. One month later in August, numbers of individuals per plant and incidence of attack had increased. More heavily attacked plants harboured mainly larval stages (Fig. 1B).

Towards the end of the *A. artemisiifolia* season (end of September, October), the incidence of attack had further increased, reaching 100% at many sites, and the plants were generally entirely defoliated and dead (Fig. 1C). However, the presence of reproductive structures varied; at some sites, no reproductive structures were produced, whereas at other sites, defoliated and dead plants still had seeds. This variation in attack is likely to reflect the arrival time of the beetles, with those plants bearing seeds only being attacked after formation of the flowers. At this time of the season, stems of *A. artemisiifolia* also showed feeding damage. Generally, adult beetles were the most frequently encountered stage, whereas the few eggs and larvae recorded were mostly observed on male flowers. In the presence of *O. communa*, plants still bearing green leaves could only be found at sites with low attack rates or at sites that had been managed by mowing and *A. artemisiifolia* plants had regrown. At these sites, hundreds of adult beetles were found on the plants, and leaves were perforated due to feeding. Sweeping a field dominated by such regrown

A. artemisiifolia plants yielded thousands of adults and larvae (Fig. 3E). When one of these sites was revisited 4 weeks later, very few green parts of the plants were left and beetles were still found on the plants.

As with the incidence of attack, the level of attack was generally higher closer to Milano Malpensa International Airport (Fig. 2), even though sites in that area were on average monitored earlier than those further away (cf. Appendix 1). This might reflect higher beetle numbers early in the season at these sites in the vicinity of Malpensa and a more rapid population build-up over the subsequent beetle generations. The incidence and level of attack was lowest in the north, west and south of the presently known distribution of *O. communa*.

Host plant range at the field sites

Even at *A. artemisiifolia* sites with high beetle numbers, they were usually not observed on other plants. Slight damage of leaves by nibbling of adults was observed at one ruderal site on several *Dittrichia (Inula) graveolens* (L.) Greuter, and at one site at a river bank on *Helianthus tuberosus* L. Adult beetles were found once on neighbouring *Conyza canadensis* (L.) Cronquist, *Persicaria maculosa* Gray and cultivated *Zea mays* L., but damage by the beetles was not observed. Beetles were only once (in a private vegetable garden in Treviglio (province of Bergamo) found on the Asteraceen *Artemisia vulgaris* L., which often co-occurred with *A. artemisiifolia*. Conversely, at sites where *O. communa* was most abundant, other arthropods (aphids, herbivorous bugs, flea beetles, larvae of generalist lepidopterans, spider mites) were only observed a few times on the *A. artemisiifolia* plants and stem-boring insects were never found.

Discussion

Introduction of O. communa *into Europe*

At present, it is not clear how *O. communa* arrived in Europe. The observed highest levels of incidence and level of attack near Milano with a generally decreasing gradient away from it, and the fact that the first observations of *O. communa* in Italy were made in the area of Milano Malpensa International Airport (province of Varese, and adjacent provinces of Novara and Como), suggest that *O. communa* may have been accidentally introduced by air traffic or commercial exchanges related to the airport. In China, the beetle is estimated to spread over hundreds of kilometres and reaching outbreak densities in about 50% of the area colonised within 3–4 years (Zhong-Shi Zhou, personal comment). Because *A. artemisiifolia* infestations in northern Italy and southern Switzerland are regularly monitored and no beetles were observed in previous years, we suspect that *O. communa* has been introduced into Europe <5 years ago. Interestingly, the North American leaf beetle *Diabrotica virgifera virgifera* LeConte, which has become the most important pest of maize in several countries of Central and Eastern Europe, showed a very similar pattern in Italy, with regard to its first detection (in close vicinity of airports in northern Italy in 1998–2000) and early spread across the Po plain (mainly Lombardia and Piemonte; Boriani *et al.*, 2006).

While in Europe economically harmful insects are banned from entering and being moved around the continent, there remain significant gaps in the interception of pest species, as well as of insects that are not listed as quarantine species (Bacon *et al.*, 2012). On the other hand, in the history of biological control there are cases where exotic organisms that were under consideration for biological control of insect pests or weeds were deliberately collected in the area of origin and released without careful pre-release studies and without permission (e.g. the pathogen *Phragmidium violaceum* (Schulz) against blackberry in Australia; Evans, 2000; McFadyen, 2004). This latter procedure is most risky and should obviously be avoided, but it cannot be excluded that *O. communa* has been introduced in this way. In any case, it will be important to determine the origin of the introduced beetles by comparing the genetic make-up of the populations in Europe with those in the native range in the USA and in China where the beetle is mass-reared and mass-released (Guo *et al.*, 2011).

Potential impact of O. communa

Initial observations made in 2013 suggest that, at least in northern Italy and southern Switzerland, *O. communa* can reach high enough densities to completely defoliate and prevent flowering of most *A. artemisiifolia* plants at a field site. These observations are in line with the results of an experimental study in China revealing that *O. communa* release densities of approximately one adult per plant when used at the early plant growth stage, or 12 adults per plant at its late growth stage (plants of 90–100 cm in height), can kill *A. artemisiifolia* prior to seed set (Kovalev *et al.*, 1983; Guo *et al.*, 2011). In August 2013, *A. artemisiifolia* plants at Swiss and Italian sites surveyed had not set seed yet, whereas the number of pupae easily exceeded 12 per plant. In September 2013, two of these sites that had not been managed in the meantime were revisited (Magnago, Rovio) and it was observed that plants were all completely defoliated, even those exceeding

1 m in height, and had only set few seeds (tens to hundreds instead of thousands). It is also promising that *O. communa* has already been found over a large area of c. 20 000 km^2 and in all habitat types occupied by *A. artemisiifolia* in this first year of discovery, reflecting its great potential for natural dispersal and wide habitat suitability. In parallel, seasonal pollen loads and daily maxima of pollen in the air in the area of Milano (70–80% lower than the lowest observed values in the previous 10 years; M. Bonini, unpublished results) and in the canton of Ticino, Switzerland (significantly reduced pollen loads in 2013 as compared with 2009–2012; M. Rossinelli, unpublished report), were remarkably low in 2013, which might be explained by the presence of the beetle. However, it remains to be shown whether the high numbers of *O. communa* in northern Italy and Switzerland in 2013 were incidental and resulting from particularly favourable weather conditions, or whether they represent a build-up of stable populations with high beetle densities that may spread further over the next few years. In this regard, it will be important to follow overwintering of the adults and oviposition in Spring 2014, as related to the *A. artemisiifolia* phenology.

Potential risks of O. communa *to other plants*

Because this beetle is already used as a biological control agent in China, its potential risks to non-target species are well known. *Ophraella communa* is reported to be oligophagous, feeding on various plants species belonging to the tribe Heliantheae (Asteraceae; Futuyma & McCafferty, 1990; Palmer & Goeden, 1991). Despite extensive host specificity tests carried out over the past two decades (reviewed by Zhou *et al*., 2011), there remains a controversial debate mainly on whether the beetle can attack and damage sunflower, *Helianthus annuus* L., in the field. Because host specificity tests revealed that *O. communa* can attack and complete its life cycle on sunflower under no-choice conditions, the species was rejected as biological control agent for Australia (Palmer & Goeden, 1991). Recent studies in Canada and China indicate, however, only a low risk of *O. communa* to sunflower plants in the field; *Ophraella communa* rarely lays eggs on sunflower under choice conditions, larval survival on sunflower is low, and newly emerged adults leave the sunflower plants in search of *A. artemisiifolia* plants (Dernovici *et al*., 2006; Cao *et al*., 2011; Zhou *et al*., 2011). All host-range tests conducted so far indicate that this beetle is specific to the tribe Heliantheae (Gerber *et al*., 2011; Zhou *et al*., 2011). If so, then the number of plant species that are potentially at risk in Europe is limited; the only native European species within the tribe Heliantheae is *Ambrosia maritima* L., which grows in coastal habitats in southern Europe (Gerber *et al*., 2011). In the past, the genus *Inula*, which includes several species native to Europe, was placed in the tribe Heliantheae, but it is now considered to be in the separate tribe Inuleae (http://tolweb.org/Heliantheae/22924). In this respect, it is noteworthy that at one field site in northern Italy, adults of *O. communa* were found sitting and nibbling, but not damaging *Dittrichia* (*Inula*) *graveolens*, a member of the tribe Inuleae.

Directions for further research

A more thorough and stratified sampling of *A. artemisiifolia* populations across a larger area will be undertaken to more precisely assess the current distribution of *O. communa*. This will allow the study of the potential relationship between its occurrence and *A. artemisiifolia* abundance, as well as with environmental variables, such as habitat and climate. The potential occurrence of this insect in other parts of Europe could be predicted using a mechanistic species distribution modelling approach, where physiological models of insect development are integrated into species distribution models based on habitat suitability (Kearney & Porter, 2009; Dormann *et al*., 2012).

The establishment of *O. communa* in northern Italy and southern Switzerland also offers the opportunity to assess both the impact and the risks of non-target attack by this potential biological control agent under field conditions. For example, with respect to impact studies, enclosure or exclosure studies can reveal the impact on *A. artemisiifolia* populations under European conditions. A population dynamics modelling approach will be useful to predict the potential impact on *A. artemisiifolia* in the long term (Morin *et al*., 2009) and to assess whether an equilibrium of low levels of *A. artemisiifolia* and biological control agent densities can be maintained (Buckley *et al*., 2005). Also, the response of parasitoids and predators, such as the Asian ladybird *Harmonia axyridis* (Pallas), which is reported to feed on *O. communa* in Asia (Moriya *et al*., 2002) and which has invaded large parts of Europe (Brown *et al*., 2008), to this new and abundant host/prey should be carefully watched and incorporated in predictions of impact.

Regarding host specificity studies, *A. maritima*, European representatives of the tribe Inuleae as well as European sunflower cultivars could be planted next to heavily infested *A. artemisiifolia* plants to monitor the likelihood of colonisation and damage of these plant species, once the *A. artemisiifolia* plants are completely defoliated by *O. communa*.

Interestingly, *Epiblema strenuana*, the other insect that is considered to be a successful biological control agent of *A. artemisiifolia* in China (Wan *et al.*, 2009), was recently detected in Israel and is believed to have been accidentally introduced via import of plant material from the USA (Yaacoby & Seplyarsky, 2011). Similarly, the noctuid moth *Tarachidia* (syn.: *Ponometia*) *candefacta* Huebner, initially released as the first intentional introduction of a natural enemy for the biological control of an invasive exotic plant into Europe (in 1969 from Canada and California for *A. artemisiifolia* control to Krasnodar and Stavropolis regions in the territory of the former Soviet Union), has recently been reported to have spread westwards to the Ukraine in 2004, Bulgaria in 2010 and Serbia in 2011 (Stojanovic *et al.*, 2011; and references therein). This leaf feeder is well established in Russia but so far is considered an ineffective agent, potentially due to predation of the larvae or unsuitable climatic conditions, but it was given first priority for further studies in view of its use as a biological control agent in Europe (Gerber *et al.*, 2011 and references therein).

The recently launched COST Action FA1023 'Sustainable management of *Ambrosia artemisiifolia* in Europe (SMARTER)' is an ideal framework to respond quickly to the recent establishments of *O. communa* and *T. candefacta* in Europe and *E. strenuana* in Israel and to collect the data that will help decide whether these events should be considered as a troublesome introduction of an alien invertebrate that causes damage to crops or native plant species, or whether it is likely to become the first case of a successful biological control of an invasive weed in Europe. If *O. communa* is unlikely to cause non-target effects in Europe, the data collected in the frame of SMARTER may help compile requests to the competent national authorities for the deliberate release of this biological control candidate into other European countries heavily affected by *A. artemisiifolia*.

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Appendix 1 Occurrences of *Ophraella communa* in Europe in 2013. The table lists sites where *O. communa* was found on *A. artemisiifolia*. The location (country, region, district/province, town, GPS data), habitat, estimated incidence of *O. communa* (% of plants attacked, NA = not available) and a description of the observed damage are given for the date of observation. Sites with * indicate beetle populations that have been used for morphological identification in this study, the site with ** indicates the population used for earlier identification by Boriani *et al*. (2013).

Country (1)	Region (2)	Distr/Prov (3)	Town	N (°)	E (°)	Habitat (4)	Date	Incidence (%)	Damage level (5)
CH	TI	LO	Locarno	46.17	8.87	C	12–9	80	NA
CH	TI	LO	Locarno	46.16	8.87	RU	20–8	10	NA
CH	TI	LU	Barbengo	45.97	8.92	RU	12–8	90	Med-high
CH	TI	LU	Barbengo	45.97	8.92	MP	12–8	80	NA
CH	TI	LU	Barbengo	45.96	8.92	MP	12–8	40	NA
CH	TI	LU	Capriasca	46.06	8.94	RU	13–9	95	Med-high
CH	TI	LU	Croglio	45.99	8.84	RU	26–9	50	Very low
CH	TI	LU	Manno	46.03	8.93	RU	26–7	30	NA
CH	TI	LU	Mezzovico	46.09	8.92	MP	17–7	NA	No damage
CH	TI	LU	Porza	46.03	8.95	MP	13–9	80	Medium
CH	TI	LU	Rovio	45.93	8.98	MP	12–8	90	High
CH	TI	ME	Balerna	45.84	9.01	RU	10–9	98	Med-high
CH	TI	ME	Balerna*	45.84	9.01	RU	12–7	100	Med-high
CH	TI	ME	Ligornetto	45.86	8.96	C	20–8	85	High
CH	TI	ME	Novazzano	45.84	9.00	RU	10–9	100	High
CH	TI	ME	Rancate	45.88	8.97	RU	25–7	95	Med-high
CH	TI	ME	Rancate	45.88	8.97	RU	25–7	95	NA
CH	TI	ME	Rancate	45.89	8.97	RU	25–7	95	Med-high
CH	TI	RI	Iragna	46.34	8.97	MP	3–9	20	Low
CH	TI	RI	Osogna	46.30	8.99	RU	20–9	80	Med-high
IT	ER	PC	Rottofreno	45.06	9.59	RO	11–9	NA	Very low
IT	LO	BG	Cene	45.77	9.82	RB	20–9	NA	Low
IT	LO	BG	Nembro	45.73	9.75	RU	20–9	NA	Low
IT	LO	BG	Orio al Serio	45.67	9.69	RO	12–9	NA	Low
IT	LO	CO	Albavilla	45.82	9.19	RO	31–8	NA	NA
IT	LO	CO	Binago*	45.8	8.92	RO	25–7	NA	Very low
IT	LO	CO	Cadorago	45.73	9.05	RO	22–8	100	Med-high
IT	LO	CO	Cantù	45.72	9.10	RO	NA	100	Med-high
IT	LO	CO	Castelnuovo Bozzente	45.77	8.95	RO	26–9	100	Med-high
IT	LO	CO	Como	45.77	9.10	RO	NA	100	Med-high
IT	LO	CO	Lomazzo	45.71	9.03	RO	22–8	100	Med-high
IT	LO	CO	Lurago d'Erba	45.76	9.23	RO	23–9	100	Med-high
IT	LO	CO	Turate	45.66	8.98	C	5–9	100	Med-high
IT	LO	CO	Uggiate	45.8	8.95	RU	25–7	NA	Med-high
IT	LO	CR	Crotta d'Adda	45.17	9.86	RB	11–9	100	Low
IT	LO	LC	Calco	45.73	9.42	RO	5–9	NA	Low
IT	LO	LO	Corno Giovine	45.13	9.76	RO	11–9	NA	Low
IT	LO	LO	Meleti	45.12	9.83	RO	11–9	100	Med-high
IT	LO	LO	San Rocco al Porto	45.10	9.73	RO	11–9	NA	Low
IT	LO	LO	San Rocco al Porto	45.08	9.71	RO	11–9	NA	Low
IT	LO	LO	Santo Stefano Lodigiano	45.12	9.75	RO	11–9	NA	Low
IT	LO	MI	Abbiategrasso	45.40	8.92	NA	10–7	NA	NA
IT	LO	MI	Arconate	45.54	8.85	NA	22–8	NA	NA
IT	LO	MI	Boffalora Sopra Ticino	45.47	8.83	NA	22–8	NA	NA
IT	LO	MI	Casorezzo	45.52	8.90	NA	22–8	NA	NA
IT	LO	MI	Cerro Maggiore	45.60	8.95	NA	22–8	NA	NA
IT	LO	MI	Cesate	45.59	9.08	NA	22–8	NA	NA
IT	LO	MI	Corbetta	45.47	8.94	C	13–8	NA	Med-high
IT	LO	MI	Cuggiono	45.51	8.82	NA	22–8	NA	NA
IT	LO	MI	Garbagnate Milanese	45.58	9.08	NA	22–8	NA	NA
IT	LO	MI	Legnano	45.60	8.91	NA	22–8	NA	NA
IT	LO	MI	Magenta	45.46	8.87	C	13–8	90	High
IT	LO	MI	Magnago	45.57	8.79	MP	13–8	NA	Med-high
IT	LO	MI	Parabiago	45.56	8.95	NA	22–8	NA	NA
IT	LO	MI	Solaro	45.62	9.08	NA	22–8	NA	NA

Appendix 1 (Continued)

Country (1)	Region (2)	Distr/Prov (3)	Town	N (°)	E (°)	Habitat (4)	Date	Incidence (%)	Damage level (5)
IT	LO	PV	Broni	45.08	9.27	RO	11–9	100	High
IT	LO	PV	Casteggio	45.03	9.13	RO	11–9	NA	Med-high
IT	LO	PV	Copiano	45.20	9.32	RO	5–9	NA	Med-high
IT	LO	PV	Montebello della Battaglia	45.01	9.09	RO	11–9	NA	Med-high
IT	LO	PV	Pavia	45.21	9.13	RO	7–10	NA	Med-high
IT	LO	PV	Torre d'Isola	45.24	9.05	C	5–9	NA	Low
IT	LO	PV	Voghera	45.00	9.04	RO	11–9	NA	Low
IT	LO	VA	Busto Arsizio	45.61	8.87	RO	22–8	100	High
IT	LO	VA	Cantello	45.8	8.90	RO	25–7	100	Very low
IT	LO	VA	Castellanza**	45.60	8.88	RU	30–7	100	High
IT	LO	VA	Malnate*	45.80	8.88	RO	25–7	NA	Low
IT	LO	VA	Malnate	45.79	8.89	RU	25–7	NA	Low
IT	PI	AL	Alessandria	44.92	8.59	RO	9–10	20	Low
IT	PI	AL	Alessandria	44.91	8.64	RO	9–10	10	Low
IT	PI	AL	Alessandria	44.97	8.56	RO	9–10	50	Medium
IT	PI	AL	Litta Parodi	44.87	8.70	RO	9–10	10	Low
IT	PI	AL	Occimiano	45.07	8.49	RO	9–10	50	Medium
IT	PI	AL	Piovera	44.95	8.74	RO	9–10	30	Low
IT	PI	AL	Quargnento	44.97	8.52	C	9–10	50	Medium
IT	PI	AL	Quargnento	44.96	8.52	C	9–10	50	Medium
IT	PI	AL	Sale	44.98	8.81	RO	9–10	30	Low
IT	PI	AL	Sale	44.99	8.81	RU	9–10	50	Medium
IT	PI	AL	Solero	44.92	8.51	RU	9–10	20	Low
IT	PI	AL	Tortona	44.90	8.84	RO	9–10	30	Low
IT	PI	BI	Biella	45.55	8.08	RO	11–9	80	Medium
IT	PI	BI	Cavaglià	45.40	8.10	RO	11–9	50	Low
IT	PI	BI	Cavaglià	45.40	8.09	RO	11–9	50	Low
IT	PI	BI	Dorzano	45.43	8.11	RO	11–9	50	Low
IT	PI	BI	Massazza	45.47	8.21	RO	11–9	50	Low
IT	PI	BI	Massazza	45.50	8.15	RO	11–9	80	Medium
IT	PI	BI	Sandigliano	45.52	8.08	C	11–9	80	Medium
IT	PI	BI	Sandigliano	45.51	8.08	RO	11–9	80	Medium
IT	PI	BI	Vergnasco	45.48	8.09	RO	11–9	50	Low
IT	PI	BI	Verrone	45.52	8.10	RO	11–9	80	Medium
IT	PI	NO	Barengo	45.60	8.51	RO	4–9	50	Low
IT	PI	NO	Barengo	45.56	8.52	RO	4–9	50	Low
IT	PI	NO	Bellinzago NoVA	45.56	8.65	RO	14–8	100	High
IT	PI	NO	Borgomanero	45.67	8.49	RO	4–9	100	Med-high
IT	PI	NO	Briona	45.53	8.51	RB	4–9	100	Medium
IT	PI	NO	Cameri	45.52	8.66	RO	14–8	100	High
IT	PI	NO	Cavaglietto	45.61	8.50	RO	4–9	40	Low
IT	PI	NO	Cavaglio d' Agogna	45.62	8.51	RO	4–9	40	Low
IT	PI	NO	Cureggio	45.68	8.46	RO	4–9	100	Med-high
IT	PI	NO	Fontaneto d'Agogna	45.66	8.47	RO	4–9	100	Med-high
IT	PI	NO	Fontaneto d'Agogna	45.63	8.51	RO	4–9	100	Med-high
IT	PI	NO	Galliate	45.48	8.74	RU	7–8	100	High
IT	PI	NO	Galliate	45.49	8.68	RO	14–8	100	High
IT	PI	NO	Marano Ticino	45.63	8.63	RO	14–8	100	High
IT	PI	NO	Nibbia	45.49	8.57	RO	4–9	100	Med-high
IT	PI	NO	Novara	45.48	8.57	RO	2–9	100	High
IT	PI	NO	Romagnano Sesia	45.63	8.40	RO	10–9	80	Medium
IT	PI	NO	Trecate	45.44	8.73	RO	25–9	100	High
IT	PI	TO	Brandizzo	45.19	7.86	RO	11–9	50	Low
IT	PI	TO	Caluso	45.30	7.91	RO	14–10	30	Low
IT	PI	TO	Chieri	45.00	7.83	RO	29–9	10	Low
IT	PI	TO	Chieri	45.03	7.80	RO	9–10	30	Low
IT	PI	TO	Chivasso	45.22	7.94	RO	11–9	50	Low
IT	PI	TO	Rondissone	45.24	7.96	RU	11–9	50	Low

Appendix 1 (Continued)

Country (1)	Region (2)	Distr/Prov (3)	Town	N (°)	E (°)	Habitat (4)	Date	Incidence (%)	Damage level (5)
IT	PI	TO	Settimo Torinese	45.15	7.75	RO	3–10	30	NA
IT	PI	TO	Settimo Torinese	45.13	7.77	RO	11–9	50	Low
IT	PI	TO	Settimo Torinese	45.12	7.74	RO	11–9	30	Low
IT	PI	TO	Torino	45.01	7.63	RU	3–10	60	NA
IT	PI	TO	Torino	45.1	7.71	RO	11–9	20	Low
IT	PI	VB	Anzola D'Ossola	45.99	8.35	RU	31–8	100	Low
IT	PI	VB	Anzola d'Ossola	45.99	8.35	RO	14–10	20	Low
IT	PI	VB	Baveno	45.93	8.48	RO	14–10	10	Low
IT	PI	VB	Cuzzago	45.99	8.37	RO	14–10	10	Low
IT	PI	VC	Alice Castello	45.38	8.08	RO	11–9	50	Low
IT	PI	VC	Borgo d'Ale	45.36	8.07	RO	11–9	50	Low
IT	PI	VC	Cigliano	45.30	8.02	RO	11–9	50	Low
IT	PI	VC	Saluggia	45.19	8.05	RO	5–9	50	Low
IT	PI	VC	San Germano Vercellese	45.35	8.26	RB	9–10	50	Medium
IT	PI	VC	Santhià	45.38	8.15	RO	9–10	50	Medium
IT	PI	VC	Stroppiana	45.21	8.46	RO	9–10	50	Medium
IT	PI	VC	Trino V.lese	45.19	8.30	RO	5–9	50	Low
IT	PI	VC	Vercelli	45.32	8.39	RO	9–10	50	Medium
IT	PI	VC	Vercelli	45.29	8.45	RU	9–10	50	Medium

1. CH, Switzerland; IT, Italy.
2. TI, Ticino; ER, Emilia-Romagna; LO, Lombardia; PI, Piemonte.
3. LU, Lugano; ME, Mendrisio; RI, Riviera; LO (CH) , Locarno; PC, Piacenza; BG, Bergamo; CO, Como; CR, Cremona; LC, Lecco; LO (IT) , Lodi; MI, Milano; PV, Pavia; VA, Varese; AL, Alessandria; BI, Biella; NO, Novara; TO, Torino; VB, Verbano-Cusio-Ossola; VC, Vercelli.
4. C, crop field; MP, meadow or pasture; RB, river bank; RO, road; RU, ruderal (including unmanaged grassland, wasteland, parking places, deposits, construction sites).
5. very low = very few leaves slightly damaged; low = some leaves damaged; medium = many leaves damaged; med-high = partly defoliated; high=huge defoliation, flowers not developed or dried; NA=not available.