Proceedings of the Tenth International Conference on Urban Pests
Rubén Bueno-Marí, Tomas Montalvo, and Wm. H Robinson (editors) 2022
CDM Creador de Motius S.L., Mare de Deu de Montserrat 53-59,
08930 Sant Adrià de Besòs, Barcelona, Spain

OXIDUS GRACILIS (DIPLOPODA: POLYDESMIDA) IN EUROPE: MASS OCCURRENCES AND CONTAINMENT

[1]KLAUS ZIMMERMANN AND [2]ANDREA OELHAFEN
[1]inatura GmbH, Biological Advisory Service, Jahngasse 9, 6850 Dornbirn, Austria
[2]Umweltberatungsstelle der Stadt Luzern, Loewenplatz 11, 6004 Luzern, Switzerland

Abstract The greenhouse millipede Oxidus gracilis (Koch), originally native to East Asia, has so far only been found in Central Europe as an introduced species in greenhouses and botanical gardens. In the last few years, however, there has been increasing evidence in Western Austria and Switzerland that this species can also establish itself in the field. These millipedes are prone to mass emergence, they occur as a nuisance on façades of buildings, on terraces and in gardens. In raised beds and kitchen gardens it can also become a plant pest. Buildings can be protected using proven methods with mechanical barriers and silicate. On the other hand, control of diplopods in raised beds and kitchen gardens is very difficult. For these areas, new methods have to be established.

Key words Neozoa, invasive species, swarming behaviour, citizen science, non-chemical control

INTRODUCTION

In the summer of 2016, the inatura expert advisors were called to Feldkirch (A) for a spontaneous mass occurrence of millipedes. After a hailstorm event, thousands of individuals populated the façades and the entire surroundings of a residential complex. To the great surprise of the researchers, it was *O. gracilis*, a species that had not been seen in this region before (Zimmermann, 2017a).

O. gracilis is a Diplopoda species from the Order Polydesmia. The flattened body consists of 20 segments with 31 or 30 pairs of legs. The adults reach a body length of 18-23 mm. They do not have eyes (Causey, 1943). Eggs are laid in summer, overwintering occurs in later larval stages (Pearsons et al., 2017). They feed on detritus, fallen leaves of soft-leaved tree species, but also fresh compost. As decomposers, they play an important role in the natural household. From its original range in East Asia, *O. gracilis* has been introduced into numerous countries all over the world through the trade in plant material. The species now colonizes tropical, subtropical and temperate areas as a cosmopolitan (Cook, 1911), only lacking in the cold regions. In Central Europe, it has been an introduced inhabitant of glasshouses and botanical gardens for more than 100 years (Stoev et al., 2010). But there have been increasing signs that *O. gracilis* can establish itself in the field (Decker et al., 2014; Gruber, 2002).

O. gracilis, like other millipedes, tends to form mass occurrences (Meyer-Rochow, 2015) and mass migrations (Ebeling, 1975). This may be because the millipedes can protect themselves efficiently from predators with a cyanide-containing defensive secretion (Taira et al., 2003). Heavy rain or hailstorms in particular cause large numbers of individuals to leave the protective ground and climb up the façades of houses. The millipedes regularly manage to penetrate into the interior of the buildings. Then, at the latest, they become a disgusting nuisance for the dwellers.

O. gracilis is also a nuisance in kitchen gardens and raised beds when thousands of individuals hide in the root zone of the plants. The foul smell of their defense secretion clings to soil and plants. There are also reports of feeding damage to lettuce and young plants (Iniesta et al., 2020). In 2000, an express train in Japan had to be stopped for several hours because thousands of individuals of *O. gracilis* crossed the railway tracks and became a safety hazard (Niijima, 2001). In the summer of 2021, a hospital in the city of Zurich (Switzerland) had problems with *O. gracilis* for over two months. The millipedes regularly invaded the interior rooms and even the operating theatres via the building façade (Gabi Müller, pers. comm.). This invasive species thus acquired a new significance as a hygiene pest.

MATERIALS AND METHODS

The basic information of this study is a result of pest advisory in Lucerne (Environmental Advisory Service), in Zurich (Urban Pest Advisory Service) and Dornbirn (inatura – Biological Advisory Service). Further information comes from local pest controllers. Of course, the first priority for pest advisors is to provide competent guidance to those seeking advice. But even to achieve this goal, some specific questions about the plague need to be answered: Where do the millipedes stay (in the garden, on building façades, indoors etc.)? How many individuals can be observed (a few, masses)? How long has the infestation been going on? Has damage to plants been observed? Has new soil been added? Where did the new earth come from? What measures have already been taken against the infestation?

This form of pest consultation corresponds to the principle of a Citizen Science approach. The advisors are dependent on the expert inputs of those seeking advice in order to be able to help them in a targeted manner. The people concerned benefit from a solution that is customised for them. In this way, the reviewed data can also be scientifically evaluated. Additional information campaigns in the yellow press and in relevant magazines also prove to be helpful. As a result, an increased number of consultation requests and a greater scientific output is regularly recorded. As with all Citizen Science projects, however, data gaps, scope for interpretation and imprecise content must be expected.

RESULTS AND DISCUSSION

A total of 124 reports were processed by the referred advisory centres, 49 of them in Dornbirn, 42 in Lucerne and 33 in Zurich. The Austrian province of Vorarlberg and the Swiss cantons of Lucerne and Zurich are hotspots of current distribution trends of *O. gracilis* in Central Europe (Figure 1). Until 2015, there were only a few individual reports of this species in the study area. From 2016 onwards, the number of reports has increased at all advisory centres (Figure 2). Information on the duration of occurrence or infestation is only available for some sites: In 13 cases (corresponding to 9% of all reports) the infestation lasted at least 2 years, in 6 cases (4% of all reports) 3 or more years.

In 106 cases, structural information on the preferred sites of the millipedes was available; multiple entries were also possible (Figure 3). “Building exteriors” were named 51 times, meaning building façades, roofs, terraces and the immediate surroundings of buildings. “Indoors” was mentioned 12 times. 40 times *O. gracilis* was found in kitchen gardens, 35 times in raised beds or flower troughs. Damage to crops was detected at 13 sites, nine of them in raised beds. In most cases, lettuce plants were affected, but also young plants of radishes, carrots and herbs were mentioned. Some of the victims described the infestation as a huge mass occurrence, on house façades or in raised beds. These subjective assessments primarily say something about the level of their suffering. In fact, the infestation at some sites met the criteria of a major mass occurrence (Zimmermann, 2017b).

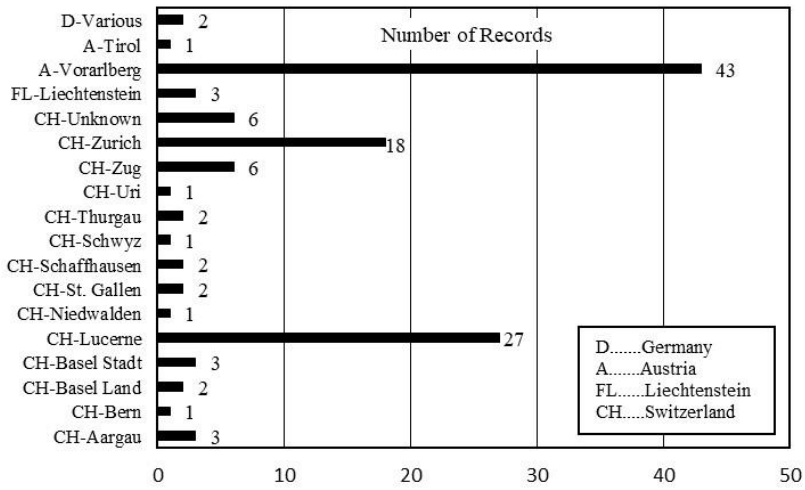

Figure 1: Geographic distribution of records (2016-2021)

In Feldkirch-Tisis, such an occurrence began in summer 2016 after a severe hailstorm. This caused thousands of individuals to climb up the façades of a residential complex. Also the immediate neighbourhood was affected. A few weeks later, the spook was over and the diplopods disappeared again. It was not until 2020 that they reappeared. Almost 500 m away from the original site, the invasion showed up again on the façades of a residential complex and in a raised bed. Further individual finds prove an expansion of this local population at a distance of 1 km or more.

In Vaduz (FL), a large-scale infestation of the city center became apparent in 2017. The millipedes populated streets and exterior façades, but also invaded shops and cultural institutions. The local pest controllers erected mechanical barriers (slug fences), and they treated large areas with silicate every day for many weeks. And they were successful, with no further reports of *O. gracilis* reaching them in the following years (Elmar Marxer, pers. comm.).

In Erstfeld (CH), the yellow press reported on an invasion of millipedes in summer 2018 that affected an entire housing estate. According to those affected, the infestation had been going on for five years at that time, but the mass occurrence had never been as bad as in 2018.

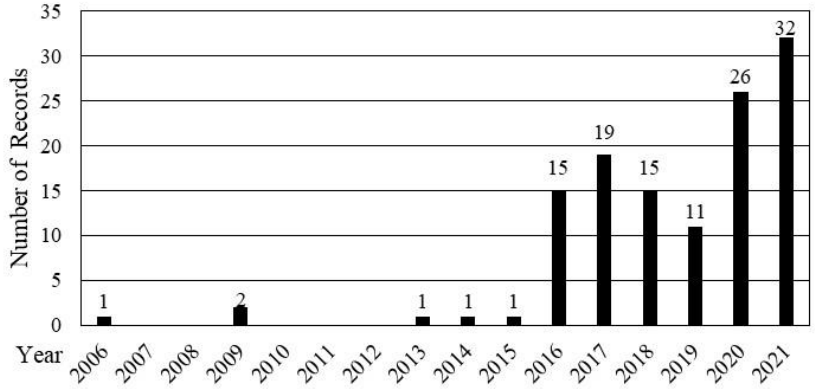

Figure 2: Distribution of records by year (2006-2021)

In 2019, a large-scale mass occurrence of *O. gracilis* was documented in the small community of Melsbach in the German state of Rhineland-Palatinate. The municipal authorities made a great effort to control this infestation. According to the Mayor Holger Klein (pers. comm.), the measures were successful. Only a few specimens of *O. gracilis* were observed in the following years.In the City of Lucerne (CH), there are quite a few reports where it is conceivable, due to their spatial proximity, that they are part of one major mass occurrence. At the very least, there is a high probability that they are due to a common introduction event.

The millipedes can be kept away from indoor areas by installing insect screens and seals, as well as by closing off cracks and crevices. With a structured arrangement of mechanical barriers (slug fences, plastic bands etc.), silicate and adhesive traps (Zimmermann, 2017b), the infestation pressure can be reduced in the immediate vicinity of the buildings. These measures have to be supported by removing all possible hiding places and shade providers (Phillips et al., 2016).

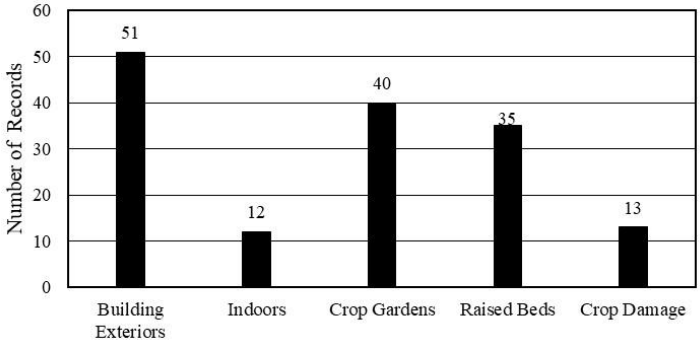

Figure 3: Distribution of records by infested structure (2006-2021)

Controlling *O. gracilis* in raised beds is much more difficult, however. It is almost impossible to prevent the animals from moving in from below. A densely woven but water-permeable fleece would have to be inserted as a barrier when the new bed is planted. However, it is questionable whether this would work reliably. Even the total replacement of the entire soil in the raised bed does not solve the problem. With the new soil, but also with new plants, millipedes can be reintroduced, or they migrate again from below. The constant mechanical skimming of the animals over a longer period of time is promising. Traps (small boards, flower pots turned upside down and filled with straw and the like) provide shelter for the millipedes. They gather under these traps and can be removed. For many garden owners, however, this method is too time-consuming. It would be much easier to apply bait against the invaders. There is evidence that certain ant or slug baits attract and kill *O. gracilis*. Likewise, nematodes are effective against these millipedes (Poinar and Thomas, 1985), but only if they are actively ingested (Arne Peters, pers. comm.). For this purpose, they would have to be released packed with attractants. These methods sound very promising, but must first be developed and tested.

CONCLUSIONS

The current reports of *O. gracilis* in Switzerland, Liechtenstein, Austria and Germany indicate that this introduced species has the potential to establish itself in the field. Assuming that these millipedes have a lifespan of about one

year, at least five generations have been able to survive for as many years at some locations. However, the chances of survival of the millipedes, which are sensitive to cold, are still best in human-dominated sites such as landfills, home gardens, compost heaps or raised beds. At these protected, synanthropic sites, they show high reproduction.

Several large mass outbreaks of *O. gracilis* have already been documented in Central Europe. When the millipedes colonize buildings and their surroundings in masses, they become unpleasant nuisances. With the proven physical control methods, the nuisance can be reduced to a tolerable level. As a pest in raised beds and kitchen gardens, *O. gracilis* will probably remain with us permanently. Mechanical collection is usually not sufficient to efficiently diminish the millipedes. The development and testing of specific feeding baits or other practicable control methods should be pursued in any case.

ACKNOWLEDGEMENTS

We would like to thank all affected house and garden owners and all professional pest controllers involved for their trust and active cooperation! Special thanks to Gabi Müller for providing the data from the Urban Pest Advisory Service Zurich.

REFERENCES CITED

Causey, N.B. 1943. Studies on the Life History and the Ecology of the Hothouse Millipede, *Orthomorpha gracilis* (C. L . Koch 1847). In: The American Midland Naturalist, 29/3. University of Notre Dame. 670-682.

Cook, O. F. 1911. The hothouse millipede as a new genus. Proceedings of the United States National Museum. 40:625-631.

Decker P., H. Reip and K. Voigtländer. 2014. Millipedes and centipedes in German greenhouses (Myriapoda: Diplopoda, Chilopoda). Biodiversity Data Journal 2: e1066. doi: 10.3897/BDJ.2.e1066.

Ebeling, W. 1975. Pests in Excessively Damp Locations, Urban Entomology, Chapter 10, University of California, Division of Agricultural Sciences. https://entomology.ucr.edu/ebeling (Jan. 25, 2022).

Gruber, J. 2002. Tausendfüßer: Doppelfüßer (Myriapoda: Diplopoda). In: F. Essl and W. Rabitsch. Neobiota in Österreich. Umweltbundesamt, Wien. 296-301.

Iniesta, L.F.M., R.S. Bouzan, P.E.S. Rodrigues, T.M. Almeida, R. Ott and A.D. Brescovit. 2020. Ecological niche modeling predicting the potential invasion of the non-native millipede *Oxidus gracilis* (C. L. Koch, 1847) (Polydesmida: Paradoxosomatidae). In: Brazilian Atlantic Forest, Annales de la Société entomologique de France.

Meyer-Rochow, V. 2015. New observations - with older ones reviewed- on mass migrations in millipedes based on a recent outbreak on Hachijojima (Izu Islands) of the polydesmid diplopod *Chamberlinius hualienensis* (Wang 1956): Nothing appears to make much sense. Zoological Research 36: 119-132.

Niijima, K. 2001. The outbreaks of a millipede (*Oxidus gracilis* KOCH) stopped trains. Edaphologia 68: 43-46.

Pearsons, K., I. Mikó and J. Tooker. 2017. The cyanide gland of the greenhouse millipede, *Oxidus gracilis* (Polydesmida: Paradoxosomatidae). Research Ideas and Outcomes 3: e12249. https://doi.org/10.3897/rio.3.e12249 (Jan. 25, 2022).

Phillips, G., R.J. Pivar, K. Vail, R.M. Shelley and J. Evitts. 2016. Occasional Invaders: Millipedes. Household and Structural Pests. W 357 03/16. Institute of Agriculture. University of Tennessy. https://extension.tennessee.edu/publications/Documents/w357.pdf (Jan. 25, 2022).

Poinar, G.O. and G.M. Thomas. 1985. Effect of Neoaplectanid and Heterorhabitid Nematodes (Nematoda: Rhabditoidea) on the Millipede *Oxidus gracilis*. J. of Invertebrate Pathology 45: 231-235.

Stoev, P., M. Zapparoli, S. Golovatch, H. Enghoff, N. Akkari, and A. Barber. 2010. Myriapods (Myriapoda) Chapter 7.2. BioRisk 4(I): 97-130.

Taira, J., K. Nakamura and Y. Higa. 2003. Identification of secretory compounds from the millipede, *Oxidus gracilis* C. L. Koch (Polydesmida: Paradoxosomatidae) and their variation in different habitats. Appl. Entomol. Zool. 38(3): 401-404.

Zimmermann, K. 1917a. Der Gewächshaus-Tausendfüßler. Weitere Überraschungen möglich? DpS Fachzeitschrift für Schädlingsbekämpfung 2017/06: 24-25.

Zimmermann, K. 2017b. Physical methods to combat mass occurences of *Cylindroiulus caeruleocinctus* (Diplopoda: Julidae). In: Davies, M.P., C. Pfeiffer and W.H. Robinson. Proceedings of the 9th International Conference on Urban Pests: 347-350.