



# AN INVASION FROM GERMANY: *DEROCERAS INVADENS* (PULMONATA: AGRIOLIMACIDAE) AND OTHER SYNANTHROPIC SLUGS IN THE SOUTHWEST CORNER OF POLAND

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**ABSTRACT:** Ten towns in the southwest corner of Poland within 57 km of the German border were surveyed for slugs. *Deroceras invadens* was found only in the four westernmost towns. In Zgorzelec, which was surveyed more intensively than the other towns, it occurs widely but only sporadically. Although *D. invadens* had been known in the adjacent German town of Görlitz since 1991, hitherto the only Polish record was from Wrocław, 140 km to the east. This pattern suggests a new colonisation across the border. Amongst the other species, one surprise was the rarity of *Deroceras reticulatum* in several towns, and another that *Arion fuscus* was common in one town but not found in any of the others. Records of *Deroceras praecox* extend its known range in Poland further west. Contrary to expectations from the literature, *Deroceras sturanyi* was adult in spring and reproducing at a small size typical of *Deroceras laeve*.

**KEY WORDS:** invasive species, urban fauna, *Arion distinctus*, *A. fasciatus*, *A. fuscus*, *A. lusitanicus*, *A. rufus*, *A. silvaticus*, *Boettgerilla pallens*, *Deroceras laeve*, *D. invadens*, *D. praecox*, *D. reticulatum*, *D. sturanyi*, *Limacus flavus*, *Limax maximus*, Oberlausitz, Lower Silesia, Dolny Śląsk, life cycle

## INTRODUCTION

*Deroceras invadens* Reise, Hutchinson, Schunack et Schlitt, 2011 (previously known as *Deroceras panormitanum* (Lessona et Pollonera, 1882): REISE et al. 2011) is a slug that has spread from southern Italy across much of the world over the last century (HUTCHINSON et al. 2014). However, in central Europe it has been slow to colonise further east than Germany. HUTCHINSON et al. (2014) suggested that this might be owing to climate, because localities at the edge of the known range in this region, as well as in Scandinavia and North America, consistently exhibit mean minimum winter air temperatures of about  $-22^{\circ}\text{C}$ . Nevertheless range extensions are liable to continue, because of climate amelioration (PROSCHWITZ 2002) or perhaps because the species might be adapting to cold environments, but also because colonisation is a stochastic process requir-

ing time for a species to reach pockets of suitable habitat.

This article reports the discovery of *D. invadens* in a region of southwest Poland, adjacent to the German and Czech borders. It was first found in Germany in 1977, but the first record from an area at all close to the Polish border was in 1991 (REISE & BACKELJAU 1994, HUTCHINSON et al. 2014). This was from the town of Görlitz, which sits directly on the opposite bank of the river Neisse (Nysa) from the Polish town of Zgorzelec. Since then *D. invadens* has gradually become widespread and fairly common in Görlitz (present in 8 out of 31 gardens, allotments and courtyards surveyed in 2014 and in 27 out of 39 gardens checked in 2015: LUDWIG et al. in press, J. BALKENHOL & H. REISE unpublished; see Fig. 1), although not as ubiquitous as it can

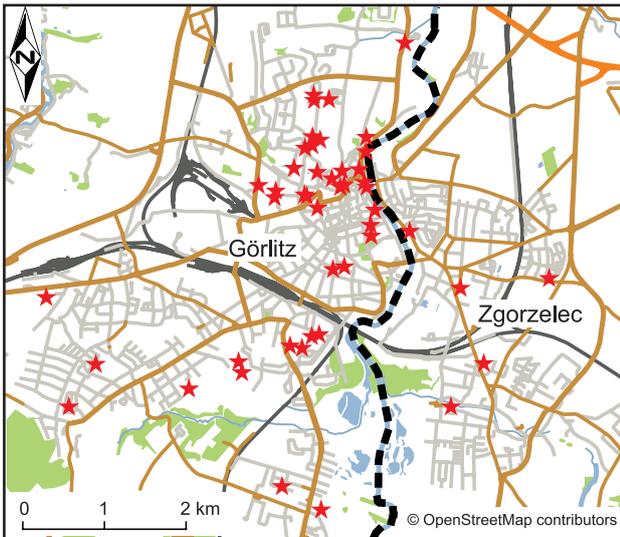


Fig. 1. All known occurrences of *D. invadens* (red stars) in Zgorzelec and Görlitz. The dashed black line is the international border running north–south along the river Neisse (Nysa). Survey targets and intensities differed considerably between the two towns. Map prepared in QGIS v. 2.8 (QGIS Development Team 2015) using data from OpenStreetMap.

be further west in Europe (e.g. NORTH & BAILEY 1989, HUTCHINSON et al. 2014). The first finding in Poland was from the botanic garden in the centre of Wrocław in 2001 (WIKTOR 2001). This population was still extant in 2013 (HUTCHINSON et al. 2014), but we are not aware of any subsequent findings from elsewhere in Poland (A. WIKTOR, pers. comm., July 2015). Wrocław is 95 km to the east of the easternmost town that we surveyed in the current study (Fig. 2).

The situation in the Czech Republic appeared to be similar to that in Poland in that the first two occurrences (from 1996 and 2002: HORSÁK & DVOŘÁK 2003) had not been followed by reports from elsewhere. However, in 2014 we found *D. invadens* at two sites in Hrádek nad Nisou, a small town in the Czech Republic just over the border from both Germany and Poland (Fig. 2; HUTCHINSON et al. 2014). This stimulated us to examine whether the species had also spread into the adjacent towns in Poland. As a by-product, the fieldwork enabled us to survey other synanthropic slugs.

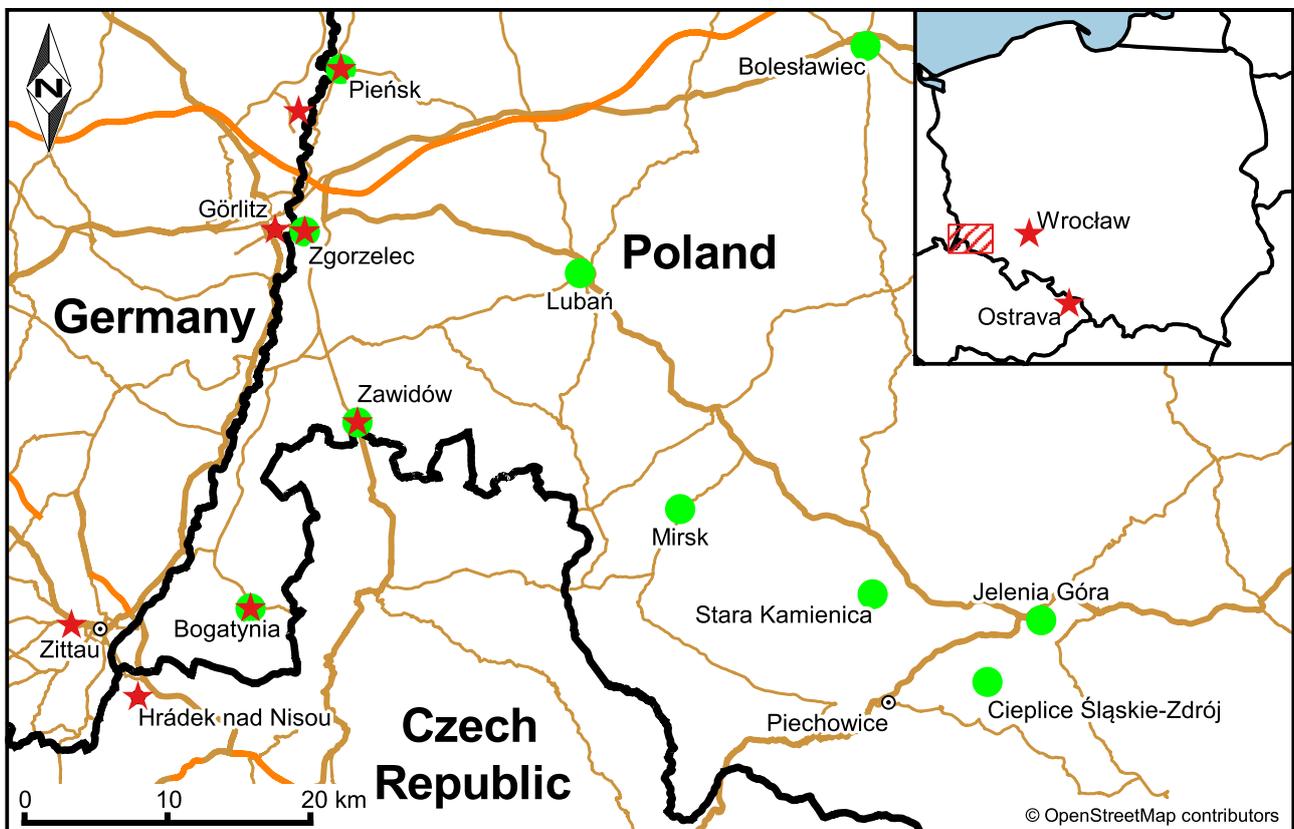


Fig. 2. Towns in which *D. invadens* has been found (red stars). Green dots indicate the towns surveyed in the current project. The shaded red rectangle in the inset shows the position of the main map on an outline of Poland. Black lines are international borders and major roads are shown brown or orange. Map prepared in QGIS v. 2.8 (QGIS Development Team 2015) using data from OpenStreetMap



## MATERIALS AND METHODS

In the first half of 2015 JMCH surveyed ten Polish towns within 57 km of the German–Polish border (Fig. 2, Table 1). Each was visited just once for 1.5–4 h except that Zgorzelec received five such visits, each concentrating on a different part of the town. The time taken for each visit was determined by other commitments rather than depending on the catch so far or whether areas remained unsearched. Collecting was avoided when the ground was very dry or after a hard frost, when slugs are driven underground. The surveys consisted of walking or cycling along streets and footpaths, stopping to examine suitable spots as they appeared, especially turning over such objects as stone slabs and wooden boards under which slugs often hide in daytime. More time was spent looking for suitable spots to search than searching these spots. JMCH had extensive experience in searching for *D. invadens* elsewhere. Particular attention was given to dumped rubbish, such as old furniture, carpets and garden debris, and to the edges of gardens and allotments where these were accessible, but linguistic barriers and logistic considerations meant that we did not seek access to private gardens. Nor did we target plant nurseries or garden centres, although some sites happened to

be near these. Most sites examined were on street margins, hedgerows, rough ground at the edge of housing, abandoned properties, and such like.

*Deroceras invadens* is difficult or impossible to distinguish morphologically from *D. laeve* (O. F. Müller, 1774) and *D. sturanyi* (Simroth, 1894) except by dissection of adults, so we collected all specimens with this appearance, noting the precise locality. If these specimens were large they were killed the same day for dissection, otherwise they were kept in Petri dishes in the laboratory until they grew large or laid eggs. Rates of occurrence of other species of slugs were recorded but without noting each locality within a town; a pooled selection from each town was collected. These surveys were too brief to make a claim that *D. invadens* was absent from any particular town, but we considered them sufficient to give a reasonable opportunity of success if the species was well established, as the results substantiate.

Slugs were killed in carbonated water and preserved in 70% ethanol. They were dissected where necessary for identification and all are retained in the collection of the Senckenberg Museum für Naturkunde Görlitz.

Table 1. Visits to survey slugs in ten Polish towns, with the number of localities found for each of three species of *Deroceras*. Search duration is approximate

Town	Inhabitants	Date	Search duration (h)	Number of localities		
				<i>D. invadens</i>	<i>D. sturanyi</i>	<i>D. laeve</i>
Bogatynia	18,385	21.05.2015	3	2	1	2
Bolesławiec	39,481	13.05.2015	4	0	0	0
Cieplice Śląskie-Zdrój	15,000	15.02.2015	2	0	0	0
Jelenia Góra (centre)	67,000	03.05.2015	1.5	0	1	0
Lubań	21,788	10.06.2015	4	0	1	0
Mirsk	4,032	01.05.2015	1.7	0	0	1
Pieńsk	5,918	25.06.2015	2.7	1	1	0
Stara Kamienica	1,200	02.05.2015	1.5	0	0	1
Zawidów	4,338	21.05.2015	1.5	1	0	0
Zgorzelec (north)	31,716	24.03.2015	2	1	0	0
Zgorzelec (centre)		29.04.2015	3	2	0	2
Zgorzelec (north-east)		06.05.2015	2	0	0	2
Zgorzelec (south-east)		08.05.2015	3	1	1	2
Zgorzelec (south)		25.05.2015	2.5	1	1	0

## RESULTS

*Deroceras invadens* was found at five distinct localities well distributed around Zgorzelec. Evidently, the species is established but known occurrences are still sporadic. *Deroceras invadens* also turned up at two localities in Bogatynia, at one site in Zawidów, and at one site in Pieńsk. These four towns are the western-

most of the ten surveyed (Fig. 2). In Zgorzelec, four of the occurrences were away from gardens or allotments and one area of occurrence extended to an area of currently undisturbed birch scrub 50 m from buildings. Three of the finds in the other towns were adjacent to gardens, but none were around allotments.

In comparison, *D. laeve* was found in four towns, at a total of nine sites (Table 1). Our experience is that *D. laeve* occurs widely in grassland, although its small size makes it difficult to find; thus its pattern of occurrence provides a form of control for sampling intensity. There was no marked east–west difference in the occurrence of this species.

*Deroceras sturanyi* was found at six sites in five towns (Table 1), also with no marked east–west difference in occurrence. Five of the samples collected in the current survey soon laid eggs or showed mating behaviour, and did so at strikingly small sizes (preserved body lengths  $\leq 13$ –17 mm: Table 2), so that we had supposed they were *D. laeve* until checking the genitalia. The sixth sample consisted of two very small slugs, of which the single survivor never laid eggs before it was killed two months later, but its genitalia had developed fully.

By far the commonest slugs were juveniles of large *Arion*, most likely predominantly *A. lusitanicus* auct. non Mabile but it was generally too early in the year to distinguish them reliably from *A. rufus* Férussac, 1819. At least at one site in Lubań (allotments beside a wood) both species occurred together. *Arion lusitanicus* was first noted in Zgorzelec in 2006 and in Lubań in 2012 (H. REISE, unpublished). Within a few years it spread throughout Zgorzelec, and concurrently the native *A. rufus* almost disappeared; this duplicated the process in Görlitz where it was first found in 1994 (REISE et al. 1996, H. REISE and colleagues, unpublished). The second most common species was usually *Arion distinctus* Mabile, 1868. A sample from each of the towns (over 40 individuals in total) was dissected to confirm that none were the more western species *A. hortensis* Férussac, 1819. Next most common was *Limax maximus* Linnaeus, 1758; in Pieńsk it was even commoner than *A. distinctus*.

*Deroceras reticulatum* (O. F. Müller, 1774) differed considerably in abundance between towns. In Bolesławiec only one specimen, probably of this species, was found in 4 h of searching, in Zgorzelec it was typical to find it at only two or three sites in a 2 h search, whereas in Lubań and Pieńsk it was commoner than *A. distinctus*. However, these last two towns were the last to be sampled and LUDWIG et al. (in press) also experienced that the relative abundances of these two species in Görlitz gardens swapped in

this direction as spring progressed. A sample of *D. reticulatum* from each town (31 individuals in total) were dissected to confirm that they were not *D. turcicum* (Simroth, 1894), *D. agreste* (Linnaeus, 1758), or *D. praecox* Wiktor, 1966.

*Boettgerilla pallens* Simroth, 1912 was found in all towns, usually at a small number of sites, but its predominantly underground habits mean that this must under-represent its occurrence. *Arion fasciatus* (Nilsson, 1823) usually turned up at only a few sites in each town, but was often numerous where it did occur. *Arion silvaticus* Lohmander, 1937 was rarer, occurring in just two towns, Lubań and Pieńsk, at one and two sites respectively. *Arion fuscus* (O. F. Müller, 1774) was common in a variety of urban habitats in Stara Kamienica, but not found in any other town.

*Deroceras praecox* occurred in Cieplice, but because of its external similarity to *D. reticulatum*, we cannot tell from how many sites we collected it within that town. It certainly occurred under logs in grassland beside buildings close to the river (50°51'46.5"N, 15°41'11.6"E). This year we have found this species also in a garden in the nearby town of Piechowice (50°50'59.9"N, 15°35'18.0"E) and well away from buildings near Przecznicza (c. 50°55'07"N, 15°27'18"E). These new records are 20–40 km further west than other Polish records of which we are aware, although we have found it further west on the other side of the Sudeten Mountains (e.g. 50°45'18"N, 14°55'29"E, near Křižany station, south of Chrastava) and a related form occurs in the Elbsandsteingebirge (REISE et al. 2005, HUTCHINSON & REISE 2009).

*Limacus flavus* (Linnaeus, 1758) in this region is mostly associated with damp cellars, and is easiest to find when active at night (BAADE 2003). The only specimen found in this survey was beneath a small block of concrete on the vegetated margin of an abandoned car park, with no cellar apparent nearby. Dissection confirmed that the specimen was not *L. maculatus* (Kaleniczenko, 1851).

We did not find *Lehmannia valentiana* (Férussac, 1822), a synanthropic slug that has spread widely in western Europe; it was reported already in the 1960s from greenhouses in Wrocław and near Wałbrzych (WIKTOR 1967), and there is a recent outdoors record from Görlitz (LUDWIG et al. in press). We also did not encounter the invasive snail *Hygromia cinctella*

Table 2. The size of adult *D. sturanyi* kept at 10–14°C until adult. Where either of two individuals sharing a container might have laid the eggs, the length given is that of the larger

Town	Habitat	Collection date	Evidence of maturity	Date eggs or mating observed	Preserved length (mm)
Zgorzelec	Flower bed (under stone)	08.05.15	eggs	12–15.05.15	13
Bogatynia	Yard/garden (under rubber mat)	21.05.15	eggs	28–30.05.15	16
Zgorzelec	Grassy parking area (under rubber mat)	27.05.15	eggs	12–15.06.15	17
Lubań	Short grass where building demolished	10.06.15	mating	15.06.15	14
Pieńsk	Grass beside bins (under cardboard)	25.06.15	eggs	29–30.06.15	15



(Draparnaud, 1801), which in 2012 was found in the adjacent German border town of Zittau (BECKMANN & KOBIALKA 2008, MÖLTGEN-GOLDMANN 2015).

## DISCUSSION

The concentration of records of *D. invadens* exclusively along the western border of Poland suggests that these populations have spread from the adjacent parts of Germany rather than from the colony in Wrocław. It is feasible that a slug attached to a leaf could blow the 40 m across the river Neisse from Görlitz to Zgorzelec but another likely mechanism of transfer would be with garden plants, either purchased in Germany or transferred between friends and family. The wholesale replacement of the human population of this part of Poland after 1945, the closure of the German–Polish border in the 1980s, and the continuing language barrier have hindered cross-border links, but more recently these are re-establishing, especially since the removal of border controls in 2007. However, although the border evidently delayed the spread of both *D. invadens* and *A. lusitanicus*, one should realise that only one cross-border transfer was required in each case. The spread into neighbouring towns in the region need not depend on repeated invasions from Germany, but only on local traffic within Poland. It will be interesting to monitor how quickly *D. invadens* spreads to the other towns surveyed, and when it appears at some of the sites within Zgorzelec at which we failed to find it this year. In these days of increased population mobility and of large businesses distributing plants on a national scale, we had not expected such a strong geographic pattern to the occurrence of *D. invadens* across towns (Fig. 2).

*Deroceras invadens* joins a number of other well-established molluscan introductions in Poland (ALEXANDROWICZ & ALEXANDROWICZ 2010). Although *D. invadens* has sometimes been reported to be a pest elsewhere (HUTCHINSON et al. 2014), in Görlitz its impact does not nearly compare with that of *A. lusitanicus*. Systematic attempts to control its spread in Poland would not be economically justifiable and seem unlikely to succeed because the species is neither conspicuous nor easy to distinguish from other common species.

*Deroceras sturanyi* is another invasive species, spreading westwards through Europe, but it was already widespread throughout Poland when first recognised there (WIKTOR 1973). In the course of our survey, we failed to find it at two sites in Zgorzelec where we had found it in earlier years. However, our experience is that this species is larger and easier to find in the autumn. KOSIŃSKA (1980), working also in Lower Silesia, wrote that only exceptionally do

JMCH was on the lookout for both these species and familiar with them from elsewhere.

adults overwinter, and that the next generation appears at the turn of April and May, with the reproductive period starting in early August. She kept slugs outdoors in food-supplemented containers and observed a mean adult length crawling of 46 mm, with reproduction starting at 36 mm and size decreasing to 29 mm when senile. This contrasts with our observation that slugs collected in May or June (from five sites) and kept in Petri dishes at 10–14°C, within a week or so could be observed either to mate or to lay eggs (Table 2). And our adults were much smaller: their lengths in alcohol of 13–17 mm imply crawling lengths measured by Kosińska's method of 19–25 mm (based on a sample of five individuals measured using both methods).

The occurrence of unexpectedly small adults in spring is not unique to 2015. In a survey of gardens in Görlitz, LUDWIG et al. (in press) also found *D. sturanyi* with adult-looking distal genitalia in spring 2014 (9.05.2014–12.06.2014). We measured the lengths in alcohol of the largest specimen from each of LUDWIG et al.'s eight samples and they ranged from 9 to 15 mm (median = 12.5 mm). Thus these slugs were mostly even smaller than those from the present study, probably because the former were killed on the day of collection rather than maintained in the laboratory until they proved to be adult. Maturation at a small size in spring appears not to be a recent change in life-cycle, because the collection of the Senckenberg Museum für Naturkunde Görlitz contains similarly small adult specimens collected in the June of 1966, 1989 and 1998. We also measured specimens in this collection collected in October and November of various years: some are indeed larger (up to 24 mm preserved), but other mature specimens were no larger than those we collected in spring. Several identification guides (e.g., KERNEY & CAMERON 1979, WIESE 2014) give the body length crawling as 30–40 mm or larger, so we suspect that smaller individuals have often been incorrectly dismissed as juveniles or *D. laeve*. One exception is the guidebook by HORSÁK et al. (2013a), which states that *D. sturanyi* is only slightly larger than *D. laeve*, although reaching 35 mm.

Besides the occurrence of *D. invadens*, between-town variation in the relative abundance of the species was mostly minor, and we cannot confidently rule out explanations based on seasonal effects or differential sensitivity to recent weather conditions. The puzzling exception is the abundance of *A. fus-*

*cus* in Stara Kamienica, whereas it was never found elsewhere. Other studies of town faunas have only sometimes noted this species (e.g. KLAUSNITZER & HÜBNER 1989). (These studies mostly predate the separation of *A. fuscus* from other species in the *A. subfuscus* (Draparnaud, 1805) group, but *A. fuscus* is the usual one in this part of Europe: JORDAENS et al. 2010). *Arion fuscus* has sometimes been reported as one of the commonest urban slugs, particularly in northern and eastern Europe (e.g. SIOŃEK 1996, SKUJENĚ 2003, TAPPERT 2009), but similarly reliable studies elsewhere report it as rare or absent (e.g. MATZKE 1973, MENG & BÖSSNECK 1998, HORSÁK et al. 2013b). Woodland is considered the normal habitat for *A. fuscus*, but this does not at all describe where we found it in Stara Kamienica. However, the town lies in the foothills of the Sudeten Mountains and MATZKE (1979) explains the occurrence of this species in a town in the Erzgebirge by the increased humidity and rainfall in hilly country.

Generally the list of other species has much in common with such lists from urban areas elsewhere in the broad region. One possible anomaly was that *D. reticulatum* seemed often not as common in our

ten towns as it is reported to be elsewhere (e.g., KLAUSNITZER & HÜBNER 1989, MENG & BÖSSNECK 1998, HORSÁK et al. 2013b, LUDWIG et al. in press). A speculative explanation is that the high population density of the large slug *A. lusitanicus* might have had an effect on *D. reticulatum*, since most published studies predate the arrival of this pest. Our casual perception in Görlitz is that *D. reticulatum* became hard to find after the arrival of *A. lusitanicus* but populations are now recovering. If only we had carried out a study like the current one earlier, we would have some evidence to support or reject such conjectures, but now we are a little better prepared to detect change in the future.

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