



EXPANSION OF THE INVASIVE SLUG SPECIES *ARION LUSITANICUS* MABILLE, 1868 (GASTROPODA: PULMONATA: STYLOMMATOPHORA) AND DANGERS TO GARDEN CROPS – A LITERATURE REVIEW WITH SOME NEW DATA

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ABSTRACT: The distribution of *Arion lusitanicus* Mabilie and the damage caused by the slug were studied in 1993–2009. A total of 38 sites were examined, characterised in terms of location, time of appearance and density of the slug, type and size of crops affected, and degree of damage to plants. At the start of the 1990s *A. lusitanicus* occurred only around Rzeszów and in the Sub-Carpathian region. In 1997 it started to appear in other regions of Poland. The rate of its spread was found to have increased significantly, particularly in the past few years. The slug mainly colonises urban areas (30 sites), and much less often – other areas (8 sites). The slug densities were the greatest in cultivations. The degree of damage done by the slug varied among plant species. Brassicas, lettuce, beetroot, carrots, beans, strawberries, numerous ornamental flower plants and some weeds were the most damaged. The increase in the spread of *A. lusitanicus* poses a serious threat to the biodiversity of native habitats and to garden-cultivated plants.

KEY WORDS: *A. lusitanicus*, pest, spread, density, damage

INTRODUCTION

Arion lusitanicus Mabilie, 1868 (also recognised as *A. vulgaris* Moquin Tandon, 1855 (ANDERSON 2005)) is a slug which, in recent years, has become a pest that constitutes a threat to garden plants and some farm crops in Poland. It originates from Spain, Portugal and the Azores (SIMROTH 1891, QUICK 1952, 1960, VAN REGTEREN ALTENA 1971, CHEVALLIER 1972). Over the last 30 years the species has spread in many European countries, including Britain (ELLIS 1965, DAVIES 1987), Italy (VAN REGTEREN ALTENA 1971, COSSIGNANI & COSSIGNANI 1995), France (VAN REGTEREN ALTENA 1955, 1971, CHEVALLIER 1972), Belgium (RISCH & BACKELJAU 1989), Germany (SCHMID 1970), the Netherlands (DE WINTER 1989), Switzerland (VAN REGTEREN ALTENA 1971, FRANK 1998), Austria (REISCHÜTZ 1984), Bulgaria (WIKTOR

1983), northern Algeria (WIKTOR 1983), the Czech Republic (HORSÁK & DVOŘÁK 2003), Sweden and Norway (VON PROSCHWITZ 1992, 1994, VON PROSCHWITZ & WINGE 1994), Croatia and Slovenia (WIKTOR 1996), and Hungary (PINTÉR & SUARA 2004).

In Poland, *A. lusitanicus* probably first appeared in the late 1980s, at a site where orchard plants were grown at Albigowa near Rzeszów, in the Sub-Carpathian region. Initially it occurred only there, but over the following few years it migrated to neighbouring localities and spread over a significant area in that region, mainly to the south-east of Rzeszów (KOZŁOWSKI & KORNOBIS 1994, 1995, KOZŁOWSKI 1995, 2000a, KOZŁOWSKI & SIOŃEK 2000a). In the last decade new sites of occurrence of *A. lusitanicus* were found in

other regions of Poland (KOZŁOWSKI 2001, 2008, KOZŁOWSKI et al. 2008), and the number of such sites is continuously increasing.

A. lusitanicus colonises very different habitats, particularly those degraded by human activity, where it lives as a synanthrope. It also occurs in garden and farm crops, as well as on uncultivated land. It is frequent in gardens and cultivated fields situated close to buildings and rivers, as well as in cemeteries, parks, meadows, ditches, baulks, brush and wasteland. The slug's large body size, high rate of reproduction and great nutritional and ecological tolerance, combined with the absence of natural predators, mean that it can very easily adapt to new habitats and quickly form very dense populations (KOZŁOWSKI & KOZŁOWSKA

1998, 2000, KOZŁOWSKI 2003, 2005, 2008, KOZŁOWSKI et al. 2008). The slug grazing and the resulting plant damage lead to serious losses in yields of various plant species, particularly vegetables and ornamental plants grown in gardens. The slug also contaminates plants with its mucus and faeces, decreasing their commercial and decorative value.

Numerous reports from garden owners about the serious damage done by *A. lusitanicus* and the problems associated with its control were the direct reasons for the commencement of research on this slug. This paper presents the results of more than a decade of observations concerning the distribution of *A. lusitanicus* and the effect which its local populations have on plants.

MATERIAL AND METHODS

Research on the distribution of *A. lusitanicus* and the damage done by this slug to selected species of cultivated and other plants was carried out in 1993–2009. Places where the slug was reported to occur were investigated to confirm or detect *A. lusitanicus*. From each site about 15 slug specimens were taken and identified based on the structure of internal organs and comparison with available descriptions (RIEDEL & WIKTOR 1974, WIKTOR 2004). Each site was described in terms of its location and the kind of habitat. The location description included the name of the locality and province, geographical coordinates (latitude and longitude) and reference to the square of Universal Transverse Mercator (UTM). The universal system of marking the location of slug sites was adopted (sequence of digits from 0 to 9) and the data from earlier papers were adapted to this system (KOZŁOWSKI 2001, 2007, KOZŁOWSKI et al. 2008, SOROKA et al. 2009). Within each marked site an estimate was made of the slug density and the degree of damage to selected plant species. The density was observed in the evening, with slugs counted within an

area of 1 m² at ten places. At these same places, damage was observed on 5–10 plants of particular species; the number of damaged plants and the degree of damage (per cent) were recorded. Detailed information on the degree of damage done to various species of cultivated and other plants by *A. lusitanicus* can be found in earlier publications (KOZŁOWSKI 2005, 2008). Here we summarise the data on plant species which are the most susceptible to the damage by *A. lusitanicus*.

Garden owners were interviewed in order to trace the history of occurrence of (probably) *A. lusitanicus* in the investigated areas, and to characterise the effects of the slug on the cultivations. Information was collected concerning the time and circumstances of the slug's first occurrence, its appearance, places of occurrence, numbers, effects of grazing on plants, methods of control, and other data relating to its occurrence. This information was expected to assist in determining the routes and manner of invasion and the slug's effect on plants and other components of the colonised habitats.

RESULTS

The presence of *A. lusitanicus* in Poland was first documented in 1993 on the basis of specimens from sites in Albigowa and Markowa, located east of Rzeszów in the Sub-Carpathian region (south-eastern Poland) (Table 1, Fig. 1). However the first mentions of the occurrence of the slug in orchards, though unconfirmed by species identification, date from 1987 (unpublished data). During more than a decade the slug spread from this location over the Sub-Carpathian region (Fig. 1; squares EA and FA). By 1991 *A. lusitanicus* probably occurred at three sites in Rzeszów (cemetery and allotment gardens), and by 1992 it was present in Łañcut near Rzeszów. Two years later it was

observed at other sites in Rzeszów and near Łañcut. The sites of occurrence of *A. lusitanicus* in these places are mainly house gardens, meadows and cultivated fields, and brush close to watercourses. In 1997–1999 the slug was found at 93 sites in 23 localities in the Rzeszów and Dynów Uplands (EA and FA; Fig. 1) (KOZŁOWSKI 2000a, KOZŁOWSKI & SIOŃEK 2000b). Very abundant populations of the species were observed in various habitats, including gardens, cultivated fields, parks, cemeteries, bushes, baulks, ditches, river banks, waste tips, rubble heaps, etc. Its populations remained at these sites and spread to neighbouring areas. In 2000 new sites of occurrence

Table 1. Sites of occurrence of *A. lusitanicus* in Poland

Collection date*	Place of collection (locality, province)	Location in UTM grid squares	Geographic coordinates	Habitat type	Average number/ m ²
10.07.93	Albigowa, Sub-Carpathian	EA 84	50°00'54"N 22°13'29"E	clover cultivation	16.8
10.07.93	Markowa, Sub-Carpathian	EA 94	50°01'32"N 22°17'59"E	vegetable cultivation and its borders	19.1
14.08.94	Wysoka, Sub-Carpathian	EA 84	50°02'42"N 22°15'44"E	carrot cultivation	21.7
14.08.94	Łańcut, Sub-Carpathian	EA 84	50°03'56"N 22°13'43"E	vegetable and flower cultivation	12.4
14.08.94	Rzeszów, Sub-Carpathian	EA 74	50°01'47"N 22°01'06"E	vegetable and fruit bush cultivation	21.6
05.09.95	Przeworsk, Sub-Carpathian	FA 04	50°03'10"N 22°29'35"E	bushes near a garden	5.4
23.07.96	Jarosław, Sub-Carpathian	FA 14	50°02'14"N 22°40'41"E	vegetable and flower cultivation	3.8
25.07.96	Głuchów, Sub-Carpathian	EA 95	50°04'52"N 22°16'21"E	raspberry plantation	3.2
27.06.97	Zabratówka, Sub-Carpathian	EA 83	49°58'29"N 22°11'28"E	roadside ditch	6.5
27.06.97	Zarzeczce, Sub-Carpathian	EA 63	50°31'26"N 22°12'17"E	roadside ditch	4.9
28.06.97	Boguchwała, Sub-Carpathian	EA 64	49°59'06"N 21°56'33"E	wasteland close to plantation	6.8
15.07.00	Poznachowice Górne, Małopolskie	DA 32	49°49'29"N 20°07'43"E	thicket by the river	8.7
05.07.01	Małujowice, Opolskie	XS 63	50°50'49"N 17°22'34"E	vegetable cultivation	15.8
17.06.05	Korczyna, Sub-Carpathian	EA 50	49°42'54"N 21°48'27"E	bushes at the cemetery	2.7
07.08.06	Zawadka, Małopolskie	DA 51	49°44'37"N 20°16'50"E	vegetable and ornamental cultivation	28.5
28.08.06	Bielsko-Biała, Silesia	CA 62	49°49'07"N 19°02'18"E	vegetable, flower, tree and shrub cultivation	13.6
20.09.06	Pisarzowice, Silesia	CA 62	49°52'37"N 19°08'27"E	balk at the rape plantation	4.8
12.06.07	Łódź, Rogi, Łódzkie	CC 93	50°58'57"N 19°47'19"E	vegetable, flower, tree and shrub cultivation	3.9
18.06.07	Leszno, Wielkopolskie	XT 04	51°50'28"N 16°34'22"E	vegetable and fruit bush cultivation	16.4
19.07.07	Prabuty, Pomerania	CE 86	53°45'20"N 19°12'18"E	ornamental plants plantation	9.5
20.07.07	Gronowo Górne, Warmińsko-Mazurskie	CF 90	54°08'27"N 19°27'37"E	vegetable, flower, tree and shrub cultivation	20.3
02.08.07	Podkowa Leśna, Mazovian	DC 87	52°07'09"N 20°44'29"E	mixed deciduous forest	5.9
03.08.07	Wołodrza, Łódzkie	CC 79	52°17'32"N 19°11'10"E	vegetable, flower, tree and shrub cultivation	14.3

Table 1. Continued

Collection date*	Place of collection (locality, province)	Location in UTM grid squares	Geographic coordinates	Habitat type	Average number/ m ²
19.10.07	Bobrek, Małopolskie	CA 74	50°03'30"N 19°15'23"E	flowering plants and fruit trees	3.5
19.10.07	Wadowice, Małopolskie	CA 92	49°52'50"N 19°29'41"E	vegetable, flower, tree and shrub cultivation	2.7
19.06.08**	Zielona Góra, Lubuskie	WT 35	51°56'11"N 15°30'52"E	perennials, flowering plants and conifers	9.6
20.06.08**	Ochla, Lubuskie	WT 34	51°52'43"N 15°28'19"E	vegetable and strawberry plantations	8.3
07.10.08**	Dębica, Sub-Carpathian	EA 34	50°03'15"N 21°25'12"E	vegetables, ornamental and fruit plants	8.8
08.10.08**	Cieszyna, Sub-Carpathian	EA 42	49°42'13"N 21°36'01"E	vegetables, flower plants, trees and shrubs	6.1
08.10.08**	Bircza, Sub-Carpathian	FA 00	49°41'32"N 22°29'00"E	ornamental tree and shrub cultivation, drainage ditches	4.2
08.10.08**	Przemyśl, Sub-Carpathian	FA 21	49°46'58"N 22°46'47"E	vegetable, flower and fruit tree cultivation	1.7
08.10.08**	Żurawica, Sub-Carpathian	FA 32	49°49'25"N 22°47'44"E	vegetable cultivation	4.7
09.10.08**	Żywnów, Sub-Carpathian	EA 62	49°49'00"N 21°50'20"E	vegetable cultivation	5.2
21.07.09**	Puszczykowo, Wielkopolskie	XT 29	52°17'01"N 16°50'36"E	vegetable, flower, tree and shrub cultivation	9.1
03.08.09**	Racibórz, Miedonia, Silesian	CA 05	50°05'20"N 18°13'06"E	vegetable and flower cultivation	5.0
15.08.09**	Poznań, Wielkopolskie	XU 21	52°22'53"N 16°53'54"E	forest and scrub near a pond	3.4
26.08.09**	Pogwizdów, Silesian	CA 32	49°48'11"N 18°36'10"E	vegetable, flower and strawberry cultivation	10.0
09.09.09**	Mikołajki Pomorskie, Pomerania	CE 77	53°51'04"N 19°10'03"E	forest and scrub	3.8

* revised date of the first signs

** sites of *A. lusitanicus* appearance from latest research

of *A. lusitanicus* were found in Małujowice near Brzeg (Opole region), and in 2001 in Poznachowice Górne near Wieliczka (Kraków region) (Table 1, Fig. 1). The populations in these sites occurred on several smallholdings (0.5–1.2 ha). The first unconfirmed observations of *A. lusitanicus* in these localities date from 1997 (Małujowice) and 1999 (Poznachowice). The slugs occurred in gardens, cultivated fields, wastelands, bushes and overgrown ruins of buildings. In 2006 *A. lusitanicus* was identified in southern Poland, at Zawadka (near Tymbark), Bielsko-Biała and Piszczowice. The slugs reached Zawadka probably in 2000 via plant material originating in Bielsko-Biała. Initially they occurred in only one garden in Zawadka, but from 2003 onwards they began to be found on the neighbouring properties. In Bielsko-Biała the popula-

tion occurs in allotments in the city centre, covering an area of approximately 12 ha. The first reports on the occurrence of the slug on this land, not confirmed by species identification, date from 1998. Now *A. lusitanicus* occurs in the whole area of the allotments and in the neighbouring city districts, where large houses are situated. At a site in Piszczowice near Kęty the slug occurs in the vegetation growing along a drainage ditch and on baulks and in ditches near a plantation of winter rape and winter cereals. The first individuals were observed there probably in 1999. In 2007 another eight populations were identified in other parts of the country. These include a population in Leszno (W. Poland), occurring in allotment gardens on the outskirts of the city, covering an area of approximately 8 ha. The slug probably appeared

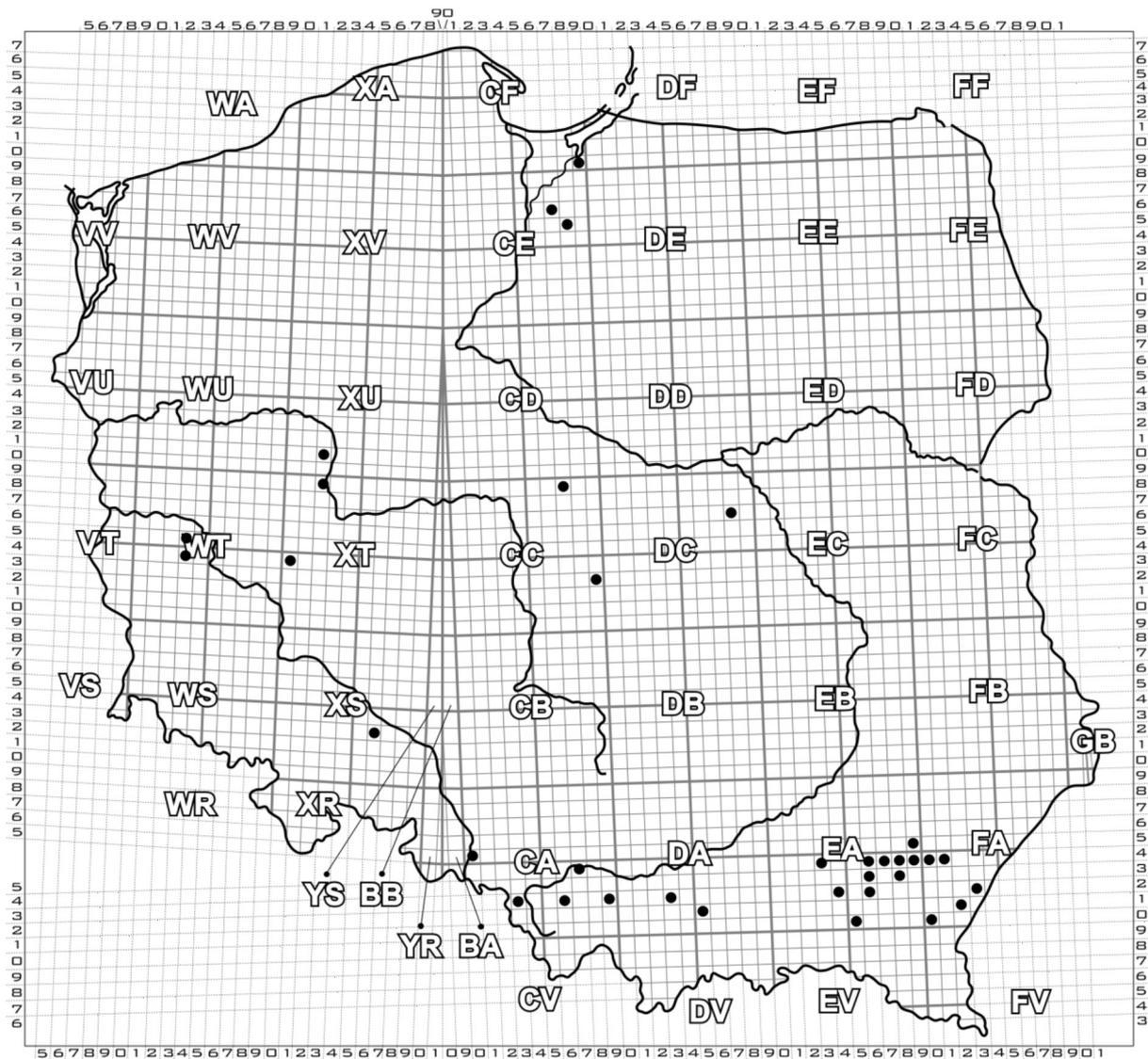


Fig. 1. Distribution of sites of *A. lusitanicus* in Poland (sites discovered in 1993–2009)

there in 2002, and is now present in half of the allotment area. In Gronowo Górne (Elbląg region, N. Poland) the slug occurs in a garden 0.14 ha in area and was first observed in 2003. At present it occurs in very large numbers at that site and in several small neighbouring gardens. Populations of *A. lusitanicus* in Łódź (Łódź region, central Poland) and in Prabuty near Kwidzyń (Pomeranian region, N. Poland) occur in small house gardens (500–700 m²) within the towns. The slug appeared there probably in 2004. The population in Wołodrza (Łódź region, central Poland) has for four years colonised gardens and cultivated fields covering several hectares. A different habitat is colonised by a population in Podkowa Leśna (Warsaw region); it is the boundary strip of a broadleaved forest close to a drainage ditch and sewer well. At a distance of 1 km from this site is an estate of large houses situated within the forest area, where probably in 2005 *A. lusitanicus* was observed for the first time. The population in Bobrek near Oświęcim (S. Poland) occurs

in several gardens with a total area of approximately 0.9 ha and colonises ditches and baulks around cultivated fields. In Wadowice (E of Bielsko-Biała, S. Poland) the slug occurs in allotment gardens situated in the town, occupying an area of about 7.6 ha. In 2008 another six sites were found in the Sub-Carpathian region (SE. Poland). One site was found in Przemyśl, in three small gardens with a total area of 0.17 ha, and two more in Bircza and Żurawica (SW of Przemyśl). The population in Bircza occurs in several gardens with various ornamental plants (shrubs, trees, perennials, flower plants). The slug occurs mainly on the banks of a stream running through the area, which are reinforced with wooden beams. In Żurawica the population occupies several gardens with an area of approximately 0.05 ha and bushes close to those gardens. The slug probably appeared in these three localities in 2005/2006. Another three sites in the Sub-Carpathian region were found in Cieszyna and Żyznów near Strzyżów (SW of Rzeszów)

and Dębica. *A. lusitanicus* was present there probably since 2006, colonising gardens, edges of cultivated fields and surrounding bushes. In 2008 two sites were also identified in the vicinity of Zielona Góra (SW. Poland). One of them is a garden in the suburbs of Zielona Góra, the other is close to Ochla near Świdnica. The species probably appeared in both places in 2005. The population in Ochla covers an area of approximately 4.5 ha. This area is surrounded by forest, water-filled drainage ditches run along two sides, with two ponds and thick bushes nearby. The area includes numerous sites of cultivation of various plants: vegetables, flowers, strawberries, shrubs and fruit trees, as well as wasteland with dense weed growth. The slug occurs over the whole area, particularly in grassy places near watercourses. In 2009 five new sites of *A. lusitanicus* were discovered. One was in a small forest within the city of Poznań, where the slug occurred close to a pond, and another was in Puszczykowo near Poznań, in an overgrown garden with an area of approximately 0.06 ha. The slug probably appeared there after 2005. Two further sites were found close to Poland's southern border, in Miedonia near Racibórz and in Pogwizdowo near Cieszyn. The slug was probably present there since 2004, and occupied gardens and cultivated fields with an area of approximately 0.4 ha in each locality. The final site, discovered in 2009 in Mikołajki Pomorskie (N. Poland), is a forest approximately 1 ha in area. It is not known when the slug first appeared there. At present it is migrating from that location to parks and gardens within the town, and can be found on paths and pavements, particularly after a rain.

Most of the sites of occurrence of *A. lusitanicus* so far identified were located in urban areas, in cities, suburban areas and villages. In these places the slug had colonised house gardens, vacation properties, cultivated fields, meadows, parks, cemeteries, etc. Eight sites were found outside built-up areas. Two of these are in bushes (Korczyna, Pisarzowice), two in ditches alongside main roads (Zabratówka, Zarzecze), three in forests (Poznań, Podkowa Leśna, Mikołajki Pomorskie), and one in a cultivated area surrounded by forest and bushes (Ochla). A characteristic feature of the sites colonised by *A. lusitanicus* is the presence of watercourses and water bodies, cultivated and other plants, and hiding places such as a thick layer of leaves and shoots of live and dead plants, rubble and stones, boards, branches, walls of buildings, fence foundations, garden and municipal waste, etc.

At the observed sites, the density of *A. lusitanicus* ranged from a few to about 15 specimens per square metre. The average density at sites of cultivation of vegetables and ornamental and orchard plants ranged from 1.7 (Przemyśl) to 28.5 specimens per square metre (Zawadka) (Table 1). In some gardens, for example at the site in Zawadka, up to 65 specimens per square metre were observed. In unculti-

vated areas, bushes and ditches (Korczyna, Zarzecze, Poznachowice, Zabratówka) the density ranged from 2.7 to 8.7 individuals per square metre, and in forest areas – from 3.4 to 5.9 per square metre (Poznań, Mikołajki Pomorskie, Podkowa Leśna) (Table 1).

The observations of symptoms of slug grazing on selected species of plants, carried out in 2003–2007, showed that the slug damaged various species of vegetables, orchard plants, ornamental plants and herbs (KOZŁOWSKI 2005, 2008). Among vegetable plants, those which were most frequently and most heavily damaged were head cabbage (*Brassica oleracea* convar. *capitata*), lettuce (*Lactuca sativa* var. *capitata*), beetroot (*Beta vulgaris* var. *conditiva*), carrots (*Daucus carota* var. *sativus*) and common bean (*Phaseolus vulgaris* var. *nanus*). Slightly damaged plants included onion (*Allium cepa* var. *cepa*), garlic (*A. sativum* var. *sativum*) and celeriac (*Apium graveolens* var. *Rapaceum*) (Table 2). The degree of damage to some vegetable species (beetroot, head cabbage, lettuce) approached 80%. The slug also caused damage to the fruit of strawberry (*Fragaria ananasa* Duch.) and raspberry (*Rubus* spp.). Among ornamental plants, there was heavy damage to the leaves and flowers of dahlia (*Dahlia variabilis*), Madonna lily (*Lilium candidum*), zinnia (*Zinnia elegans*), cutleaf coneflower (*Rudbeckia laciniata*) and Mexican marigold (*Tagetes erecta* L., Asteraceae). Damage to *R. laciniata* and *L. candidum* (Liliaceae) reached approximately 50%. Peony (*Paeonia corallina*) was not damaged in spite of the large numbers in which the slug occurred, and there was only very slight damage to garden clematis (*Clematis* sp.) and fuchsia (*Fuchsia magellanica*). At the sites located away from cultivated plants (Zabratówka, Zarzecze, Poznachowice, Korczyna) and in forests (Podkowa Leśna, Poznań, Mikołajki Pomorskie), the slug damaged dicotyledon weeds, particularly such species as ground-elder (*Aegopodium podagraria*) and common nettle (*Urtica dioica*). In some places (Łañcut, Wysoka, Markowa) the damage done by the slug to *Ae. podagraria* was so great that after several years the plants were completely destroyed and replaced by other species, particularly those of the genera *Impatiens*, *Epilobium* and *Potentilla*, which now grow densely there.

The discovery, particularly in the past few years, of numerous new sites of occurrence of *A. lusitanicus* indicates that this slug is spreading rapidly in Poland. This is mainly related to human activity, most of all transport of goods. This involves the exchange of plant material in various forms and by various means of transport (containers, road vehicles, trains), in which the slug may be present at any stage of its development. It is also transported along with reproductive material (bulbs, tubers, rhizomes, tuberous roots, seedlings), with plant products intended for consumption or processing (vegetables, fruit) and with ornamental plants (pot plants, cut flowers), or in vari-



Table 2. Numbers of *A. lusitanicus* and degree of damage to selected plant species. *Density of slugs per square metre: (0) none; (×) up to 5 specimens; (××) 6–10; (×××) >10. **Percentage of plant damage: (0) no damage; (+) up to 5%; (++) 6–30%; (+++) 31–50%; (++++) > 60%

Plant species	Family	Plant	Density*	Degree of damage**
Vegetable plants				
<i>Allium cepa</i> L. var. <i>cepa</i> Helm	Liliaceae	onion	×	+
<i>A. sativum</i> L. var. <i>sativum</i> L.	Liliaceae	garlic	×	+
<i>Apium graveolens</i> L. var. <i>rapaceum</i> (Mill.) Gaud.	Apiaceae	celeriac	×	+
<i>Armoracia lapathifolia</i> Gilib.	Cruciferae	horseradish	×××	++
<i>Beta vulgaris</i> L. var. <i>conditiva</i> Alef.	Chenopodiaceae	beetroot	×××	++++
<i>Brassica oleracea</i> L. convar. <i>capitata</i> (L.) Alef. var. <i>sabauda</i> L.	Brassicaceae	savoy cabbage	××	+++
<i>B. oleracea</i> L. convar. <i>capitata</i> (L.) Alef. var. <i>capitata</i> L. f. <i>alba</i> DC.	Brassicaceae	head cabbage	×××	++++
<i>Cucumis sativus</i> L.	Cucurbitaceae	cucumber	×××	++
<i>Cucurbita maxima</i> Duch.	Cucurbitaceae	giant pumpkin	×××	++
<i>Daucus carota</i> L. ssp. <i>sativus</i> (Hoffm.) Schyl. et G. Martens	Apiaceae	carrot	×××	++++
<i>Lactuca sativa</i> L. var. <i>capitata</i> L.	Asteraceae	head lettuce	×××	++++
<i>Lycopersicon esculentum</i> Mill. var. <i>esculentum</i>	Solanaceae	tomato	×	++
<i>Petroselinum crispum</i> (Mill.) Nym. ex Hill convar. <i>radicosum</i> (Alef.) Danert	Apiaceae	parsley	××	+++
<i>Phaseolus vulgaris</i> L. var. <i>nanus</i> (L.) Aschers	Fabaceae	field bean	×××	++++
<i>Raphanus sativus</i> L. var. <i>sativus</i>	Brassicaceae	radish	×××	+++
Ornamental and herb plants				
<i>Althaea rosea</i> (L.) Cav.	Malvaceae	common hollyhock	××	++
<i>Calendula officinalis</i> L.	Asteraceae	pot marigold	××	++
<i>Callistephus chinensis</i> (L.) Ness	Asteraceae	china aster	×	++
<i>Clematis</i> L.	Ranunculaceae	garden clematis	×	+
<i>Dahlia variabilis</i> Desf.	Asteraceae	dahlia	×	+++
<i>Digitalis grandiflora</i> P. Mill.	Scrophulariaceae	yellow foxglove	××	++
<i>Fuchsia magellanica</i> Lam.	Onagraceae	hardy fuchsia	×	+
<i>Lilium candidum</i> L.	Liliaceae	Madonna lily	×××	+++
<i>Paeonia corallina</i> Retz.	Paeoniaceae	wild peony	×××	0
<i>Rudbeckia laciniata</i> L.	Asteraceae	cutleaf coneflower	×××	+++
<i>Tagetes erecta</i> L.	Asteraceae	Mexican marigold	××	+++
<i>Zinnia elegans</i> Jacq.	Asteraceae	zinnia	××	+++
<i>Aegopodium podagraria</i> L.	Apiaceae	ground-elder	××	+++
<i>Artemisia dracunculus</i> L.	Asteraceae	tarragon	×	++
<i>Papaver rhoeas</i> L.	Papaveraceae	common poppy	××	++
<i>Urtica dioica</i> L.	Urticaceae	common nettle	××	+++

ous growing media (gardening soil) as well as with soil from excavation works and with municipal waste. There were many observations of eggs and young slugs in agricultural crops ready for transport (let-

tuce, cabbage, carrots, beetroot), on shrub cuttings and in plant waste. A significant contribution to the spreading of the slug beyond the region of its occurrence is the transport of fruit and vegetables to forests

as food for game animals. *A. lusitanicus* also spreads actively, without human intervention, by migrating beyond its area of occurrence in search of food and shelter. It spreads mainly along ditches, baulks and watercourses, and over several years may reach new

habitats. The sites of occurrence of the slug which appeared after 1993 in various places in the vicinity of Rzeszów, originating from Poland's first confirmed population in Albigowa, are good examples of this.

DISCUSSION

A. lusitanicus probably arrived in Poland at the end of the 1980s (Albigowa near Rzeszów). At first it was found only at locations to the east of Rzeszów (Albigowa, Markowa, Wysoka), but later came to be found at many other places in the Sub-Carpathian subregion (KOZŁOWSKI & KORNOBIS 1994, 1995). Twenty new sites were identified outside this subregion since 2000, and new sites are continuously found in other parts of the country (KOZŁOWSKI 2000a, 2001, 2008, KOZŁOWSKI et al. 2008). A similar rate of spread of *A. lusitanicus* has been observed in other countries of Europe: in Austria (REISCHÜTZ 1984), Great Britain (DAVIES 1987), Sweden and Norway (VON PROSCHWITZ 1992, 1994, VON PROSCHWITZ & WINGE 1994), and Switzerland (FRANK 1998). In Sweden the slug was first identified in 1975 (VON PROSCHWITZ 1992), and by 1980 spread throughout the district of Göteborg (SW. Sweden). In subsequent years new sites of occurrence were found in central and eastern Sweden and along the Baltic coast, and by the end of 1993 there were 379 known sites (VON PROSCHWITZ 1994). In Norway the first identification of *A. lusitanicus* took place in 1988. Over the next few years there was a rapid increase in the rate of spread to areas along the northern edge of Trondheimsfjord in central Norway (VON PROSCHWITZ & WINGE 1994). These examples show that *A. lusitanicus* quickly extends the boundaries of its occurrence. It is possible that the slug is present at many other locations, where it still remains undetected or is mistaken for *A. rufus*, from which it does not differ in external appearance.

A. lusitanicus shows a wide nutritional and ecological tolerance. Within its native range it lives in open and forested habitats. In Poland it chiefly colonises environments which have undergone major anthropogenic degradation, where it occurs in large numbers. The slug occurs mainly in cultivated gardens and fields situated close to buildings and watercourses, where it causes serious damage, similarly as in such countries as Austria and Sweden (REISCHÜTZ 1984, VON PROSCHWITZ 1994). It also occurs in forests, bushes and wastelands (VON PROSCHWITZ 1994, KOZŁOWSKI 2005). The density of *A. lusitanicus* on cultivated plants in Poland is similar to its density in meadows and in strips of wild flowering plants close to fields in Switzerland (BRINER & FRANK 1998). VON PROSCHWITZ (1994) reported that in garden crops in Sweden the density of *A. lusitanicus* ranged from 5 to 7 specimens per square metre. Our data imply that its

density in most garden crops (more than 70% of cases) is 2–3 times greater. Our observations on the size of damage done to vegetable, orchard, ornamental and weed plants by *A. lusitanicus* revealed large differences in the susceptibility of particular plant species to damage by this slug. Heavily damaged plants include – among others – cabbage, lettuce, carrots, beans, strawberries, cutleaf coneflower, Madonna lily, ground-elder and common nettle. According to some authors, the greatest damage done by *A. lusitanicus* occurs on plantations of vegetables, particularly those of the family Brassicaceae, on certain ornamental plants and in crops of winter rape and winter wheat (SOUTH 1992, PORT & ESTER 2002, MOENS & GLEN 2002, KOZŁOWSKI 2003, 2005).

Many years of studies on the occurrence and spread of *A. lusitanicus* in Poland suggest that the species, in the process of finding new food resources, shelter and egg-laying sites, may displace other slug species. Such a situation was observed at an allotment site in the city of Rzeszów, where *A. rufus* occurred in 1993–1998; since 2002 only *A. lusitanicus* was found there (KOZŁOWSKI 2008). The mass occurrence of *A. lusitanicus* may also lead to extinction of some plant species. Near Łañcut (Sub-Carpathian subregion), in places where the slug occurs in large numbers, it has almost completely destroyed wild-growing ground-elder (*Aegopodium podagraria*) (KOZŁOWSKI & KOZŁOWSKA 2000). Other plants now occur there (*Potentilla*, *Epilobium* and *Impatiens*) which are not eaten by the slug. This shows that selective grazing by *A. lusitanicus* may change the species composition in natural plant stands, as has also been reported by other authors (KELLER et al. 1999, FRANK 2003, BUSCHMANN et al. 2005, LANTA 2007).

The rapid spread of *A. lusitanicus* is favoured by its high fecundity (ca. 450 eggs), ability to self-fertilise, high mobility, resistance to unfavourable ambient conditions, and the absence of natural enemies in new habitats (KOZŁOWSKI 2000b, 2008; KOZŁOWSKI & SIONEK 2000b). Recent mild winters have led to higher survival rates of eggs and overwintering individuals, significantly increasing the slug's numbers and rate of expansion. New populations originate both from sites within Poland and from other places in Europe. Genetic research carried out in 2006 on populations of the slug at various sites in Poland revealed a high level of variation between and within populations (SOROKA et al. 2009). This indicates that



A. lusitanicus in Poland may come from multiple independent introductions into Poland from Western Europe. It has been shown that most newly colonised sites originate from specimens brought from various places in Europe, with only a small proportion coming from the original sites near Rzeszów. It is very likely that in something over a decade, due to successive introductions of the slug to new habitats in Poland, it will occur over the whole area of the country.

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