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INVASION OF SPANISH SLUG *ARION VULGARIS* MOQUIN-TANDON, 1855 (GASTROPODA ARIONIDAE) IN LATVIA BETWEEN 2016 AND 2020

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The paper presents data on the distribution of *Arion vulgaris* Moquin-Tandon, 1855 in Latvia. This study shows that the involvement of citizens in science activities markedly help collect data on species distribution. The involvement of citizens resulted in the registration of 94 new localities of Spanish slug in Latvia between 2016 and 2020. In Latvia, species mainly occur in anthropogenic habitats, but also invade natural habitats..

Key words: *Arion vulgaris*, Latvia, invasion.

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INTRODUCTION

Alien and invasive species are considered to be one of the most important indicators for changes and threats to biodiversity. Also, they cause large economic losses, threats to ecosystems and environmentally sensitive species or have a negative impact on human health. In this research, we focus on the Spanish slug *Arion vulgaris* Moquin-Tandon, 1855 who is one of the most important agriculture and horticulture pest and one of the hundred worst alien species in Europe (Hulme 2009, Slotsbo 2014, Zając et al. 2017). Because of its resistance, phenotypic plasticity and ability to adapt to changing environmental conditions, the species have successfully infested most of central, northern and eastern Europe (Knop, Reusser 2012, Slotsbo 2014).

Initially, it was considered what the natural distribution area of the species was the Iberian Peninsula and southern France (Лихарев & Виктор 1980); however, according to Quinteiro et al. (2005) the genetic differences between the slug species of Iberian Peninsula and southern France were found. Therefore, the taxon *A. vulgaris* Moquin-Tandon 1855 is used to describe the invasive agricultural pest in Europe, while *Arion lusitanicus* J. Mabille, 1868, which was originally used as a synonym for *A. vulgaris*, refers to the endemic species of Portugal (Pfenniger et al. 2014, Zemanova et. al 2016).

For the first time, *A. vulgaris* outside of its natural range was recognized in the UK in the early 1950s (Winter 1989, Kerney 1999). In less than 30 years, the species has spread to most of Europe's moderate climate zones hemiboreal forest region. Now, the Spanish slug inhabits Austria, Belgium, Czech, Estonia, Poland, Germany, Lithuania, Ireland, Denmark, Sweden, Norway, Finland, Slovakia, Hungary, Romania, Bulgaria, Serbia, Ukraine and Western Russia (Slotsbo 2014, Лихарев & Виктор 1980). The species is common in Austria, Belgium, Germany and Denmark. It often occurs in Finland,Faeroe Islands,Netherlands, Norway and Sweden. Local deposits are in Czech Republic, Ireland, Lithuania, Estonia and Poland. The species is rare in Iceland and Russia. Some deposits are also known in Slovakia, Hungary, Romania, Bulgaria and Serbia (Păpureanu et al., 2014). Outside Europe, *A. vulgaris* found in USA, Canada and Mexico (Zemanova et al. 2018, Araiza-Gómez et al. 2021). In Latvia, the Spanish slug for the first time was found in 2009 (Rudzīte et al. 2010) and until 2016 it was known only in 16 localities (Jakubāne et al. 2016).

There is reason to believe that international trade has spread *A. vulgaris* from other infested countries with plant materials thus infesting the majority of central, northern and eastern Europe and Baltic countries (Barr et al. 2009; Slotsbo 2014). According to many authors, the main factors of successful invasion are the high fertility, faster development, better ecological tolerance, drought resistance, less natural enemies, increased distribution capacity, increased survival at elevated temperatures, the plasticity of behavioural ability to hybridize with other species of *Arion* genus (Turner et al. 1998, Knop & Reusser, 2012, Zemanova et al. 2017,Zając et al. 2017).

To collect data of *A. vulgaris* distribution within Latvia territory, in 2015, the invasive alien species monitoring program was developed in the frame of the project of Nature Conservation Agency: "The development of invasive alien species monitoring program in Latvia" (Nr. 7.7/103/2105-P), whereas to control the animal spread in Latvia the plan of distribution control of Spanish slug was designed in 2018 (Pilāte et al. 2018).

MATERIAL AND METHODS

This study focused on the actualization of the distribution of the Spanish slug in Latvia between 2016 and 2020. The information on the distribution of slugs was collected from citizens by public information campaign that started in 2016. To involve citizens in research activities, the information on the Spanish slug was published in various popular and popular scientific magazines and radio every year. New localities of Spanish slugs also were found by chance during other activities of researchers such as the invasive alien species monitoring program. Citizens sent information about large slug species in the email specially created by the Nature Conservation Agency (invazivs@daba.gov.lv).

The authors checked all reports and confirmed new localities of Spanish slug by collecting material of slug specimens. Identification of slugs was done on the key of differences in reproductive system features for particular slug species according to Noble (1992).

Information on the approved localities of the Spanish slug is updated each year and submitted to the Nature Conservation Agency of Latvia for identification of the spread of invasive species in the country.

RESULTS AND DISCUSSION

Based on the received reports, more than 520 localities of specimens were checked between the 2016 and 2020 years. The active invitation of citizens to report the occurrence of the Spanish slug resulted in the registration of 350 new localities. The main part of them was citizens' gardens, agricultural lands and parks.

Until 2014, only two localities of Spanish slug was known: 1) in Pastende - confirmed in 2009

(Rudzīte et al. 2010) and 2) in Jelgava - confirmed in 2010 (Stalažs et al. 2014). During the next two years, 14 new species localities were confirmed. The number of known localities with Spanish slugs occurrence increased by eight after the first informative campaign provided for citizens in 2016 (Jakubāne et al. 2016). The rapid increase in the number of new localities from 2017 is related to the education and information of citizens in the frame of the project "Collection of data on the Invasive Species Spanish slug (*Arion lusitanicus*) in Latvia" (No 1-08/47/2017) financed by the Latvian Environmental Protection Fund. In the next years, reporting of species occurrence became a common practice and markedly increased every year (Fig 1).

Between 2016 and 2020, 94 new localities of Spanish slug was confirmed. In total, there are 110 localities of *A. vulgaris* in Latvia (Fig. 2.).

In Latvia, species mainly occur in anthropogenic habitats like gardens, roadsides, ditches similarly to other Baltic and European countries (Eek & Kukk 2013, Slotsbo 2014 ,Adomaitis & Skujienė 2016). Though species mostly occurs in agricultural and horticultural habitats with permanent vegetation and in compost heaps, unfortunately, the species also invade natural habitats. In Latvia, species was found in protected habitats of the European Union, like Molinia meadows on calcareous, peaty or clayey-silt-laden soils (*Molinion caeruleae*) (6410*), Wooded dunes of the Atlantic, Continental and Boreal region (2180*), Fennoscandian deciduous swamp woods (9080*), Tilio-Acerion forests of slopes, screes and ravines (9180*), Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (Alno-Padion, Alnion incanae, Salicion albae) (91E0*), Sub-Atlantic and medio-European oak or oak-hornbeam forests of the Carpinion betuli (9160*) and Western Taïga (9010*). The same situation documented in other countries like Austria (Dörler et al. 2018), Norwey (Hatteland et al. 2013), Switzerland (Fechter & Falkner 1990) and Germany (Turner et al., 1998). According to citizens reports the Spanish slug is a serious pest of vegetable crops, strawberries, vegetable seedlings and arable crops especially *Brassica napus*. Other countries invaded with species also facing this type of problem, for example, in Norway, Spanish slug ruined more than 50% of strawberry harvest (Weidema 2006).

This study showed that the involvement of citizens in science studies markedly help collect data on species distribution (Fig. 2.). The same conclusion was reached by Dörler et al (2018) involving local citizens in research about the occurrence of the invasive Spanish slug in gardens of Austria. Although many people reported that the invasive species inhabit a particular area for

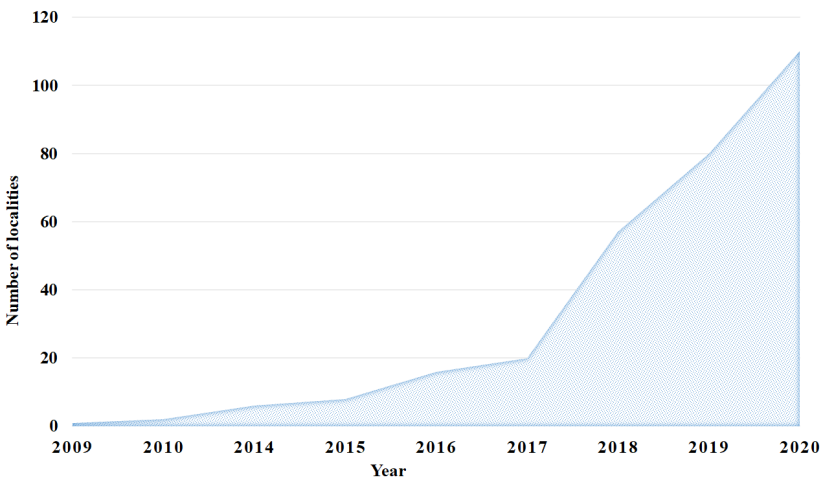

Fig. 1. Invasion of *Arion vulgaris* Moquin-Tandon, 1855 in Latvia during 2009 – 2020.

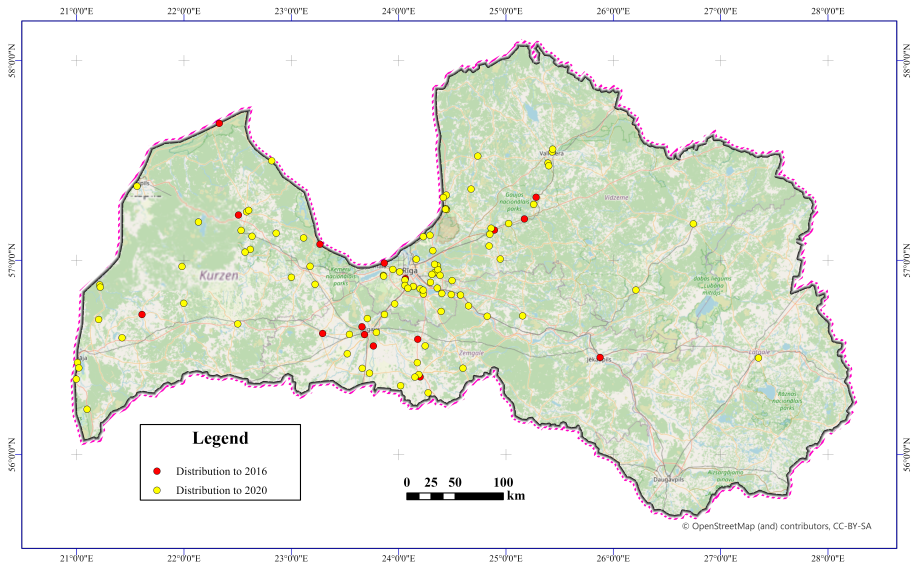

Fig. 2. Distribution of *Arion vulgaris* Moquin-Tandon, 1855 in Latvia (map drawn by M. Nitcis).

a few years species localities were approved only after an anatomical examination by malacologists. The successful species distribution may be partly explained by the hybridization with others *Arion* genus species such as *A. ater* and *A. rufus* (Zemanova et al. 2017), producing highly plastic and adaptable forms (Knop and Reusser, 2012). Local population prevalence studies should be continued.

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