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Invasion of the Asian Ladybird *Harmonia axyridis* (Pallas, 1773) in the European Part of Russia

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The natural range of the Asian ladybird *Harmonia axyridis* (Pallas, 1773) covers the territories of China, Mongolia, Korea, Japan, and Russia (Far East, Southern Siberia, and Altai). Since the early 1980's, the global invasion of *H. axyridis* began, first on the territory of the United States, from where the Asian ladybird spread to South America, Africa, and Europe. By 2016, this species occupied all of Western Europe with the exception of its northern and southern regions. Penetration of *H. axyridis* on the territory of the Russian Federation (Kaliningrad) was discovered in 2010, and since 2011, the species has spread to the Black Sea coast. This report presents our data on the distribution of *Harmonia axyridis* in central Russia, from its western borders, to the Volga River. The occupation of this huge territory by this species occurred mainly in the last 3 years—2018–2020. The rate of movement of the species on the territory of the European part of Russia is about 200 km/year.

Keywords: Asian ladybug, *Harmonia axyridis*, invasion, propagation speed, European part of Russia

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INTRODUCTION

The natural range of the Asian ladybird *Harmonia axyridis* (Pallas, 1773) (Coleoptera: Coccinellidae) covers the following territories: North-Eastern and Central China, Mongolia, Korea, Japan, Eastern Kazakhstan, and in Russia—the Far East, southern Siberia, Tyva, and Altai (Orlova-Bienkowskaja et al., 2015; Blekhman and Goryacheva, 2017; Andrianov et al., 2018). In the early 1980's, the global invasion of *H. axyridis* began first in the United States (Koch et al., 2006), from where the Asian ladybird spread to South America, Africa, and Europe where it mixed with populations used in biological protection of greenhouse crops that escaped into the open (Lombaert et al., 2010; Roy et al., 2016). In Europe, invasive populations of *H. axyridis* were discovered in the early 2000's (Adriaens et al., 2003), and by 2016, this species occupied all of Western Europe except for its northernmost and southernmost regions (Roy et al., 2016).

In the European part of Russia, the occurrence of *H. axyridis* was observed from 2004 to 2006 in the territory of the Belgorod Region (Binkovskaya, 2004; Orlova-Bienkowskaja, 2013). In 2010, mass reproduction of the species was recorded by one of the authors in Kaliningrad (Zakharov et al., 2011). The presence and reproduction of *H. axyridis* have been observed since 2011 on the Black Sea coast of the Caucasus (Orlova-Bienkowskaja, 2013; Ukrainsky, 2013) and since 2012–2013 in the Krasnodar Territory (Korotyaev, 2015a,b). During the same period, there were reports of *H. axyridis* finds in Ukraine [since 2007—(Nekrasova and Tytar, 2009; Verizhnikova and Shylova, 2013)], in Belarus [since 2011—(Kruglova, 2015; Kruglova and Sinchuk, 2017)], and in Latvia [since 2009—(Barševskis, 2009)].

This report presents the authors' data on the distribution of *H. axyridis* in central Russia, from its western borders to the Volga River. The discussed species captured this huge territory mainly in the last 3 years—2018–2020.

MATERIALS AND METHODS

The presence of *H. axyridis* was recorded during the implementation of special collections of coccinellids or when collecting other insects. Beetles *H. axyridis* were collected at the stages of imago, pupae, and last instar larvae. Collections were carried out on various shrubs and trees, in cities—mainly on lime trees (*Tilia* sp.), as well as during the autumn flight and in wintering areas. Methods of collecting beetles and keeping them in the laboratory are described in Andrianov et al. (2018). In the collections of *H. axyridis*, where morphs were counted, three phenotypes were distinguished: *succinea* (yellow or red with a different number of black spots), *spectabilis*, and *conspicua* (both are black, with four and two red spots, respectively) and *axyridis* (black with many red/yellow spots). Among the *succinea* morphs, the proportion of individuals without spots was taken into account (see **Table 2**).

RESULTS AND DISCUSSION

Information about the materials collected by the authors of this paper and the collections of other researchers is presented in **Table 1** and the map (**Figure 1**). It can be seen that *H. axyridis*

TABLE 1 | Collections of *Harmonia axyridis* in 2018–2020 years in the European part of Russia.

Collection sites (westerly to easterly)	Geographical coordinates (lat/long)	Dates of collections	Collections—solitary/mass	Population state	Collector or publication
Kaliningrad	54.71 / 20.51	08.2019	Mass	B	I.A. Zakharov
Kursk region	52.31 / 35.38	10.06.2019	Solitary	B	Ruchin et al., 2020
Oryol	52.96 / 36.08	08.10.2018	Solitary	A	Sazhnev et al., 2020
Kaluga	54.53 / 36.17	10.2018	Solitary	C	Ruchin et al., 2020
Moscow, Gagarin square	55.71 / 37.58	14.10.2020	Mass	C	I.A. Zakharov
Moscow, South district	55.61 / 37.68	09.2020	Mass	B	I.A. Zakharov
Moscow, Zhulebino district	55.69 / 37.84	06-08.2020	Mass	B	D.A. Romanov
Sochi, Lazarevskoe	43.91 /39.33	06.2019	Mass	B	D.A. Romanov
Rostov-on-Don	47.22 / 39.72	10.2019	Mass	A	D.E. Romanov
Ryazan region	53.59 / 40.03	10.2019	Mass	D	I.I. Goryacheva
Ryazan region	54.21 / 40.98	6–13.10.2020	Solitary	A,D	A.B. Ruchin
Ryazan region	54.07 / 41.45	6–13.10.2020	Solitary	A,D	A.B. Ruchin
Tambov region	52.49 / 42.80	24.08.2019	Solitary	A	Ruchin et al., 2020
Republic of Mordovia, Pushta	54.72 / 43.23	10.2019 10.2020	Mass	D	A.B. Ruchin
Saransk	54.18 / 45.18	10.2019 10.2020	Mass	A,C,D	A.B. Ruchin E.A. Lobachev A.V. Meshcheryakova
Volgograd region	49.55 / 45.07	15.09.2018	Solitary	A	Ruchin et al., 2020
Saratov	51.52 / 45.98	06.09.2019	Mass	A	Ruchin et al., 2020
Penza region	52.78 / 46.80	10.07.2018	Mass	A	Ruchin et al., 2020
Republic of Chuvashia	54.51 / 46.35	23.08.–25.10.2019	Solitary	A	Egorov et al., 2019
Republic of Chuvashia	55.00 / 46.42	14.10.2020	Solitary	A	L.V. Egorov
Cheboksary	56.08 / 47.08	14.10.2020	Solitary	A	N.V. Borisova
Cheboksary	56.08 / 47.15	23.08.–25.10.2019	Solitary	A	Egorov et al., 2019
Republic of Chuvashia	54.51 / 47.22	27.06.2020	Solitary	A	L.V. Egorov
Ulyanovsk region	53.08 / 47.38	25.07.2019	Solitary	A	Ruchin et al., 2020
Ulyanovsk,	54.18 / 48.07	3.10.2020	Solitary	A	Kichigin, 2020
Astrakhan	46.35 / 48.03	10.04.2019	Solitary	A	Ruchin et al., 2020
Kazan	55.85 / 49.07	30.09.2019	Solitary	B	Ruchin et al., 2020
Samara region	53.74 / 49.45	27.06.2020	Solitary	A	D.S. Pasynkova
Samara region	53.46/ 49.84	29.08.2019	Solitary	A	Egorov et al., 2019
Republic of Udmurtia	58.13 / 52.67	24.09.2019	Solitary	A	Sazhnev et al., 2020

Population state: A – active, only imago, B – reproduction (presence of pupae and larvae), C – winter flight, D – wintering; solitary/mass - single find / mass collection.

FIGURE 1 | *Harmonia axyridis* distribution in the European part of Russia (2018–2020).

TABLE 2 | Constitution of *Harmonia axyridis* populations, number and percent of morphs.

Collection sites	Dates of collections	Total	Conspicua	Spectabilis	Axyridis	Melanic		Succinea, total	succinea without spots	
						Total	Percent (95%c.i.)		Total	Percent (95%c.i.)
Kaliningrad	08.2019	164	1	1	-	2	1.2 (0.02–4.34)	162	6	3.7 (1.35–7.79)
Moscow, South district	09.2020	84	1	10	-	11	13.0 (/6.72–22.22)	73	1	1.2 (/0.03–6.46)
Moscow, Zhulebino district	06-08.2020	169	1	6	-	7	4.1 (1.68–8.35)	162	2	1.2 (0.14–4.21)
Sochi	06.2019	107	-	6	-	6	5.6 (2.09–11.81)	101	25	23.4 (15.73–32.53)
Rostov-on-Don	10.2019	69	4	5	-	9	13.0 (6.14–23.32)	60	7	10.1 (4.18–19.79)
Republic of Mordovia, Pushta	10.2020	268	5	16	-	21	7.8 (4.92–11.73)	247	9	3.4 (1.55–6.28)
Saransk	10.2019 10.2020	206	3	13	1	17	8.3 (4.88–12.88)	189	3	1.5 (0.30–4.20)

95%c.i., 95% "exact" confidence interval.

occupied a huge territory—from the western borders of the Russian Federation to the Volga.

Almost exclusively the morphs found commonly in Europe—*succinea*, *spectabilis*, *conspicua*—were present in all the collections, with *f. succinea* dominating. The West Siberian morph *axyridis* was found only once—in Saransk (one individual). The least number of melanics (*spectabilis, conspicua*) was in Kaliningrad. The proportion of beetles of the *succinea* morph without spots was the greatest in Sochi in comparison with other populations (**Table 2**). This suggests that the settlement of the Black Sea coast of the Caucasus occurred not only from the west, as in other regions, but also from the south, from Asia Minor.

It is known that in the new territories occupied by *H. axyridis*, this species successfully competes with the local Coccinellidae, as a result of which the number of the latter decreases

TABLE 3 | The ratio of three species of coccinellids in collections in Moscow, Zhulebino district (end of June – August 2020).

Species	Number of larvae	Number of pupae	Total
Harmonia axyridis	21	148	169
Adalia bipunctata	56	457	513
Adalia decempunctata	14	91	105

(Brown and Roy, 2018). In two geographical locations, the authors calculated the ratio of *H. axyridis* and local species of the genus *Adalia* [*Adalia bipunctata* (Linnaeus, 1758) and *Adalia decempunctata* (Linnaeus, 1758)], which occur on the same plants with aphid colonies and reproduce at the same

time. In Kaliningrad (August 2019), where *H. axyridis* were collected, *Adalia* ladybirds were not found at all, although in previous years, before the appearance of *H. axyridis* here, *Adalia* findings were numerous (observations of IZ). The same was noted by one of the authors (IZ, unpublished) in Munich (Germany), where in 2015, with a significant number of found *H. axyridis*, *Adalia* ladybirds were not found. In Moscow, where mass reproduction of *H. axyridis* was observed for the first time in 2020, *Adalia* ladybirds still predominate among coccinellids (**Table 3**). These data should be supplemented in subsequent years.

The rate of progress of the species was estimated from the findings in Kaliningrad (2010), the first breeding colony in Moscow [2015—(Zakharov, 2015)], and in Saratov [2019—(Sazhnev et al., 2020)]. Taking into account the distance from Kaliningrad to Moscow (1,100 km) and from Kaliningrad to Saratov (1,750 km), the propagation speed is about 200 km/year. At this speed, beetles can spread both naturally (Jeffries et al., 2013) and using passing transport. The rate of spread calculated here is the same as that calculated in other parts of Europe (Brown et al., 2011).

Given the wide adaptability of *H. axyridis* to various environmental and climatic conditions, one can expect the spread of this species in the coming years to the north, at least to St. Petersburg (in 2019, *H. axyridis* was not there yet) and to the east, to the Urals.

If *H. axyridis* spreads to the east beyond the Urals, it will be possible to observe an interesting natural experiment, when the populations of two subspecies of *H. axyridis*, which clearly differ in morphological features [color and pattern on the elytra—(Blekhman and Goryacheva, 2017)] and in mitotypes—variants of mitochondrial DNA (Zakharov et al., 2011), unite in the Tomsk—Novosibirsk area (the western edge of the native range). Given the rate of spread of *H. axyridis*, one can expect that nature will stage this population-genetic experiment in the next 10 years.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding authors.

AUTHOR CONTRIBUTIONS

IZ conceived the project, designed methodology, and led the writing of the manuscript. IZ, AR, LE, DR, and AS contributed to ladybird collection and identification. All authors contributed critically to the drafts and gave final approval for publication.

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