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The Ladybird Spider *Eresus kollari* Rossi, 1846 (Araneae: Eresidae) in Poland: Distribution and Current Status of Threat

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Abstract: The ladybird spider *Eresus kollari* Rossi, 1846 (Araneae: Eresidae) is a thermophilic species distributed from Europe to West Siberia. Due its rare presence in Poland, this species is protected. This paper presents data about its distribution in the studied country as a result of an overview of published literature and new records of *E. kollari* in Poland. Habitat preferences and the current category of threat of this endangered spider species are also discussed. Additionally, our work reveals new records of its parasitoids, hunting-spider wasps: *Eoferreola rhombica* (Christ, 1791) and *Ferreola diffinis* (Lepeletier, 1845).

Key Words: *Eresus kollari*, Ladybird spider, distribution, Poland, Pompilidae

Introduction

The genus *Eresus* Walckenaer, 1805 contains 21 valid species from Europe, North Africa and Asia, of which 15 occur in Europe (World Spider Catalog 2019). In Poland, there is only one representative of this genus, i.e. *Eresus kollari* Rossi, 1846. This thermophilic species with European-West Siberian distribution (Řezáč et al. 2008, Kovács et al. 2015) is highly endangered (category EN of IUCN). It has been included in the Red List of Becoming Extinct and Endangered Animals in Poland (Staręga et al. 2002) and in the Polish Red Book of Animals (Rozwałka 2004). In Poland, due to its rarity, disappearance of natural habitats and strong fragmentation of posts, the ladybird spider is the subject to legal protection (Regulation of the Minister of the Environment of 16 December 2016).

Eresus kollari inhabits open and warm environments covered by loose and low herbaceous vegetation, often associated with heather. This spider occurs most commonly in both alkaline soils covered by grassland communities of *Festucetalia valesiacae* and acidic soils with psammophilic grasslands of *Corynephoretalia canescentis* (Řezáč et al. 2008; Fig. 1). Less commonly, it has been also recorded in dry and very bright pine forests (e.g. *Cladonio-Pinetum*), bright oak woodlands (*Potentillo albae-Quercetum*) and other young forest stands (Wiehle 1953, Wąsowska 1964, Buchar 1975, Żmihorski 2004, Řezáč et al. 2008, Szpila et al. 2011). It is possible that some information about *E. kollari* in forest stands is related to disappearing, dwarf populations, e.g. in forested inland dunes and xerothermophilous grasslands recolonised by trees and shrubs (Rozwałka 2004).

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The ladybird spider is a settled species, which forms small colonies of several up to several dozen (rarely several hundred or more) individuals (Wiehle 1953). The females (Fig. 2) and young specimens of *E. kollari* have a sedentary lifestyle in self-dug, up to 5-10 (15) cm deep burrows. The entry is covered with a small tent-like lid made of cobweb and well-masked with plant fragments (Wiehle 1953, Bellmann 2004; Figs. 3, 4). Males (Fig. 5) after reaching adulthood in their third year, usually around the second half of August, begin wandering in search of females (Wiehle 1953, Rozwałka 2004). During the reproduction period and until the first frosts nomadic males can be spotted in the area, so most of the records of this species refer to migrant, often single males (e.g. Wąsowska 1964, Banaszak et al. 2002, Żmihorski 2004, Barańska 2007, Szpila et al. 2011). According to Baumann (1997), the distance walked by migrating males could reach 76 m with an average of about 13 m. At the same time, he noted that the daily record was over 59 m. However, these migrations may only benefit in gene flow between (sub)populations in neighbouring area. Because of the sedentary life of females and young spiders usually digging their burrows close to the place where they were born, this species shows very low level of migration ability. There are no direct observations of dispersion of young spiders of the genus *Eresus* by ballooning, but in laboratory conditions this behaviour was observed for *E. walckenaeri* (Ratschker 1995). Krejci (2012) observed pre-ballooning behaviour like *tip-toeing* and *drop and swing* in *E. moravicus* and *E. kollari* (also in a laboratory experiment). Regarding *E. kollari*, this process may play marginal (if any) role in dispersion to new habitats.

In Poland, *E. kollari* is considered rare (Prószyński & Staręga 1971) and threatened with extinction (Staręga et al. 2002, Rozwałka

Fig. 1. Ladybird spider's burrow masked with a small tent-like lid made of cobweb (marked with a ring). Photo by R. Rozwałka

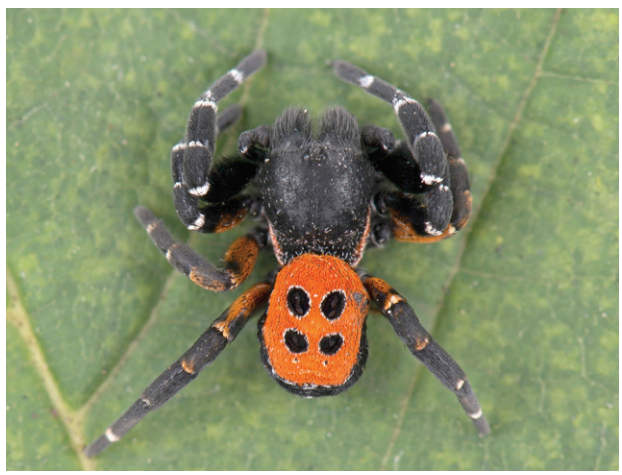

Fig. 3. Male of *Eresus kollari*. Photo by M. Szewczyk

Fig. 2. Lid raised up, the oval entrance to burrow is visible. Photo by R. Rozwałka

Fig. 4. Female of *Eresus kollari*. Photo by R. Rozwałka

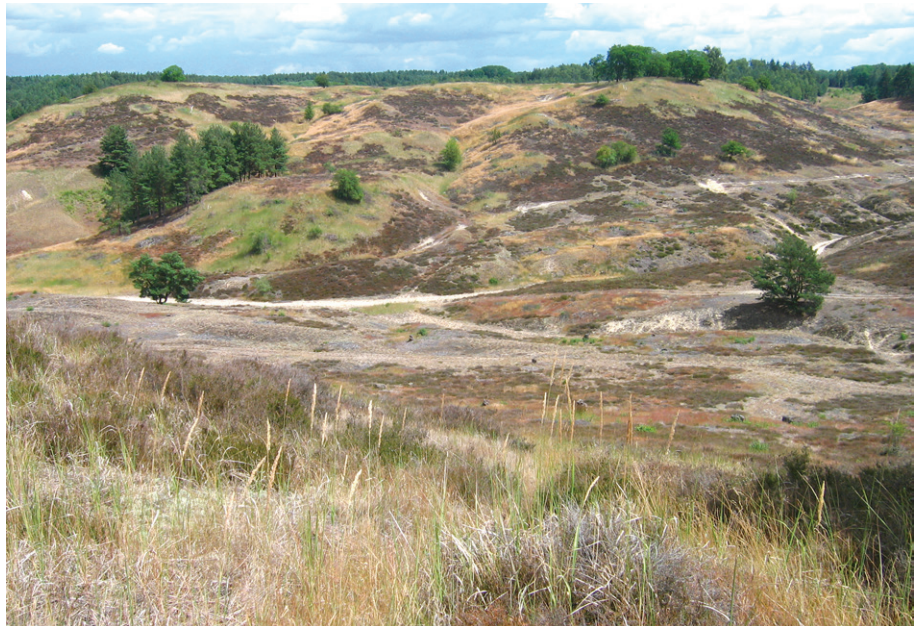

Fig. 5. General view of nature reserve "Wrzosowiska Cedyńskie" – habitat of abundant population of *Eresus kollari*. Photo by P. Sienkiewicz

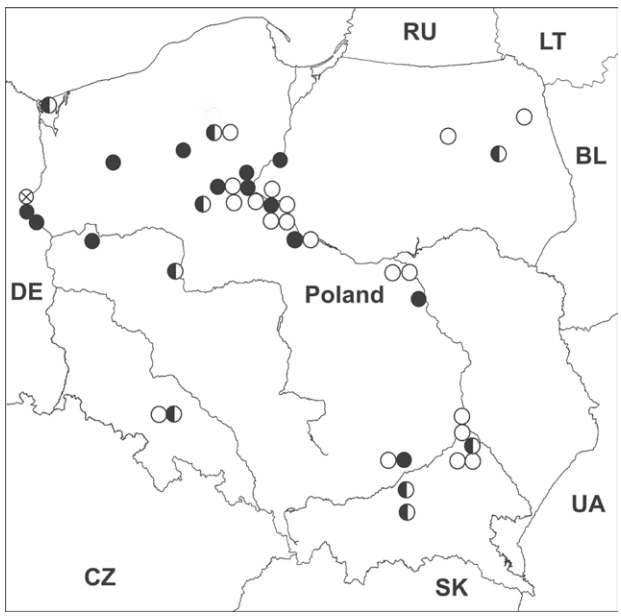

Fig. 6. Distribution of *Eresus kollari* in Poland
○ – known localities of *Eresus kollari*
◐ – known localities of spider-hunting wasps
● – new locality records of *Eresus kollari*
⊗ – localities probably extinct

2004). In the last review of the distribution of this spider in Poland, only 12 locations were reported, of which only half was treated as still existing (Rozwałka 2004). In subsequent years, new records of *E. kollari* have been published (Żmihorski 2004, Barańska 2007, Szpila et al. 2011, Brodacki 2015, Rozwałka & Łysiak 2015; Fig. 6).

Apart from direct observations of the ladybird spider, additional locations were obtained from the records of spider-hunting wasps (Pompilidae), which females hunt exclusively on spiders of the genus *Eresus*. The two species of these pompilids in Poland are: *Eoferreola rhombica* (Christ, 1791) and *Ferreola diffinis* (Lepeletier, 1845) (Wiśniowski 2009). Females of these spider wasps look for ladybird spider burrows, enter it and after finding the spider paralyse it with its strong venom. The female lays one egg on the immobilised spider and leaves the nest without changing it. The spider recovers after a while but is not as active as before the wasp attack. After 2-3 days the wasp larva hatches and starts feeding externally on the spider, sucking its haemolymph. The parasitoid larva eats the host, killing it eventually (Peeters & Raemakers 2011). Also, such close parasitoid/host association may be very useful for an inventory of new stands of *E. kollari*, as presence of parasitoid may prove the presence of the host.

The aim of the paper is to present up-to-date information about distribution of the ladybird spider in Poland, the analysis of threats to habitats preferred by *E. kollari*, as well as the analysis of the current protection status of of the ladybird spider in the country. We also point out the usefulness of connecting records of *E. kollari* and spider-hunting wasps of the genera *Ferreola* and *Eoferreola* in the course of detection of unknown populations of this spider and new localities of its parasitoids.

Materials and Methods

The known distribution data of the ladybird spider in Poland were analysed on the base of published papers. Additional information was collected by the authors from various studies on invertebrates. The spiders were collected during 2009–2011 as part of the studies of epigeic invertebrate fauna of poorly investigated xerothermophilous grasslands of the class *Festuco-Brometea* located in north-western concentration of these habitats. Grasslands were located in the valleys of two rivers, namely Odra (its lower course) and Vistula, as well as along the Toruń-Eberswalde ice-marginal valley. Altogether they form a very important ecological corridor in Central Europe. On each of the tested localities, a series of five pitfall traps were used. The traps were plastic containers of 0.5 L capacity filled with preservative fluid (ethylene glycol). The traps were exposed from late April to early November and were emptied once every month.

Other records were obtained during the research on the biodiversity of Western Poland, conducted in 2012. The study area was located in the vicinity of Skwierzyna, on wide clearing under power line in dry Scots pine forest, covered with heather, grasses and lichens. The material was collected in 20 pitfall traps of 0.2 L capacity filled with water with a few drops of detergent. The traps were used from the end of March to the end of November; they were emptied usually in two-week periods. Also, the authors visited a number of published locations of *E. kollari* in Poland (R. Rozwałka). During these verifications, both the tent-like lids shading the entrances to the spider's burrows, and the migrating males in the second half of summer (August) to late autumn (November), were searched. In addition, a lot of information was obtained during the studies from various contributors. All data on new records, number of specimens and photographic documentation are included in Table 2.

The spider wasps were either collected on flowers with entomological net or swept from plants. After mounting the wasps were identified with the key to Polish species (Wiśniowski 2009). Literature data were analysed; in such cases the information on the number of wasp specimens was not always available. All data on new records and number of specimens are included in Table 3.

The spider material is deposited in the Department of Zoology, Maria Curie-Skłodowska University in Lublin and in Natural History Collections, Faculty of Biology, Adam Mickiewicz University in Poznań. Specimens of spider-wasps are deposited in the collections of Piotr Olszewski, Jacek Wendzonka and Bogdan Wiśniowski.

Results

According to current data from the literature, *E. kollari* was listed in Poland from 28 localities (Table 1). During our studies, 12 new locations were found, most of which were clustered in two regions: (1) the Middle and Lower Odra Valley, (2) the Małopolska Upland and Sandomierz Basin (Table 2, Fig. 6). *Eresus kollari* was mentioned in the past from the Polish part of the Odra Valley, in the vicinity of Bielinek nad Odrą (Hesse 1937, Prószyński & Staręga 1971). Later studies, both by Szymkowiak (2000) and those carried out in 2009-2010 by one of the authors (P. Sienkiewicz), did not confirm the presence of this species. Therefore, we assumed that this locality of the spider had been lost (Fig. 6). On the other hand, four new localities have been identified in the Odra Valley (Table 2). The nature reserve 'Wrzosowiska Cedyńskie' (Fig. 5), where *E. kollari* has been found seemed to be of special value (Table 2). The high number of specimens of the spider found in the reserve (Table 2), its large area – about 70 ha and abundance of habitats suitable for this species (Filipek 1974, Ziarnek et al. 2007) let us assume that there is a numerous and stable population (or metapopulation) of the spider inhabiting most of the area of the reserve. This population is perhaps also linked to a recently published locality from Rudnica (Barańska 2007). It is probable, that the Polish localities of *E. kollari* along the Odra River form a larger supermetapopulation connected with locations on the German side of the river (Heimer et al. 1980, Breoen & Jakobitz 2002, Arachnologische Gesellschaft 2019).

The location in Skwierzyna is also very valuable. The habitat suitable for *E. kollari* extends here over several kilometres in the form of a broad strip of heather, chaff and psammophilous grasslands under high voltage energy line running through dry coniferous forests. Although only a small section was studied, it could be said that it was one of the most abundant localities of this species in the country.

The localities in the Sandomierz Basin, i.e. Nowa Dęba and Bojanów (Table 1) were already recorded by Rozwałka (2004) but without further description. They are located on an extensive (nearly 13,000 ha), heavily-used military training ground, covered mostly by psammophilous grasslands and moors, which form a mosaic of scattered pine and birch groves, open sand, as well as inland dunes. During our research in August 2005, we recorded a

Table 1. Known localities of the ladybird spider *Eresus kollari* Rossi, 1846 in Poland.

No	Locality	UTM coordinates	References
1	Nakło	XU79	Torka 1909
2	'Bielinek' Nature Reserve	VU46	Haupt 1937, Hesse 1937
3	'Krzyżanowice' Nature Reserve	DA68	Kostrowicki 1953, 1954
4	Toruń	CD37	Wąsowska 1964
5	Strzeblów	XS14	Czajka 1966
6	'Kulin' Nature Reserve	CD73	Prószyński & Staręga 1971
7	Góra Nartowa	DC79	Prószyński & Staręga 1971
8	Wydma Łużne	DC99	Prószyński & Staręga 1971
9	Augustów vicinity	FE36	Prószyński & Staręga 1971
10	Toruń	CD37	Staręga 1984
11	Góry Wysokie	EB52	Staręga 1978
12	Bory Tucholskie National Park	XV66	Banaszak et al. 2002
13	Solec Kujawski vicinity	CD18	Rozwałka 2004
14	Nowa Dęba	EA58	Rozwałka 2004
15	Bojanów	EA68	Rozwałka 2004
16	'Góry Pieprzowe' Nature Reserve	EB51	Rozwałka 2004, Rozwałka & Łysiak 2015
17	Puszcza Piska	EE44	Żmihorski 2004
18	Rudnica	VU45	Barańska 2007
19	Toruń, military area, vicinity of 'Żymierski Hill'	CD36/37	Szpila et al. 2011
20	Toruń, military area, vicinity of 'Wiatraczna Hill'	CD36/46	Szpila et al. 2011
21	Toruń, Airport of the Pomeranian Aeroclub	CD37	Szpila et al. 2011
22	Toruń-Glinki	CD37	Szpila et al. 2011
23	Toruń-Barbarka	CD38	Szpila et al. 2011
24	Toruń-Stawki	CD47	Szpila et al. 2011
25	Maksymilianowo	CE00	Szpila et al. 2011
26	Puszcza Bydgoska	XU98	Szpila et al. 2011
27	Bydgoszcz	XU99	Szpila et al. 2011
28	Gacki near Pińczów	DA68	Brodacki 2015

colony of about 50-60 burrows gathered on an area of about 1.5 m^2. At the same time, numerous migrating males (40-60 specimens) were observed, which were easily noticeable along the roads, paths and grooves created by military equipment. In some places, up to 4 individuals were recorded on a 10-meter stretch of sandy path. The obtained data indicated that there was a very large population of the spider in this area, consisting of numerous burrows difficult to spot. Probably it was a metapopulation, inhabiting almost the entire range of the military training ground and the position from the outskirts of Bojanów was only part of it.

Interesting supplementary data on the occurrence of *E. kollari* come from the analysis of information on the occurrence of wasps of the family Pompilidae, which hunt the spider and use it as food for their larvae (Wiśniowski 2009, Olszewski et al. 2013). Known localities of the two pompilids partly confirm the published information on the spider distribution. There were both *E. kollari* and spider-hunting wasps recorded at the same localities, e.g. 'Bielinek' Natrure Reserve Toruń, Skwierzyna, Włocławek and nature reserve Góry Pieprzowe by Sandomierz (Olszewski et al. 2013, Wendzonka – unpublished data). On the other hand, there are a handful of records of the two pompilid wasps hunting *E. kollari* in locations, where the spider was not recorded so far (Table 3). Therefore, further research is needed to find the spider itself, determine the size of its population, the need for protective measures, etc. (Table 3, Fig. 6). Some of these data may be of historical value now (compare the publications listed in Wiśniowski 2009) but it is still worth to verify them, because even with the disappearance of the local population, there is a high probability of the presence of the spiders in neighbouring areas. Similar is the situation e.g. along the Odra River, where despite the extinction of this species in 'Bielinek' Natrure Reserve it was found in Gozdowice, Cedynia (Table 2) and Rudnica (Barańska 2007).

The data presented in Tables 1-3, as well as on the map (Fig. 6), also show some regions in Poland, where *E. kollari* can be expected. Currently, the

Table 2. New locality records of the ladybird spider *Eresus kollari* Rossi, 1846 in Poland.

No	Locality	UTM coordinates	Data of collected specimens	Habitat description
1	'Wrzosowiska Cedyńskie' Nature Reserve	VU45	41♂♂ – 1 VIII – 1 IX 2009; 34♂♂ – 1 IX-6 X 2009; 7♂♂ – 6 X-2 XI 2009: Barber's trap, leg. P. Sienkiewicz, det. R. Rozwałka	Mixture of thermophilous grasslands, heathlands and light pine forests on low hills (Fig. 5) (Filipek 1974, Ziarnek et al. 2007)
2	Stary Kostrzynek	VU45	1 juv. – 22 III-24 IV 2010: Barber's trap, leg. P. Sienkiewicz, det. R. Rozwałka	*Potentillo-Stipetum* grassland covering ca. 3 ha of an old sand pit, slopes facing W, SW, and SE; inclination 30°-45°. Plant cover consists of clumps of grasses (*Stipa capillata* and *Festuca*), as well as carpets of small perennials; plant cover 40%-70%
3	Gozdowice	VU54	30♂♂ – 1 VIII-1 IX 2009; 9♂♂ – 1 IX-6 X 2009; 2♂♂ – 6 X-2 XI 2009: Barber's trap, leg. P. Sienkiewicz, det. R. Rozwałka	*Potentillo-Stipetum* grassland covering ca. 1 ha of a slope facing SW and inclination 30°-45°; clumps of grasses and tall perennials, with patches of bare ground. Plant cover 50%-70% (Barańska & Żmihorski 2005)
4	Włocławek vicinity	CD63	1♂ – VIII 1993; 1♂ – 2 IX 1994: observation, P. Jałoszyński	Sandy heathland in a pine forest glade under high voltage line
5	Panieńska (Dziewcza) Góra in Dwikozy	EB52	2002-2003 – some males observed in autumns, K. Pałka	*Sisymbrio-Stipetum* xerotermophilous grassland on loessic ground, area ca. 0.7 ha, facing S to SW; inclination 40-60°, plant cover dense (80-90%), mainly tall grasses (*Stipa capillata*, *Stipa pulcherrima*, *Elymus hispidus*)
6	Skorocice on the Nida	DA78	18 VII 2009: small colony of ca. 15 burrows on an area of 0.5 square metre – obs. R. Rozwałka	Small patch of xerothermophilous grasslands on a slope facing S, inclination 30°, covered sparsely with intermediate wheatgrass, clumps of sedums, thyme, etc.
7	Skwierzyna vicinity	WU22	3 juv. – 28 IV-10 V 2012; 2 juv. – 10 V-17 VI 2012; 2 juv. – 17 VI-02 VII 2012; 6♂♂, 1♀ – 2 VII-8 VIII 2012; 169♂♂, 2 juv. – 8 VIII-24 VIII 2012; 93♂♂ – 28 VIII-13 X 2012; 5♂♂ – 13 X-05 XI 2012: Barber's trap, leg. and det. T. Rutkowski	Abundant population in the area which extends here over several kilometres in the form of a broad strip of heathlands, chaff and psammophilous grasslands under high voltage energy line running through dry coniferous forests
8	Grudziądz – Rządz	CE42	Migrating males observed during 2007-2015, burrows and hunting nets present since 2012 (max. 15), doc. phot. D. Trzybiński	Mixture of psammophilous grasslands with planted oak and pine trees; area ca. 7,000 square metres
9	Zalesie Górne near Piaseczno	EC06	August 2000; 1 female, obs. M. Grzyb	In a garage, probably migrating specimen from surrounding sandy fallow land
10	Bydgoszcz-Fordon	CD09	1♂ – 12 IX 2014 and more specimens observed following years, obs. A. Oleksa & K. Oleksa	Xerothermic grasslands on the hills surrounding city
11	Military area S of Drawsko Pomorskie	WV41	Since 2007 annual observations of several males during September – October, doc. phot. & obs. Ł. Solecki	Mixture of sparse pine forests, heathlands, psammophilous grasslands, etc.
12	'Skotniki Górne' Nature Reserve	DA78	1♂ – 18 IX 2015; doc. phot. G. Kolago	Scarce xerothermophilous grassland on gypsum

known localities of the spider in Poland are clustered in two areas. One of them is the area of the Toruń-Eberswalde ice-marginal valley, where it is most likely that the species is more widely distributed. The second area includes Nida Valley, Vistula River Gorge in Małopolska and Sandomierz Basin (Tables 1-2, Fig. 6). Also here, the potential area of occurrence is probably greater than observed so far.

Discussion

Taking into account the much broader distribution of *E. kollari* as compared to previous records, its category of threat could be lowered. Also, the spider wasp species hunting the ladybird spider seem to spread in Europe recently, after several years of collapse (Schmid-Egger 2010, Peeters & Raemakers

Table 3. Known localities of *Eresus*-specialised parasite spider wasps (Pompilidae) in Poland.

No	Locality	UTM grid	Comments
***Eoferreola rhombica* (Christ, 1791)**			
1	Białogrądy (Biebrza National Park)	FE02	1♀ collected in 2002, current locality (Wiśniowski 2009)
2	'Bielinek' Nature Reserve	VU46	Currently extinct; *E. kollari* was observed here in the 30s of 20th century (Hesse 1937)
3	'Góry Pieprzowe' Nature Reserve near Sandomierz	EB51	1♀ collected in 1955, current locality (Wiśniowski 2009); confirmed presence of numerous spider specimens (Rozwałka & Łysiak 2015)
4	Łętowice	DA83	1♂ collected in 2014 (Wiśniowski – unpublished)
5	Maksymilianowo	CE00	Wasps collected during 90s of 20th century (Wiśniowski 2009, Szpila et al. 2011)
6	Nakło	XU79	Historical data (Wiśniowski 2009)
7	Bory Tucholskie National Park	XV66/76	Wasps observed during 2013-2014 in sandy areas of forest compartments 51a and 120a; confirmed presence of spider (Wendzonka, unpublished)
8	Toruń-Glinki	CD37	1♀ collected in 2010 (Olszewski et al., 2013); confirmed presence of spider (Szpila et al. 2011)
9	Toruń (Pomeranian Aeroclub)	CD37	1♀ collected in 2005 (Olszewski et al. 2013); confirmed presence of spider (Szpila et al. 2011)
10	Toruń military area 'Żymierski Hill'	CD37	7♀♀, 1♂ collected during 2005-2010 (Olszewski et al. 2013); confirmed presence of spider (Szpila et al. 2011)
11	Wał Ruda	DA85	1♂ collected in 2014 (Wiśniowski – unpublished)
12	Wielkopolska National Park	XT29	Historical data (Wiśniowski 2009)
13	Włocławek	CD63	Historical data (Wiśniowski 2009)
14	Skwierzyna vicinity	WU22	Wendzonka, unpublished
15	Szczepice	XU77	Historical data (Wiśniowski 2009)
***Ferreola diffinis* (Lepeletier, 1845)**			
16	Sandomierz Basin; Lipie Forest Department, compartment no. 145	EA69	1♀ collected in 2008 (Wiśniowski 2009)
17	Międzyzdroje	VV67	1♀ collected in early 20th century (Wiśniowski 2009); recently *E. kollari* was recorded from Nowe Warpno (Arachnologische Gesellschaft 2019), proves the presence of the spider in the region of the Szczecin Lagoon
18	Sępia Góra (Radunia) in Ślęża Massif	XS23	Czajka (1966) recorded *E. kollari* (as *E. niger*) from Strzeblowo (XS14); the presence of the wasps suggests that the spider was quite recently distributed on larger area

2011). However, we suggest maintaining the current EN (endangered) category of threat for the spider as proposed by Staręga et al. (2002). The reasons for this are as follows: 1) habitats suitable for the ladybird spider are still threatened by both anthropogenic pressure and natural succession of forest communities (level of these threats have not lowered during the last decades and there are no natural phenomena that would 'refresh' habitats suitable for the spider); 2) the current lack of knowledge about stability of small populations of the ladybird spider observed during our studies.

Based on our results and reference data, we present the distribution of the ladybird spider *Eresus kollari* in Poland. This rare and legally protected species until recently has been known from very few localities, scattered throughout the country. The collected material raises the number to 42 localities, out of which 30 should be considered current, including 28 direct records of the spider and six probable records based on the presence of spider wasps hunting this spider species. Other ten records should be verified, as they are over 50 years old. From one locality, at Bielinek on the Odra River, the spider should be considered extinct. A distribution analysis showed, however, that *E. kollari* has two distinct occurrence centres in Poland: one in the Toruń-Eberswalde ice-marginal valley and the other in southern Poland, covering Małopolska Upland and Sandomierz Basin.

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