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Original article

Geographical distribution of *Dermacentor marginatus* and *Dermacentor reticulatus* in Europe

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ABSTRACT

The goal of this paper is to present up-to-date maps depicting the geographical distribution of *Dermacentor* species in Europe based on georeferenced sampling sites. Therefore, a dataset was compiled, resulting in 1286 *D. marginatus* (Sulzer, 1776) and 1209 *D. reticulatus* (Fabricius, 1794) locations. Special emphasis is given to the region of the European Alps depicting a presumable climate barrier of the mountains and to overlaps in the distribution of both species as well as on the situation in eastern European countries. For the latter newly described *Dermacentor* findings comprise 59 locations in Romania and 62 locations in Ukraine. The geographical distributions of both species in Europe range from Portugal to Ukraine (and continue to the east of Kazakhstan). Although it is well known that *D. marginatus* is adapted to a warmer and drier climate at more southern latitudes and *D. reticulatus* to a moderately moist climate at more northern latitudes, the distribution limits of both species were not well known. Here, the northern and southern distribution limits for both species in Europe, as determined from the georeferenced database, were specified for *D. marginatus* by the belt of 33–51° N latitude and for *D. reticulatus* by the belt of 41–57° N latitude. Thus, overlapping species distributions were found between 41° N and 51° N.

1. Introduction

The goal of this paper is to present up-to-date maps depicting the geographical distribution of *Dermacentor* species in Europe based on georeferenced locations.

Two Eurasian *Dermacentor* tick species, *D. marginatus* (Sulzer, 1776) and *D. reticulatus* (Fabricius, 1794), are endemic in Europe. Fig. 1 depicts the whole geographical distribution of these two tick species as published by Kolonin (2009), but it does not include the recently documented range expansions of *D. reticulatus*. Also not shown are the patchy distribution patterns of both tick species, which seem to prefer somewhat different ecological conditions. They are known vectors of various pathogens causing human and animal diseases of public interest (see Section 4).

Dermacentor marginatus, the ornate sheep tick, is distributed from Portugal through southern Europe up to Iran, Kazakhstan, and the mountain areas of central Asia (Pomerantzev, 1959). Generally, the species inhabits steppes, Alpine steppes, forest steppes and semi-desert areas. In Germany it prefers xerophilic steppe-like vegetation, particularly open sheep meadows. In the mid and higher altitudes of Italy, open oak forests and dry meadows are typical habitats, whereas in southern Italy it inhabits forest areas. In southern France, areas from the coast up to an elevation of 960 m are inhabited (Bonnet et al., 2013). It seems that the main hosts for adults in Germany are sheep, especially among domestic animals (Liebisch and Rahman, 1976), which is nicely reflected by the German vulgar name 'Schafzecke' (sheep tick). This host has also been reported from e.g. Turkey and Italy (Iori et al., 2010; Aydin et al., 2012). Other domesticated hosts are dogs, cattle, goats and horses. As wild animal hosts deer, hare, hedgehog, wolf (Arthur, 1960) and wild boar (Masala et al., 2012) have been mentioned. Larvae and nymphs are found on small mammals like rodents and insectivores of the genera *Myodes*, *Apodemus* and *Microtus*, but also on rabbits. Adult ticks occasionally bite humans (Estrada-Peña and Jongejan, 1999). The life cycle takes 1–2 years, depending on when the rather long-lived unfed adults acquire their blood meal. The main activity

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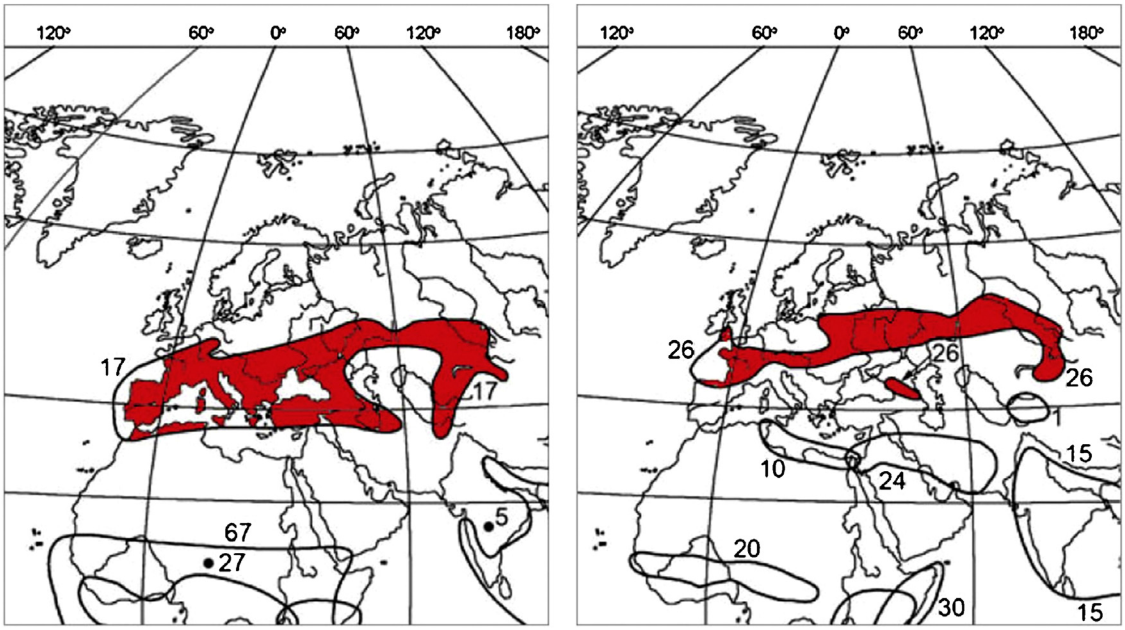

Fig. 1. Geographical distribution of two Eurasian *Dermacentor* species taken from *Fauna of Ixodid Ticks of the World* (Kolonin, 2009). Left: *D. marginatus* (red area, 17), right: *D. reticulatus* (red area, 26). Comparable maps were published by Parola et al. (2009).

periods of unfed adults are in spring and autumn, but may extend throughout the winter in more southern regions.

Dermacentor reticulatus (junior synonym *D. pictus*) is the second most reported tick species after *Ixodes ricinus* in central Europe (Rubel et al., 2014). It may locally, or on certain hosts, be even more abundant than *I. ricinus* (Földvári and Farkas, 2005; Mierzejewska et al., 2015b). *D. reticulatus*, not occurring in the Mediterranean climatic zone, is a tick of somewhat cooler areas. It has a broad geographical overlap with *D. marginatus* from northern Portugal through Kazakhstan and western Siberia (Rar et al., 2005), but generally extends more to the north than *D. marginatus*. Preferred habitats are alluvial forests and swamps where it can survive flooding for certain periods (Nosek, 1972). However, it readily colonizes somewhat drier habitats like fallow and heathland as well as grassland interspersed with bushes or trees. In Hungary, it occurs on more xerophilic vegetation in the vicinity of oak forests (Hornok and Farkas, 2009). In more humid habitats *D. reticulatus* often occurs sympatrically with *I. ricinus*. Remarkable is its occurrence in some urban and suburban areas like city parks and fallow land (Gilot et al., 1973; Zahler et al., 2000; Dautel et al., 2006). Larvae and nymphs feed on certain rodent species, particularly of the genus *Myodes* (Pfäffle et al., 2015), whereas adults feed on larger mammals like cattle, deer and dogs but only occasionally bite humans. Similar to *D. marginatus*, the tick has a developmental cycle of about 1–2 years, and development from egg to unfed adult has to take place in one growing season. Adults are active from late August/September through April/May, only interrupted by low temperatures or snow cover in the winter. Oviposition takes place exclusively in spring and the resultant short-lived larvae and nymphs have their main activity periods in July and August, respectively, irrespective of their geographic origin (Dautel et al., 2006).

The up to now most complete maps showing the geographical distribution of the two European *Dermacentor* species were recently compiled from georeferenced data by Estrada-Peña et al. (2013). These maps were also published in an even more appealing presentation in the book *Ticks and Tick-borne Diseases* edited by Salman and Tarrés-Call (2013). Although these maps are based on the most comprehensive dataset collected so far, mainly western and southern Europe are covered. Large areas of Central (Germany, Austria, Switzerland), northern (Baltic countries) and eastern Europe (Balkans, Ukraine) were not or only sparsely covered. Moreover, Estrada-Peña et al. (2013) stated: "The actual geographical distribution and northern limits of this species are not well known". The *Dermacentor* maps presented here should help to fill this serious gap. This has become possible since giving georeferenced tick locations is a standard information in recent papers (Obsomer et al., 2013; Rubel et al., 2014; Paulauskas et al., 2015). In the present paper, data so far not published were integrated to close the data gaps mentioned above. Additionally, a high number of well-documented European *Dermacentor* locations were digitized. This renders not only improved *Dermacentor* maps, but also a database, ready to be applied for habitat modelling. Data given as shapefiles representing political districts, as for example provided for *D. reticulatus* by the European Centre for Disease Prevention and Control (ECDC, 2015), do not fulfil the requirements of habitat modelling and were therefore not considered.

2. Materials and methods

Knowledge on the geographical distribution of *Dermacentor* species in Europe is based on the existing datasets of the Global Biodiversity Information Facility (GBIF, 2014) with 1 *D. marginatus*/16 *D. reticulatus* locations, VectorMap (Foley et al., 2014) with 35/46 locations and data compiled by Estrada-Peña et al. (2013) with 533/385 locations. Using this information, a comprehensive literature review was carried out. It refers mainly to those studies in which georeferenced findings were documented. Exceptions were made when precise information on the locations or printed maps were available as a basis for digitization. According to Table 1 the following numbers of locations (*D. marginatus*/*D. reticulatus*) were incorporated: Austria (4/6), Belarus (0/32), Belgium (0/25), Bulgaria 5/0), Croatia (24/5), Czech Republic (0/47), Germany (83/115), Great Britain (0/2), Greece (26/0), Hungary (18/54), Italy (35/0), Latvia (0/12), Lithuania (0/66), Netherlands (0/51), Poland (0/114), Portugal (6/7), Romania (433/68), Serbia (4/8), Slovakia (14/71), Slovenia (1/5), Switzerland (33/13), Turkey (16/0), Ukraine (15/61). Thus, the dataset presented here comprises a total of 1,286 locations for *D. marginatus* and 1,209 locations for *D. reticulatus* covering

Table 1
Number of georeferenced *Dermacentor* sampling sites compiled in this study. Sampling sites not referenced were contributed by the authors MP (1 site in Germany), OK (4 sites in Germany, 2 sites in Poland), LC (59 sites in Romania) and YD (62 sites in Ukraine).

D. marginatus	*D. reticulatus*	Accuracy	Country	References
–	2	h	Austria	Wetscher et al. (2014)
–	2	m	Austria	Leschnik et al. (2012), Duscher et al. (2013)
–	2	m	Austria	Sixl (1975)
4	–	m	Austria	Thaler (2003)
–	32	l	Belarus	Reye et al. (2013)
–	25	u	Belgium	Obsomer et al. (2013)
4	–	m	Bulgaria	Arnaudov et al. (2014)
1	–	m	Bulgaria	Kanchev et al. (2012)
24	5	h	Croatia	Krčmar (2012), Krčmar et al. (2014)
–	1	m	Czech Rep.	Hubálek et al. (2003)
–	46	h	Czech Rep.	Siroky et al. (2011)
77	96	u	Germany	Rubel et al. (2014)
–	12	l	Germany	Dautel et al. (2006)
4	1	h	Germany	MP, OK
–	2	l	Germany	Lügner (2015)
–	3	h	Germany	Petney et al. (2013)
2	1	m	Germany	Pluta et al. (2010)
–	2	m	Great Britain	Tijsse-Klasen et al. (2013)
26	–	l	Greece	Papadopoulos et al. (1996)
17	23	l	Hungary	Hornok and Farkas (2009), Hornok and Horváth (2012)
1	–	m	Hungary	Pintér et al. (2013)
–	31	l	Hungary	Földvári and Farkas (2005)
3	–	h	Italy	Dantas-Torres and Otranto (2013)
8	–	l	Italy	Lorusso et al. (2011)
20	–	l	Italy	Selmi et al. (2008), Martello et al. (2013)
3	–	l	Italy	Ceballos et al. (2014)
1	–	l	Italy	Cassini et al. (2014)
–	12	l	Latvia	Paulauskas et al. (2015)
–	66	l	Lithuania	Paulauskas et al. (2010), Paulauskas et al. (2015)
–	6	m	Netherlands	Nijhof et al. (2007)
–	45	m	Netherlands	Jongejan et al. (2015)
–	10	h	Poland	Kiewra and Czulowska (2013)
–	4	m	Poland	Stanczak (2006)
–	5	h	Poland	Biernat et al. (2014)
–	7	l	Poland	Nowak (2011)
–	54	h	Poland	Mierzejewska et al. (2015)
–	5	m	Poland	Mierzejewska et al. (2015b)
–	7	h	Poland	Wójcik-Fatla et al. (2013)
–	12	h	Poland	Biaduń (2011)
–	2	h	Poland	OK
–	8	l	Poland	Kadulski and Izdebska (2009)
2	–	l	Portugal	Norte et al. (2012)
4	7	m	Portugal	Santos-Silvia et al. (2006)
433	9	l	Romania	Mihalca et al. (2012)
–	59	m	Romania	LC
4	7	l	Serbia	Mihaljica et al. (2012)
–	1	l	Serbia	Tomanović et al. (2007)
14	11	l	Slovakia	Nosek (1972)
–	30	h	Slovakia	Kubelová et al. (2011)
–	30	m	Slovakia	Bullova et al. (2009)
1	5	l	Slovenia	Ploj (2007)
24	6	l	Switzerland	Immler et al. (1970)
9	–	l	Switzerland	CSCF (2015)
–	2	h	Switzerland	Schaarschmidt et al. (2013)
–	5	l	Switzerland	Porchet et al. (2007)
1	–	h	Turkey	Hekimoglu et al. (2011)
5	–	h	Turkey	Bakirci et al. (2011)
3	–	m	Turkey	Yesilbag et al. (2013)
7	–	l	Turkey	Aydin et al. (2012)
11	1	l	Ukraine	Akimov and Nebogatkin (2011)
–	2	h	Ukraine	Karbowiak et al. (2014)
4	58	h	Ukraine	YD
35	46	u	–	VectorMap see Foley et al. (2014)
1	16	u	–	GBIF (2014)
533	385	u	–	Estrada-Peña et al. (2013)
1286	1209		Total	

the entire region of the European Union. Additionally, neighbouring countries such as Belarus, Ukraine and Turkey, but also some regions in northern Africa were covered.

As depicted in Table 4, the majority of the references considered were published during the period 2010–2015. Contrary to an increasing number of *Dermacentor* studies from Poland, recently published studies from other countries such as Austria or Switzerland are sparse. Thus, data from previous studies are still relevant even if they had to be digitized before they could be added to the dataset compiled for this review. In Austria, for example, locations documented by Sixl (1975) and Thaler (2003) were digitized. Swiss data were digitized following the documentation by Immler et al. (1970) and data for Slovakia were digitized from Nosek (1972). Digitized locations, of course, are generally of lower accuracy than locations described by geographical coordinates determined by GPS in the field. To provide evidence of this, accuracy measures were given for all data referenced in Table 1 in accordance with the scheme applied by Rubel et al. (2014). It is distinguished between high (h), medium (m), low (l) and unspecified (u) accuracies. The latter has been applied to transnational datasets (Estrada-Peña et al., 2013; Foley et al., 2014; GBIF, 2014) as well as national datasets (Obsomer et al., 2013; Rubel et al., 2014) with data of different accuracy. A high accuracy (±0.1 km) was allocated to coordinates given in degrees, minutes and seconds or in decimal degrees with at least 4–5 relevant decimal places. A medium accuracy (±1 km) was assumed for coordinates given in degrees and minutes or in decimal degrees with at least 2–3 relevant decimal places. A medium accuracy was also assumed for ticks collected from animals (e.g. deer, dogs) or humans and for coordinates digitized from local maps. Coordinates digitized from regional maps were classified as low-accuracy data (±10 km).

After data collection and homogenization of the associated geographical coordinates (conversion to decimal degrees with 4 digits), the final dataset was compiled by eliminating the numerous duplicate entries.

3. Results and discussion

Fig. 2 depicts the geographical distribution of *D. marginatus* in Europe and adjacent areas of Asia and Africa compiled from georeferenced sampling locations. The distribution of *D. marginatus* is in the range of 33–51° N latitude. The southern distribution limit is outside Europe, in northern Africa. In the dataset compiled for this study, this southern limit is marked by a sampling location in Morocco, more precisely in a valley in the northern part of the Atlas mountains at 5.38° W/33.28° N at about 1200 m altitude. This southern distribution limit of *D. marginatus* is confirmed by further findings in Morocco and Algeria. All sites were part of the dataset compiled by Estrada-Peña et al. (2013). The southernmost site in the eastern part of the map (Fig. 2) is in Syria, south of Damaskus at 36.47° O/33.35° N, and was taken from the VectorMap dataset (Foley et al., 2014). The northern distribution limit is defined by a location in Germany, northwest of Gießen at 8.32° O/50.65° N (Rubel et al., 2014). That location is in the northern extension of the Rhine basin renowned for its mild climate. A similar northern distribution limit is only known from Ukraine, where Akimov and Nebogatkin (2011) described a *D. marginatus* site in Riwne at 26.39° O/50.57° N. Unfortunately, Akimov and Nebogatkin (2011) gave georeferences only for those locations at the northern distribution limit of *D. marginatus* in Ukraine. It is a well-known fact that *D. marginatus* is endemic in the entire region of southern Ukraine. However, except for one location in the Crimean Peninsula and 4 locations near Rozivka (Donetsk region), no georeferenced data are available to show this in the map (Fig. 2).

Fig. 3 depicts the distribution of *D. reticulatus* at geographical latitudes 41–57° N. A remote site in southern Portugal at 8.33° W/37.38° N was not considered, although included in the map. This extremely southern location from the dataset compiled by Estrada-Peña et al. (2013) has not been confirmed by further findings. Thus, the most southern location of *D. reticulatus* may be in Spain at 1.28° W/41.20° N, as well taken from the dataset compiled by Estrada-Peña et al. (2013). In the Montesinho Natural Park in northern Portugal, however, numerous *D. reticulatus* and *D. marginatus* locations were documented. For this study, those sampling sites were digitized following the documentation given by Santos-Silvia et al. (2006). They are located between 41.75 and 41.95° N. Whilst *D. reticulatus* is widespread from the north of the Iberian Peninsula to southern France, no data were found for Italy. Thus, the situation in Italy is unclear. Although Italy is declared free of *D. reticulatus* by most authors, Iori et al. (2010) identified, beside 200 *D. marginatus*, a single adult *D. reticulatus* tick collected from a dog. They noted that *D. reticulatus* may be found in northern Italy, although very rarely as also mentioned by Manfredi (1995). However, georeferenced *D. reticulatus* locations are still missing for northern Italy. In contrast, georeferenced locations were available from the Balkans, where *D. reticulatus* extends less further south than in the Iberian Peninsula. The current southern distribution limit of *D. reticulatus* in the Balkans is in Serbia near Belgrade at 20.36° O/44.77 ° N (Mihaljica et al., 2012). Even further east, in Ukraine, the southernmost occurrence is found in the Crimean Peninsula at 34.03° O/44.27° N. Further georeferenced *D. reticulatus* locations in Ukraine, exclusively compiled for this study, are in Kyiv and its vicinity along the Dnieper river. This regional distribution extends to the Chernobyl exclusion zone at the boundary to Belarus (Karbowiak et al., 2014) and beyond. Generally, the northern distribution limit of *D. reticulatus* is at lower latitudes in western Europe compared to eastern Europe. In England, the current northern distribution limit of *D. reticulatus* is marked by a finding at 2.53° W/53.72° N taken from the VectorMap dataset (Foley et al., 2014), while in Latvia it is marked by the coordinates 22.05° O/56.68° N after Paulauskas et al. (2015). Thus, the northern distribution limit in the Baltics is about 3 degrees of latitude higher than in the British Isles. It is tempting to speculate that in eastern Europe the more continental climate offers warmer summers than in western Europe, which might be favourable for *D. reticulatus* to complete its development from the egg to the unfed adult stage in one growing season.

The absence of *D. reticulatus* in almost the entire region of the European Alps is remarkable (Fig. 4). Although *D. reticulatus* is present in the valleys of the western Alps in France and also in the Swiss northern foothills of the Alps, no findings are documented in the Austrian, Italian or Slovenian Alps. It is well known that the Alps and their northern foothills do not form a physical barrier to disease vectors (Pfeffer and Dobler, 2010), however, they presumably form a climate barrier to both *Dermacentor* species. Whilst *D. reticulatus* was frequently found at the northern periphery of the entire European Alpine arc but virtually not south of the Alps, the situation is different with *D. marginatus*. The latter is widely distributed in France, Italy and Croatia. North of the Alps, suitable habitats for *D. marginatus* are restricted to the Rhine basin with its warm and dry summers. It is not surprising that *D. marginatus* is endemic in the Rhine basin, which is known for the occurrence of various Mediterranean animal and plant species. The most northern site with *D. marginatus* was found near Gießen at 8.32° W/50.65° N (Rubel et al., 2014). Other regions north of the Alps located in southern Germany, Austria and the Czech Republic are, as a result of generally lower summer temperatures at higher altitudes, free from *D. marginatus*. However, the occurrence of *D. marginatus* at the southern slopes of single sunny Alpine valleys has been documented in several studies. Well known for a long time are some locations in the southern Swiss Canton of Ticino, where Immler et al. (1970) found *D. marginatus* (Fig. 4). In the present study, the sampling sites from Immler et al. (1970) were georeferenced. Their findings were confirmed and complemented by more recent studies such as those by Beati et al. (1994) and CSCF (2015). Unfortunately, a systematic investigation on the occurrence of *D. marginatus* in the entire Alpine region is missing. Particularly noteworthy are locations in the Inn valley in Austria that were georeferenced following the documentation of Thaler (2003). They are the only documented locations with *D. marginatus* in the central part of the Alps and characterized by extraordinarily hot summers with about 10 hot days per year, i.e. temperatures of $T \geq 30^\circ$ C (Brugger and Rubel, 2009).

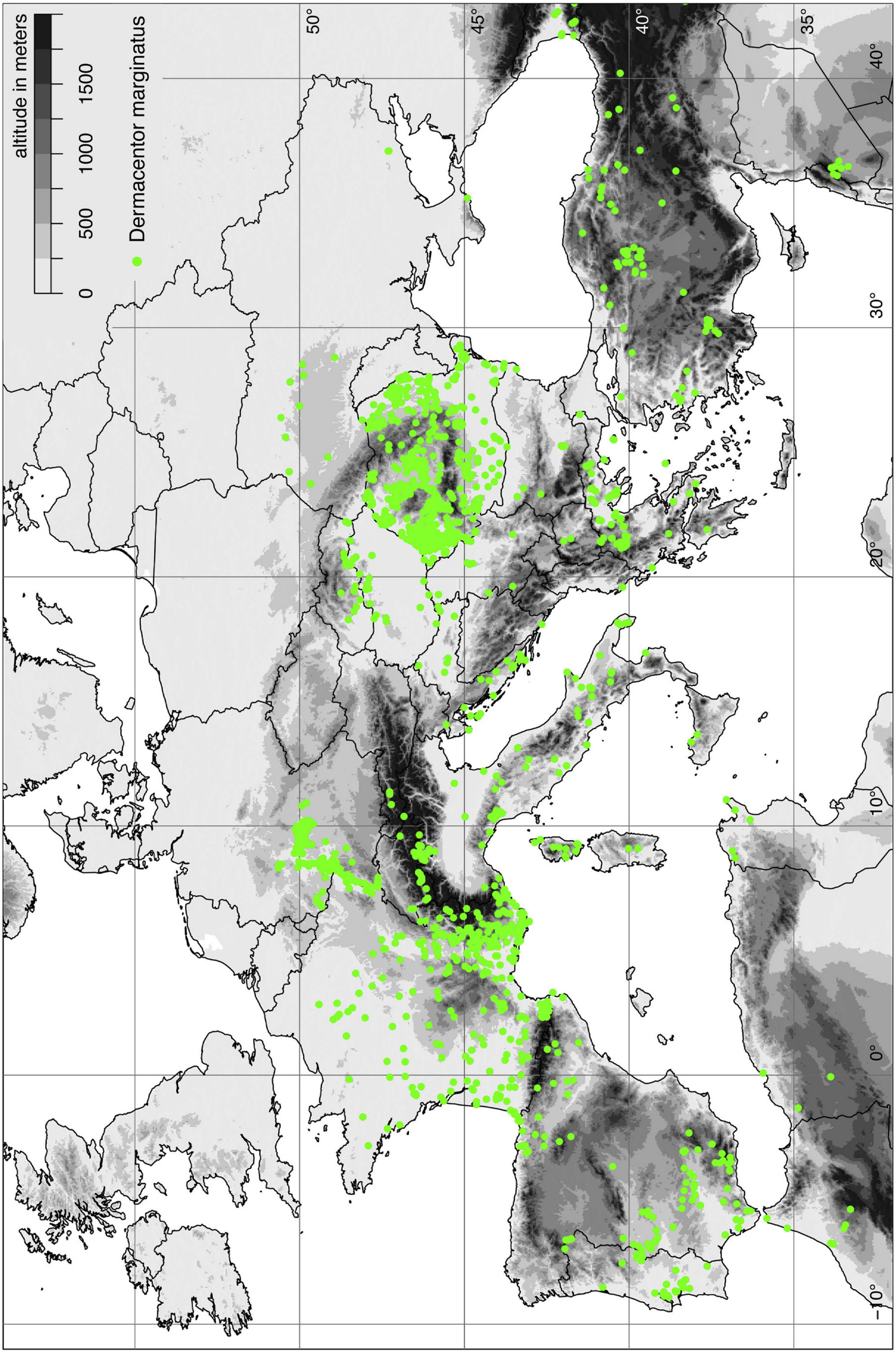

Fig. 2. Map of georeferenced *Dermacentor marginatus* locations.

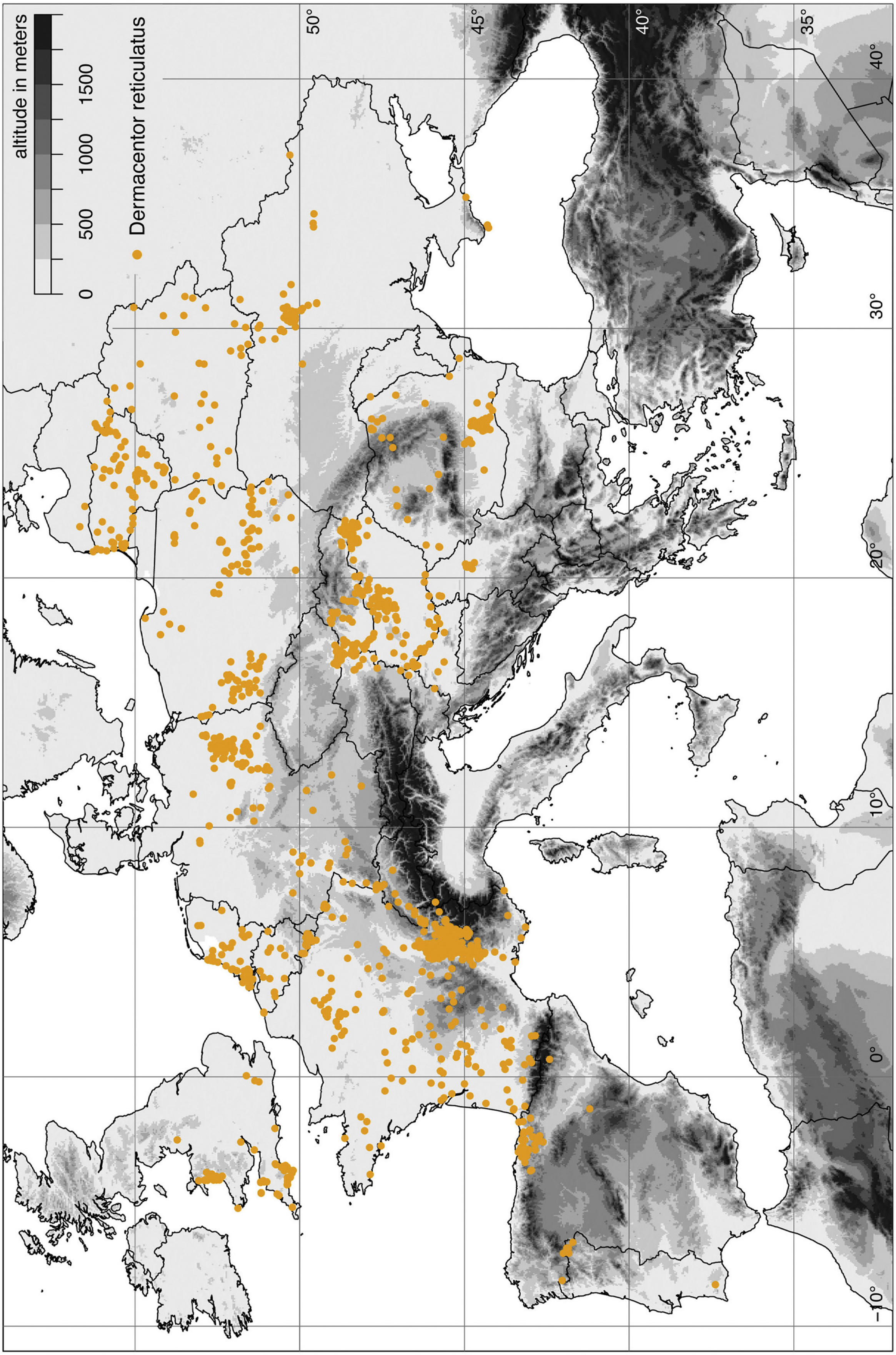

Fig. 3. Map of georeferenced *Dermacentor reticulatus* locations.

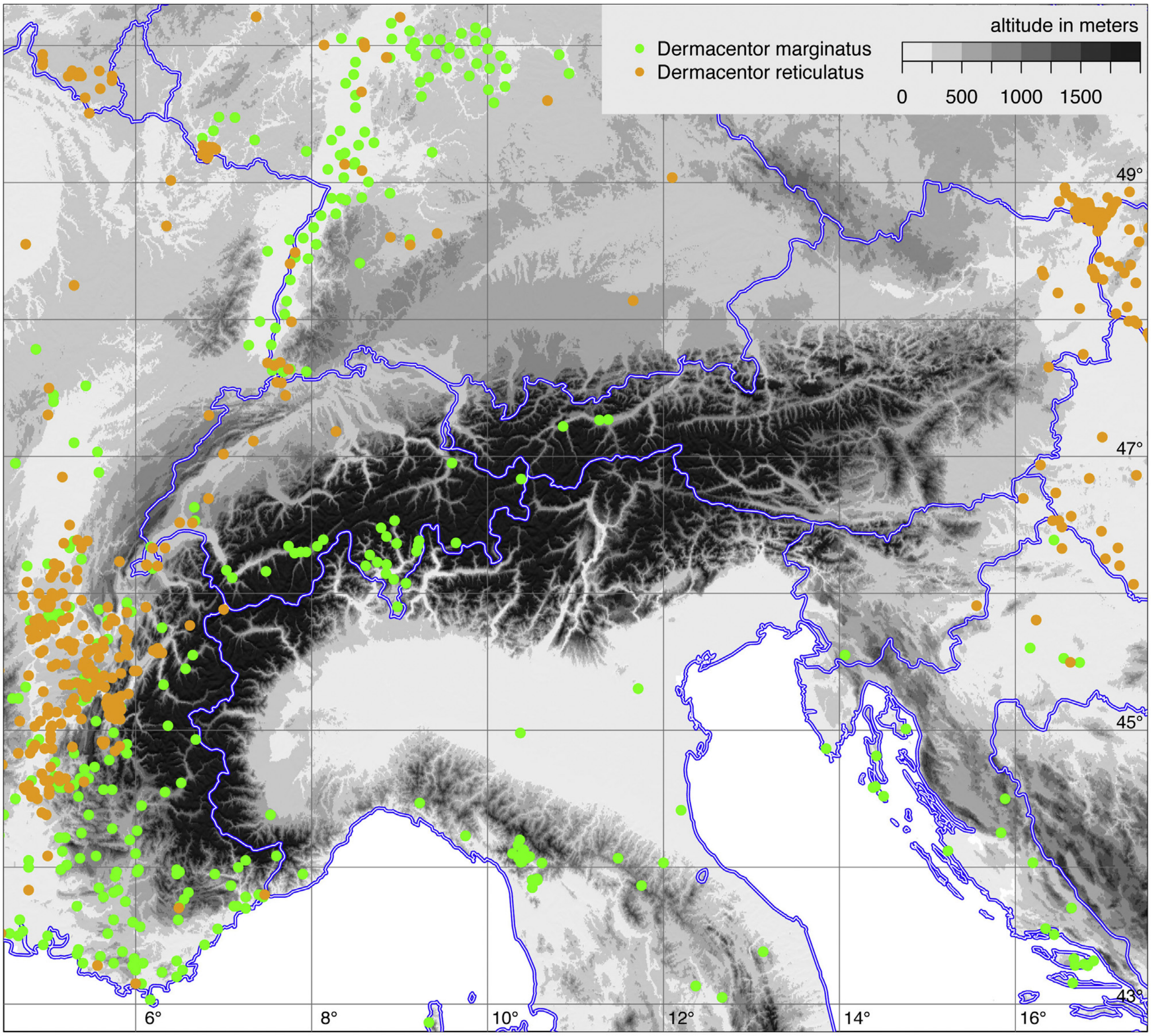

Fig. 4. Map of georeferenced *Dermacentor* locations depicting the climate barrier of the European Alps. Whilst no georeferenced sampling sites of *D. reticulatus* (orange dots) were documented south of the Alpine arc, the distribution of *D. marginatus* (green dots) north of the Alpine arc is restricted to the Rhine basin (1). A few *D. marginatus* locations in the Alpine valleys were documented in the southern Swiss Canton of Ticino (2) and the Inn valley in Austria (3).

Because the geographical distribution of ticks is usually considered in conjunction with tick-borne diseases, Table 2 provides a short summary of pathogens transmitted by *D. reticulatus*. Thus, *D. reticulatus* is considered as the main vector of the Omsk haemorrhagic fever virus, of *Babesia canis*, *B. caballi*, *Rickettsia slovaca* and *R. raoultii*, whilst *D. marginatus* is the known main vector of *R. slovaca* and *R. raoultii* causing tick-borne lymphadenopathy (TIBOLA), also called *Dermacentor*-borne necrosis erythema and lymphadenopathy (DEBONEL). As demonstrated by Parola et al. (2009), the geographic distribution of these rickettsiae likely parallels that of *Dermacentor* ticks. Additionally, Table 3 provides a summary on frequent pathogen findings in adult questing *D. reticulatus* ticks without proven vector function and Table 4 summarises the results of three experimental transmission studies, again representative for *D. reticulatus*. Without proven transmission capability vector function of a given tick species for a given pathogen is not

Table 2
Pathogens found in adult questing *Dermacentor reticulatus*, the proven main vector.

Pathogen	Disease	Region	References
Omsk haemorrhagic fever virus	Omsk haemorrhagic fever	Western Siberia	Růžek et al. (2010)
Babesia canis	Canine babesiosis	Eurasia	Leschnik et al. (2012) Schaarschmidt et al. (2013) Karbowiak et al. (2014)
Babesia caballi	Equine babesiosis	Southern Europe	Jongejan et al. (2015)
Rickettsia raoultii	TIBOLA/DEBONEL	Eurasia	Reye et al. (2013) Parola et al. (2009)
Rickettsia slovaca	TIBOLA/DEBONEL	Eurasia	Földvári et al. (2013)

Table 3
Pathogen findings in adult questing *Dermacentor reticulatus* ticks without proven vector function.

Pathogen	Disease	Region	References
Kemerovo virus	Kemerovo tick fever	Western Siberia	Dedkov et al. (2014)
Tick-borne encephalitis virus	Tick-borne encephalitis	Eurasia	Biernat et al. (2014)
Murid herpesvirus 4	Not known	Slovakia	Kúdelová et al. (2015)
Anaplasma phagocytophilum	Human, canine and equine granulocytic anaplasmosis, Tick-borne fever of cattle	Eurasia	Bonnet et al. (2013) Karbowiak et al. (2014)
Anaplasma marginale	Bovine anaplasmosis	France	Bonnet et al. (2013)
Borrelia burgdorferi s.s	Lyme borreliosis	Eurasia	Reye et al. (2013)
Borrelia burgdorferi s.l.	Lyme borreliosis	Eurasia	Kahl et al. (1992)
Borrelia afzelii	Lyme borreliosis	Eurasia	Reye et al. (2013)
Borrelia valaisana	Lyme borreliosis	Eurasia	Reye et al. (2013)
Borrelia garinii	Lyme borreliosis	Eurasia	Rar et al. (2005)
Coxiella burnetii	Q-fever	Eurasia	Bonnet et al. (2013)
Francisella tularensis ssp. *holarctica*	Tularemia	Eurasia	Wójcik-Fatla et al. (2015)
Francisella philomiragia	Opportun. human pathogen, Fish pathogen	Eurasia	Bonnet et al. (2013)
Francisella-like organisms	Not known	Eurasia	Wójcik-Fatla et al. (2015)
Bartonella henselae	Cat scratch disease	Eurasia	Reye et al. (2013) Rar et al. (2005)
Bartonella quintana	Five-days fever	Eurasia	Rar et al. (2005)
Babesia microti	Human babesiosis	Eurasia	Wójcik-Fatla et al. (2012)
Babesia divergens	Bovine babesiosis, Redwater fever	Spain	García-Sanmartín et al. (2008)
Babesia bigemina	Texas fever	Spain	García-Sanmartín et al. (2008)
Theileria sp. OT1	Not known	Spain	García-Sanmartín et al. (2008)
Theileria equi	Equine theileriosis	Spain	García-Sanmartín et al. (2008) de la Fuente et al. (2008)
Rickettsia helvetica	Aneruptive fever, Endocarditis	Eurasia	Tijsse-Klasen et al. (2013)
Rickettsia sibirica sibirica	Siberian tick typhus	Eurasia	Estrada-Peña and Jongejan (1999)

Table 4
Experimental infection studies with *Dermacentor reticulatus* ticks.

Pathogen	Disease	Dissemination	References
Bluetongue virus (BTV-8)	Bluetongue disease	Disseminated infection: yes transstadial: no transovarial: no	Bouwknegt et al. (2010)
Palma virus	Not known	Transmission by cofeeding on laboratory mice: yes	Labuda et al. (1997)
Anaplasma marginale	Bovine anaplasmosis	Disseminated infection: yes transmission calf to calf: yes	Zivkovic et al. (2007)

substantiated (Kahl et al., 2002). Mere demonstration of the carrier status of field-collected ticks is only the very first step to prove vector competence.

4. Conclusions and outlook

The most extensive data collection regarding European *Dermacentor* species to date was used to compile a distribution map for both *D. marginatus* and *D. reticulatus*. From these maps the current species distribution, the overlap between the two species as well as the northern and southern distribution limits were estimated. Using georeferenced data was more successful in this respect than using maps based on the coarser spatial resolution of political districts as for example provided for *D. reticulatus* by ECDC (2015). Except for Germany, the latter does not depict the typical fragmented distribution and gives an unrealistic impression on the spatial distribution of *D. reticulatus*. This is especially true for Spain and northern France, while well documented *D. reticulatus* observations from Austria, the Netherlands, Romania, Serbia, Croatia and Ukraine as well as a map for *D. marginatus* are missing. Nevertheless, the *D. reticulatus* map compiled by ECDC provides valuable information for Russia and other countries where data are exclusively available on the level of political districts.

The *Dermacentor* data collected in this study form a proper basis for ongoing research activities concerning the development of habitat models, also known as species distribution models. Such an application was recently presented by Walter (2015), who modelled the potential geographical distribution of *D. marginatus* in Germany. As these models have serious problems to predict reliable tick distributions for regions where data are sparse or even missing, the application of the datasets presented in Figs. 2 and 3 will significantly improve the results from species distribution models. Other investigations may focus on recently observed range expansions of *D. reticulatus* as discussed for Germany (Dautel et al., 2006) and Poland (Kiewra and Czulowska, 2013; Karbowiak, 2014) or focus on future range expansions in relation to climate change scenarios.

However, also major data gaps became visible through the presented *Dermacentor* distribution maps. Due to the general trend to concentrate on molecular biological and genetic studies, basic research on the occurrence and distribution of important vectors of tick-borne pathogens has been neglected. Especially in Central Europe (Fig. 4) it will be appropriate to close the observational gaps by future field studies, not least because of changes in habitat suitability due to climate change. Linking large-scale tick occurrence with prevalences of pathogens investigated in various local and experimental studies (Tables 2–4) would further offer the possibility for a comprehensive risk analysis to support public health authorities.

The digital datasets presented in this study are provided on the website http://epidemic-modeling.vetmeduni.ac.at.

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