

Original Article

Spatial Distribution of Ticks (Arachniada: Argasidae and Ixodidae) and Their Infection Rate to Crimean-Congo Hemorrhagic Fever Virus in Iran

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Abstract

Background: The Crimean-Congo Hemorrhagic Fever (CCHF) is one of the most important arthropod-borne viral diseases with a mortality rate of about 30% among humans. The disease, caused by a *Nairovirus*, is transmitted to humans and animals by hard and soft ticks. This study aimed to determine the distribution of soft and hard ticks in the past three decades in Iran with an emphasis on the vectors of the CCHF virus.

Methods: In this study, all studies that were carried out in different regions of Iran from 1979 to 2018 and their results were published in prestigious journals were used to create a database. The distribution of ticks was mapped using ArcMap10.3.

Results: Based on the results, nine genera and 37 species of soft and hard ticks were recorded in Iran. So far, six genera and 16 species of hard and soft ticks were reported to be infected with the CCHF virus. The infection to this virus was reported from 18 out of 31 provinces, with a high rate in Sistan and Baluchistan as well as Khuzestan provinces. The highest levels of CCHF infection belonged to *Hyalomma marginatum* and *H. anatolicum*.

Conclusion: The main vectors of CCHF, *H. marginatum* and *H. anatolicum*, were reported in more than 38.7% of Iran's provinces, and these two species were identified as invasive species in Iran. Thus, control activities should be strengthened to avoid the outbreaks of CCHF.

Keywords: Argasidae; Ixodidae; Distribution; Hemorrhagic fever, crimean; Geographic information systems

Introduction

Ticks, the arthropods belong to the Arachnida class, are characterized by several attributes that are easily distinguishable from insects, including four pairs of legs, no antenna and wings and the absence of specific clauses in the body. They are obligatory ectoparasites of vertebrate, especially wild animals (1, 2). A total of 899 species of ticks (185 species of Argasidae and 714 species of Ixodidae family) have been reported in the world (3). Ticks can transmit various pathogens such as bacteria, viruses, spirochaete, rickettsia, blood protozoa and can cause important diseases such as relapsing fever, crimean-congo hemorrhagic fever, lyme

disease, Q fever, babesiosis, rocky mountain spotted fever, encephalitis and an-aplasmosis (4). Ticks may also cause paralysis, poisoning, irritation, and sensitivity in humans and animals. In addition, they can result in economic losses and significantly reduce milk and animal weight and increase the rate of infection of animals to various types of infections (5). Studies on the fauna of ticks in Iran began in 1810 by Dupre (6) and continued by Delpy in 1936 and 1938 (7, 8). Then, Abbasian (9) and Mazlomi (10) produced a list of ticks in animals from different regions in Iran. One of the most important tick-borne diseases is Crimean-Congo

hemorrhagic fever (CCHF), with a mortality rate of about 30% in humans (11). This disease is distributed in the Eastern Mediterranean, Central Asia, Eastern Europe and Africa (12, 13). It is a viral disease caused by a Nairovirus from the *Bunyaviridae* family (14). The virus has been reported repeatedly from animals, humans and ticks from different regions in Iran (15-18). The CCHF can be transmitted by ticks among domestic animals as the most important reservoirs. Although humans usually become infected via contact with the meat and blood of infected animals, this fever can be transmitted by the bites of infected ticks, especially in people who have close contact with animal reservoirs (19). To date, the disease has been reported from 23 provinces of Iran; however, most cases have been reported in provinces bordering with Afghanistan and Pakistan (20, 21). Ticks are the most important vectors and reservoirs of the CCHF virus and play an important role in the maintenance of the virus in nature (22). The most important vectors are *Hyalomma*, *Boophilus*, *Rhipicephalus*, *Amblyomma*, *Dermacentor* and *Haemaphysalis*. Of these, the *Hyalomma* genus contains the highest number of vectors. *Hyalomma marginatum* and *H. anatolicum* are among the most important invasive species in Iran (23). By 2007, 26 species of soft and hard ticks had been reported (10, 24-25). So far, in several studies, the CCHF virus has been isolated from different species of ticks in Iran (26, 27). The use of geographic information system (GIS) is a new technology in the study of arthropod-borne diseases such as CCHF and has led to significant changes in data interpretation and decision making. Using geographic technology, researchers are now able to quickly discover the global distribution of the disease, identify and monitor the high-risk areas of the disease and take the necessary environmental interventions (28). Considering the importance of tick vectors in transmitting CCHF and the frequency of species reported across Iran, this study aimed to determine the distribution of soft and hard ticks in Iran as the most important

ectoparasites of animals and humans. Emphasis was placed on the vector species and their infection to the CCHF virus in Iran.

Materials and Methods

Study area

Iran is located in the southwest of Asia, with a geographical range of 25.3 to 39.47 °N latitude and 44.5 to 63.18 °E longitudes and 1,648,195 square kilometers. Based on the census conducted in 2016, the population was 79,926,270 people. Iran is one of the most unique countries in terms of weather. The difference in temperature in winter between the hottest and coldest points can sometimes reach more than 50 °C. Iran is semiarid and dry in terms of precipitation (29).

Study design

The present study is conducted on the spatial distribution of ticks (Families Argasidae and Ixodidae) and the infection rate in vectors of CCHF in Iran. MSc and PhD theses and articles related to ticks were collected from PubMed, Google Scholar, Elsevier, Science Direct, Scopus, Web of Science, Magiran, Iran doc, Scientific Information Database (SID) and Iran medex databases from 1987 to 2018. The following terms were searched in line with the purpose of the study: ticks, hard ticks, soft ticks, the fauna of ticks, tick-borne diseases, veterinary ticks, medical ticks, Argasidae, Ixodidae, the epidemiology of ticks, the ecology of ticks, CCHF, the CCHF virus, the CCHF reservoirs and Crimean-Congo hemorrhagic. In this study, all articles on soft ticks and hard ticks were collected and the data were categorized according to the genus and species in the three levels of the province, county and village. The data were then entered into the Excel software, and the geographic coordinates of all regions were extracted from Excel and entered into the ArcMap in ArcGIS 10.3 software (30). Next, the distribution maps of ticks and CCHF vectors were provided. The inclusion criteria were

all studies conducted in universities and research centers in Iran, and their results were published in prestigious domestic and foreign publications in the 37-year period of the study.

Results

During the 39 years study period, 1979–2018, a total of 115 articles and 43 MSc/PhD theses were published on the study of hard and soft ticks on animals and the infestation rate of the CCHF virus in different regions of Iran. The study areas included 31 provinces, 321 cities and 379 villages. Most studies were done (31.65%) in the north and northwest of Iran. The results of the ticks' infestation to pathogens showed that 6–11% of ticks were infected to the CCHF virus on average, 17% for *Borrelia*, 16.6% for *Theileria*, 10.5% for *Babesia* and 5% for *Ehrlichia*. Ticks' infection with the CCHF virus was reported in 18 provinces. The highest CCHF infection rate was reported from Sistan and Baluchistan (18.85%) and Khuzestan provinces (16.1%), while the lowest infection rate was observed in Razavi Khorasan Province (0/8%) (Table 1, Fig. 1). From 1979 to 2018, a CCHF infection rate of 0.5–33.30% was reported in both Argasidae and Ixodidae families, so that the two species of soft ticks and 14 species of hard ticks were reported to be infected. The highest number of infected ticks was reported from Hamadan Province, western Iran (Table 1). The results of the earlier studies showed that 37 species of soft and hard ticks were distributed in Iran. Of the two families of soft and hard ticks in Iran, three genera (*Ornithodoros*, *Argas* and *Otobius*) belonged to the soft ticks, and six genera (*Boophilus*, *Dermacentor*, *Hyalomma*, *Haemaphysalis*, *Ixodes*, and *Rhipicephalus*) belonged to hard ticks. The most frequent species was *Hyalomma* genus with 11 different species reported from all over the country, and the least frequent species belonged to *Ixodes*, *Boophilus* and *Otobius* genera of which only one species was reported in the country.

Distribution of Argasidae and Ixodidae ticks and infection rate of CCHFV in Iran

Argas: This genus includes two species of *Argas persicus* and *A. reflexus*, reported from 15 provinces of Iran: Ardabil, West Azerbaijan, Chaharmahal and Bakhtiari, Fars, Isfahan, Golestan, Hamedan, Kurdistan, Lorestan, Markazi, Mazandaran, Qazvin, Qom, Semnan, Sistan and Baluchistan (Fig. 2). The infection to the CCHF virus was reported only from *A. reflexus* (Table 1).

Ornithodoros: This genus consists of 4 species of *Ornithodoros canestrinii*, *O. lahorensis*, *O. tartakovskyi* and *O. tholozani*. They were found in 14 provinces: Ardabil, West Azerbaijan, Chaharmahal and Bakhtiari, Isfahan, Fars, Hamedan, South Khorassan, Kurdistan, Lorestan, Zanjan, Markazi, Mazandaran, Qazvin and Semnan. Among species of this genus, the infection of CCHF virus was detected only in *O. lahorensis* from three provinces of Ardabil, East Azarbaijan and Mazandaran, which are located in northern and northwest of Iran (Fig. 3).

Otobius: This genus included one species of *Otobius megnini*, reported from three provinces of Isfahan, Lorestan and Tehran (Fig. 4). There was no report of infection to CCHF virus in this genus.

Boophilus: This genus has one species of *Boophilus annulatus*, which was reported from 8 provinces: West Azarbaijan, Isfahan, Fars, Golestan, Gilan, Mazandaran, Tehran and Qazvin (Fig. 5). No infection of this genus was reported.

Dermacentor: This genus included 5 species of *Dermacentor marginatus*, *D. niveus*, *D. raskemensis*, *D. daghestanicus*, and *D. silvarum* reported from 15 provinces: Ardabil, West Azarbaijan, East Azarbaijan, Fars, Isfahan, Kerman, South Khorassan, Razavi Khorassan, Kurdistan, Lorestan, Mazandaran, Qazvin, Semnan, Yazd and Zanjan (Fig. 6). Among the above mentioned species, the infection with the CCHF virus was detected only in *D. marginatus* from East Azerbaijan Province.

Hyalomma: This genus comprised 11 species of *Hyalomma schulzei*, *H. marginatum*, *H. impeltatum*, *H. dromedarii*, *H. detritum*, *H. excavatum*, *H. asiaticum*, *H. anatolicum*, *H. egyptium*, *H. rufipes* and *H. turanicum* reported from 28 provinces: Alborz, Ardabil, East Azerbaijan, West Azerbaijan, Chaharmahal and Bakhtiari, Isfahan, Fars, Golestan, Gilan, Hamadan, Hormozgan, Ilam, Kerman, Kermanshah, South Khorassan, North Khorassan, Razavi Khorassan, Khuzestan, Kohkiluyeh and Boyerahmad, Kurdistan, Lorestan, Mazandaran, Qazvin, Qom, Semnan, Sistan and Baluchistan, Yazd and Bushehr (Fig. 7).

Haemaphysalis: This genus consisted of 8 species of *Haemaphysalis sulcata*, *H. punctat*, *H. parva*, *H. inermis*, *H. erinacei*, *H. numidiana*, *H. choldokovskyi* and *H. concinna* reported from 21 provinces: Ardabil, East Azerbaijan, West Azerbaijan, Isfahan, Fars, Golestan, Gilan, Hamadan, Ilam, Kermanshah, South Khorassan, Razavi Khorassan, Khuzestan, Kohkiluyeh and Boyerahmad, Kurdistan, Lorestan, Mazandaran, Qazvin, Qom, Sistan and Baluchistan and Zan-

jan (Fig. 8). The virus infection of three species, *H. inermis*, *H. punctat*, and *H. sulcata* was reported from four provinces: Isfahan, Sistan and Baluchistan, Hamedan and Mazandaran.

Ixodes: This genus included *Ixodes ricinus* species and was reported from the north of Iran in Golestan, Gilan and Mazandaran provinces (Fig. 9). The CCHF virus infection in in this genus has not been reported so far.

Rhipicephalus: This genus included 4 species of *Rhipicephalus bursa*, *R. sanguineus*, *R. annulatus* and *R. turanicus* reported from 27 provinces: Alborz, Ardabil, East Azerbaijan, West Azerbaijan, Isfahan, Fars, Golestan, Hamadan, Hormozgan, Ilam, Kerman, Kermanshah, South Khorassan, North Khorassan, Razavi Khorassan, Khuzestan, Kohkiluyeh and Boyerahmad, Kurdistan, Lorestan, Mazandaran, Qazvin, Qom, Semnan, Sistan and Baluchistan, Tehran, Yazd and Zanjan (Fig. 10). The contamination of *R. sanguineus* and *R. bursa* with the CCHF virus was reported from nine and four provinces, respectively.

Table 1. The average infection rate of ticks to CCHF virus in Iran, 1979–2018

Family	<i>Ixodidae</i>									<i>Argasidae</i>			<i>Ornithodoros</i>	
	<i>Hyalomma</i>		<i>Dermacentor</i>		<i>Haemaphysalis</i>			<i>Rhipicephalus</i>		<i>Argas</i>				
Genus	<i>H. marginatum</i>	<i>H. anatolicum</i>	<i>H. asiaticum</i>	<i>H. detritum</i>	<i>H. dromedarii</i>	<i>H. schulzei</i>	<i>D. marginatus</i>	<i>Ha. inermis</i>	<i>Ha. punctata</i>	<i>Ha. sulcata</i>	<i>R. bursa</i>	<i>R. sanguineus</i>	<i>A. reflexus</i>	<i>O. lahorensis</i>
Fars	1	1.5	-	-	-	-	-	-	-	-	-	2	-	-
Isfahan	-	1.42	0.95	-	-	-	-	-	-	-	0.5	-	1.42	-
Razavi Khorassan	0.6	-	-	-	-	-	-	-	-	-	-	-	-	-
Qom	7.1	-	-	-	-	-	-	-	-	-	-	-	-	-
Sistan and Baluchistan	-	-	-	-	-	-	-	8.3	-	-	-	-	-	-
Yazd	0.71	0.71	0.71	1.42	2.14	-	-	-	-	-	-	-	-	-
Lorestan	16.7	13.2	7.4	-	-	-	-	-	-	-	-	4.3	-	-
Kermanshah	-	4.1	4.54	-	-	-	-	-	-	-	-	11.11	-	-
Ardabil	0.8	-	-	-	0.8	0.8	-	-	-	-	13.84	-	-	6.92
Khuzestan	12	2.94	-	-	33.3	-	-	-	-	-	-	-	-	-
Hamadan	3.4	6	1	14.63	2.2	-	-	-	1.1	-	2	4	6	-
East Azerbaijan	22	-	8.4	-	13	-	7	-	-	-	-	-	-	25
Golestan	7	2.3	-	-	1.6	-	-	-	-	-	-	7	-	-
South Khorasan	3	4	7.5	-	-	-	-	-	-	-	17	11	-	-
Ilam	1.35	1.35	1.35	-	-	-	-	-	-	-	-	-	-	-
North Khorassan	-	4.5	-	-	-	-	-	-	-	-	-	3	-	-
Mazandaran	-	-	-	-	-	-	-	2.4	2.4	-	2.4	1.7	-	2.4
Tehran	-	-	2	-	-	-	-	-	-	-	-	-	-	-

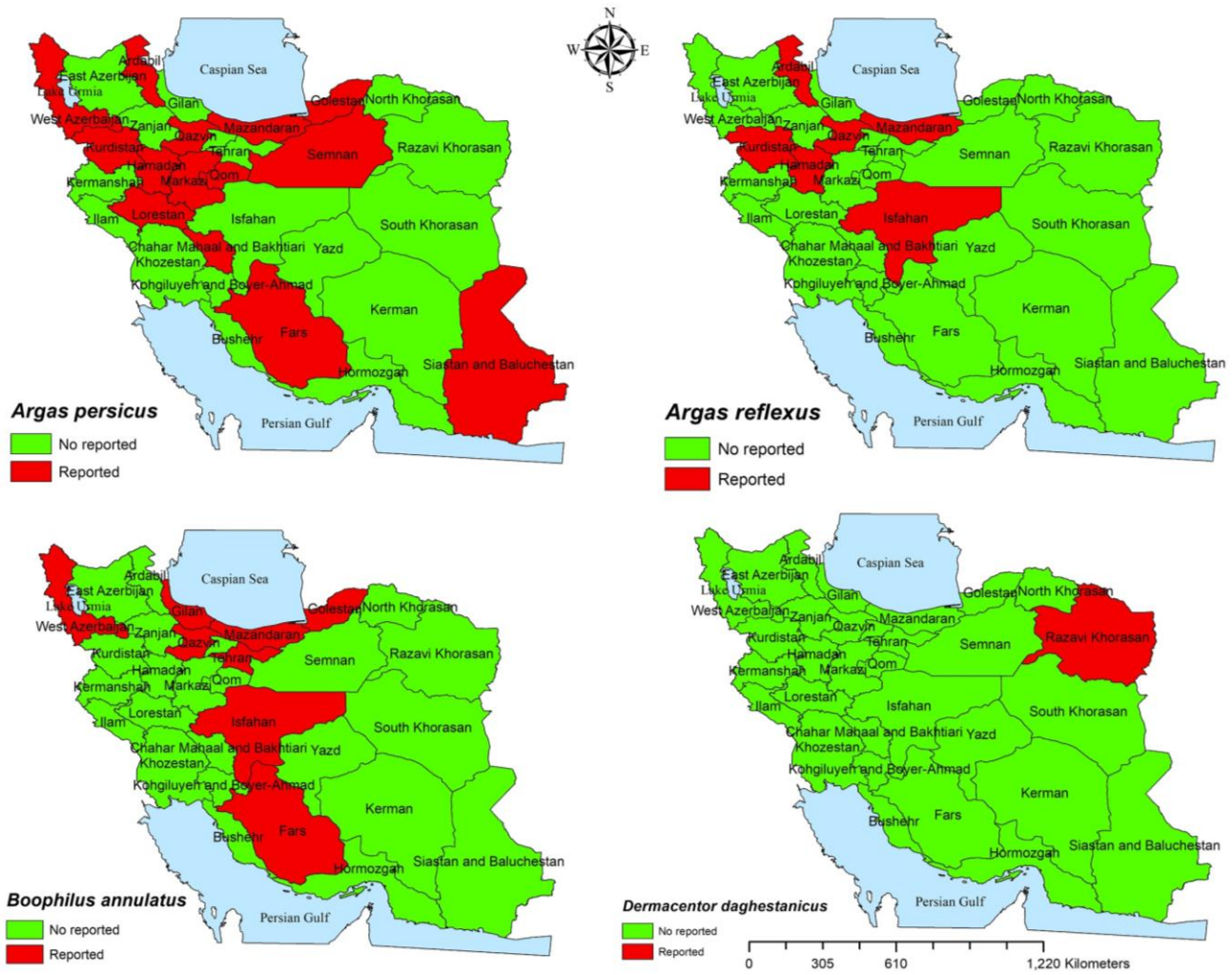


Fig. 1. Presence of *Argas reflexus*, *Argas persicus*, *Dermacentor daghestanicus* and *Dermacentor annulatus* (down) report in Iran at the county

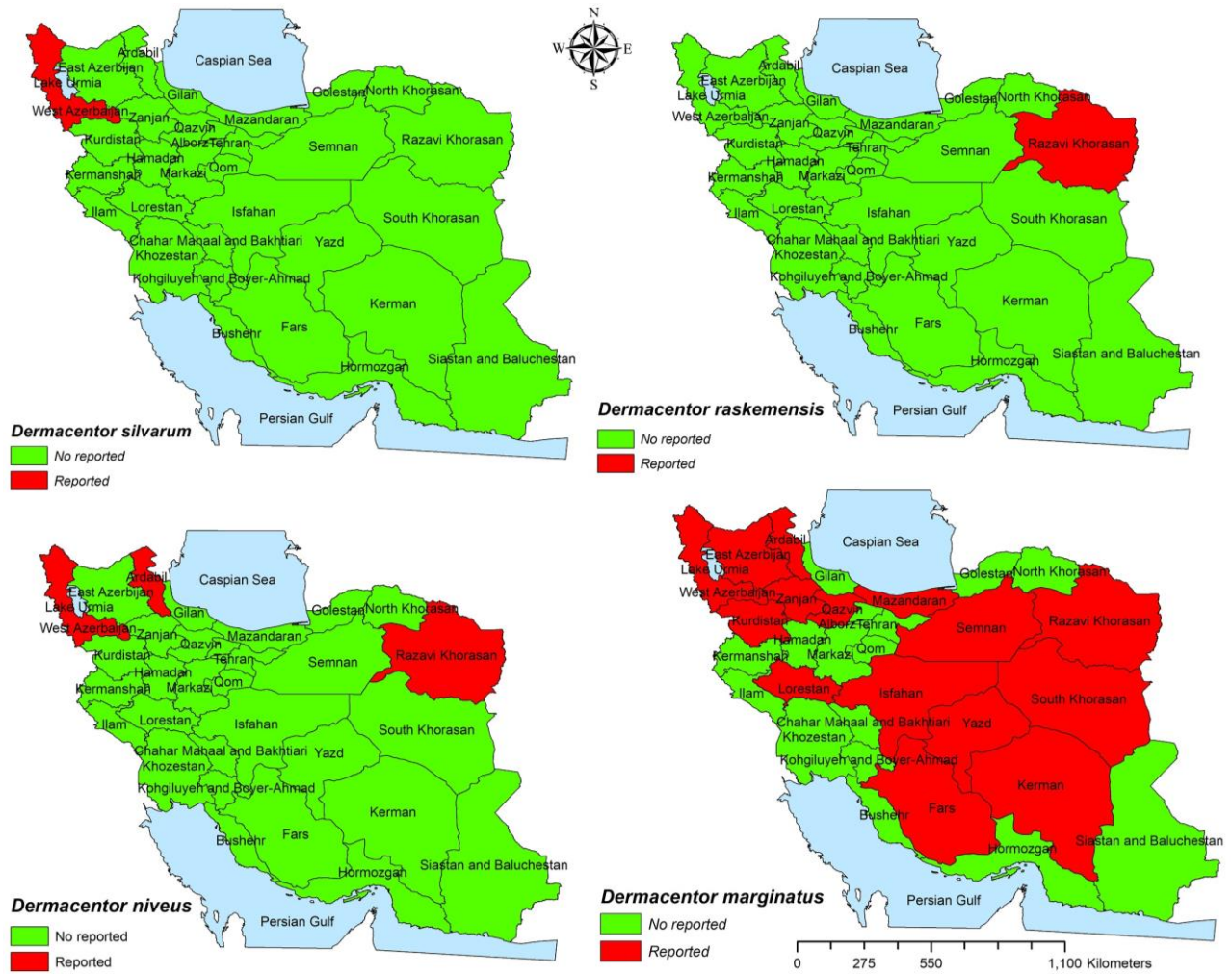


Fig. 2. Presence of *Dermacentor silvarum*, *Dermacentor marginatus* (up) and *Dermacentor raskemensis* and *Dermacentor niveus* (down) report in Iran at the county

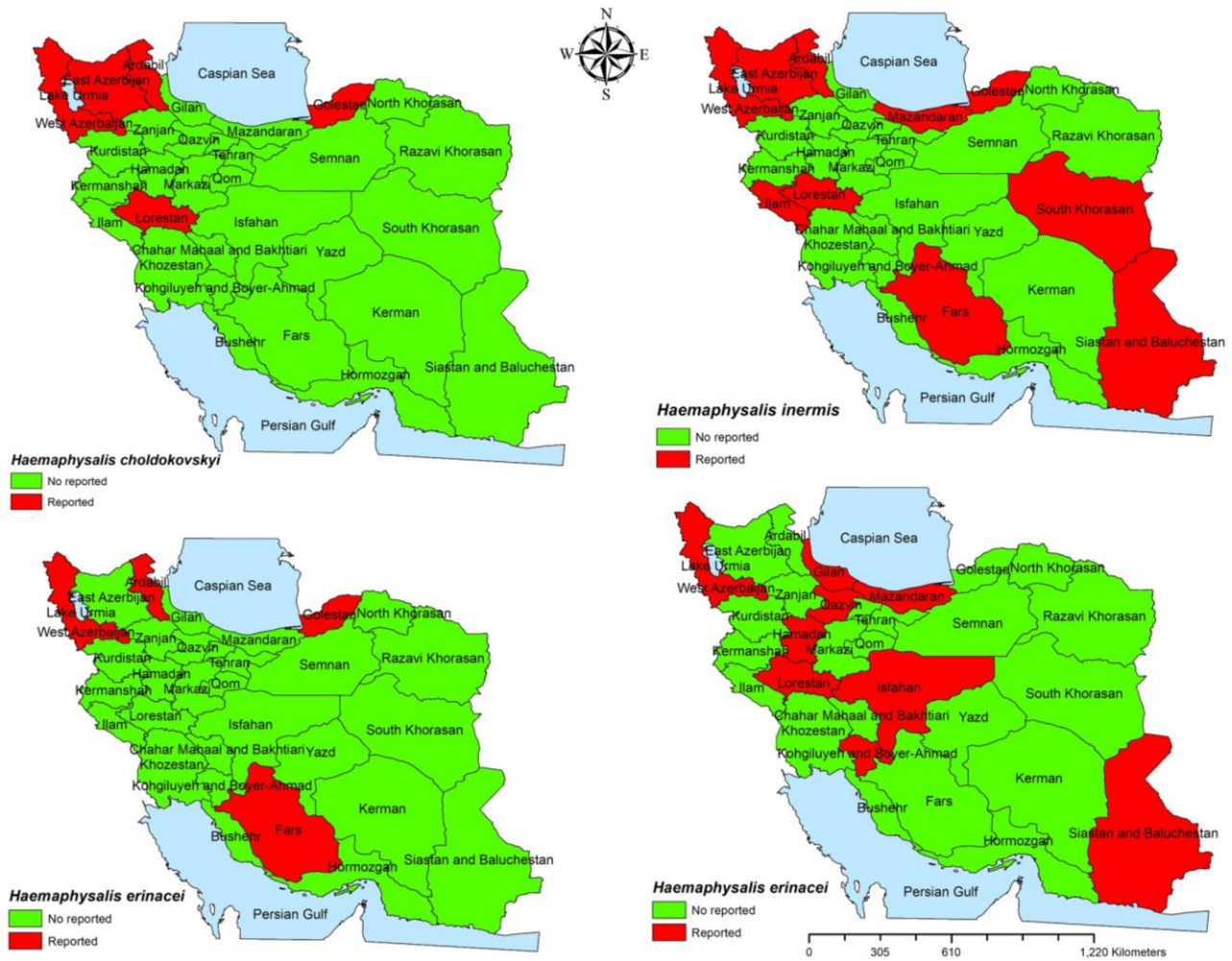


Fig. 3. Presence of *Haemaphysalis choldokovskyi*, *Haemaphysalis inermis* (up) and *Haemaphysalis concinna* and *Haemaphysalis erinacei* (down) report in Iran at the county

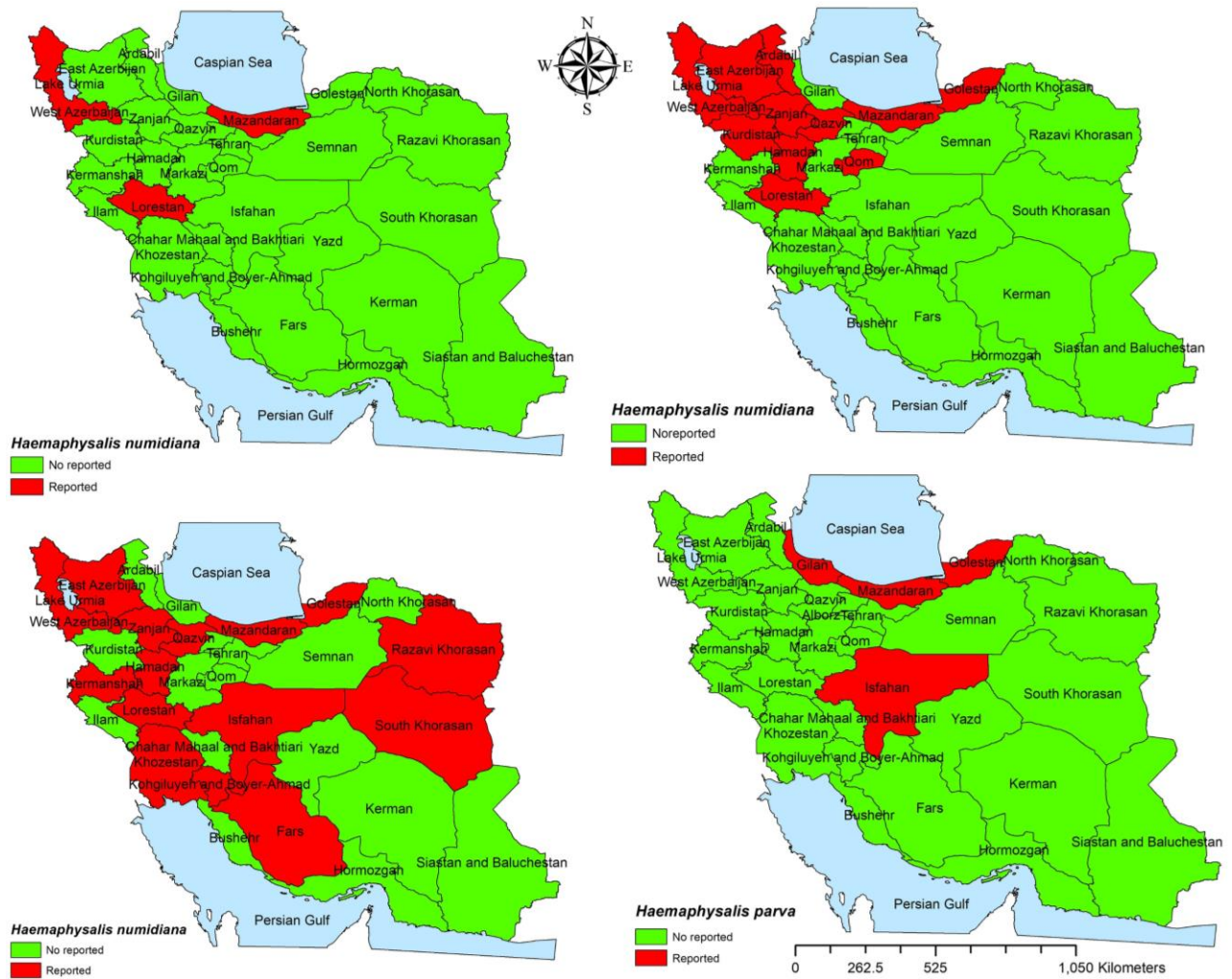


Fig. 4. Presence of *Haemaphysalis numidiana*, *Haemaphysalis punctata* (up) and *Haemaphysalis sulcata* and *Haemaphysalis parva* (down) report in Iran at the county

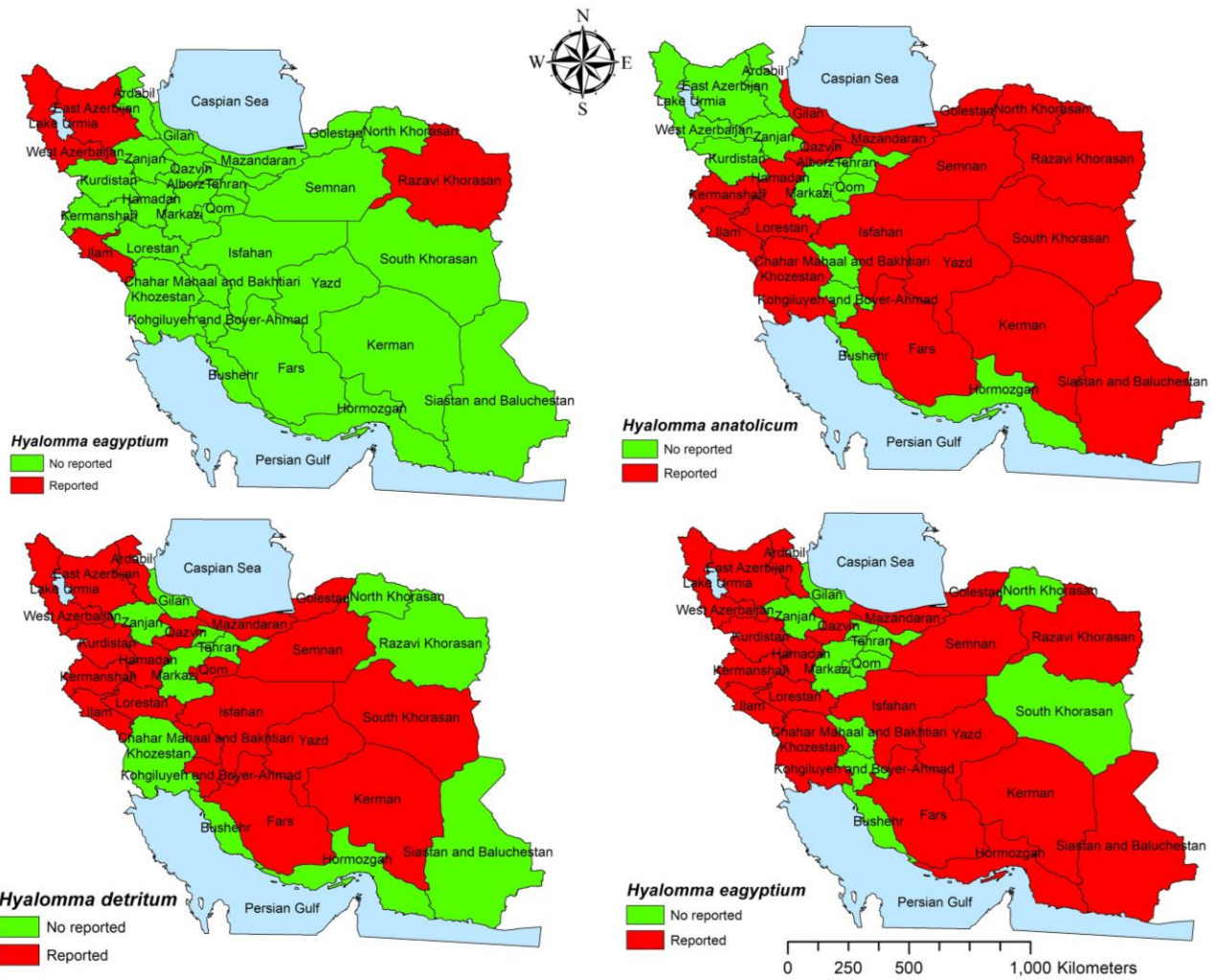


Fig. 5. Presence of *Hyalomma egyptium*, *Hyalomma anatolicum*, (up) and *Hyalomma detritum* and *Hyalomma asiaticum* (down) report in Iran at the county

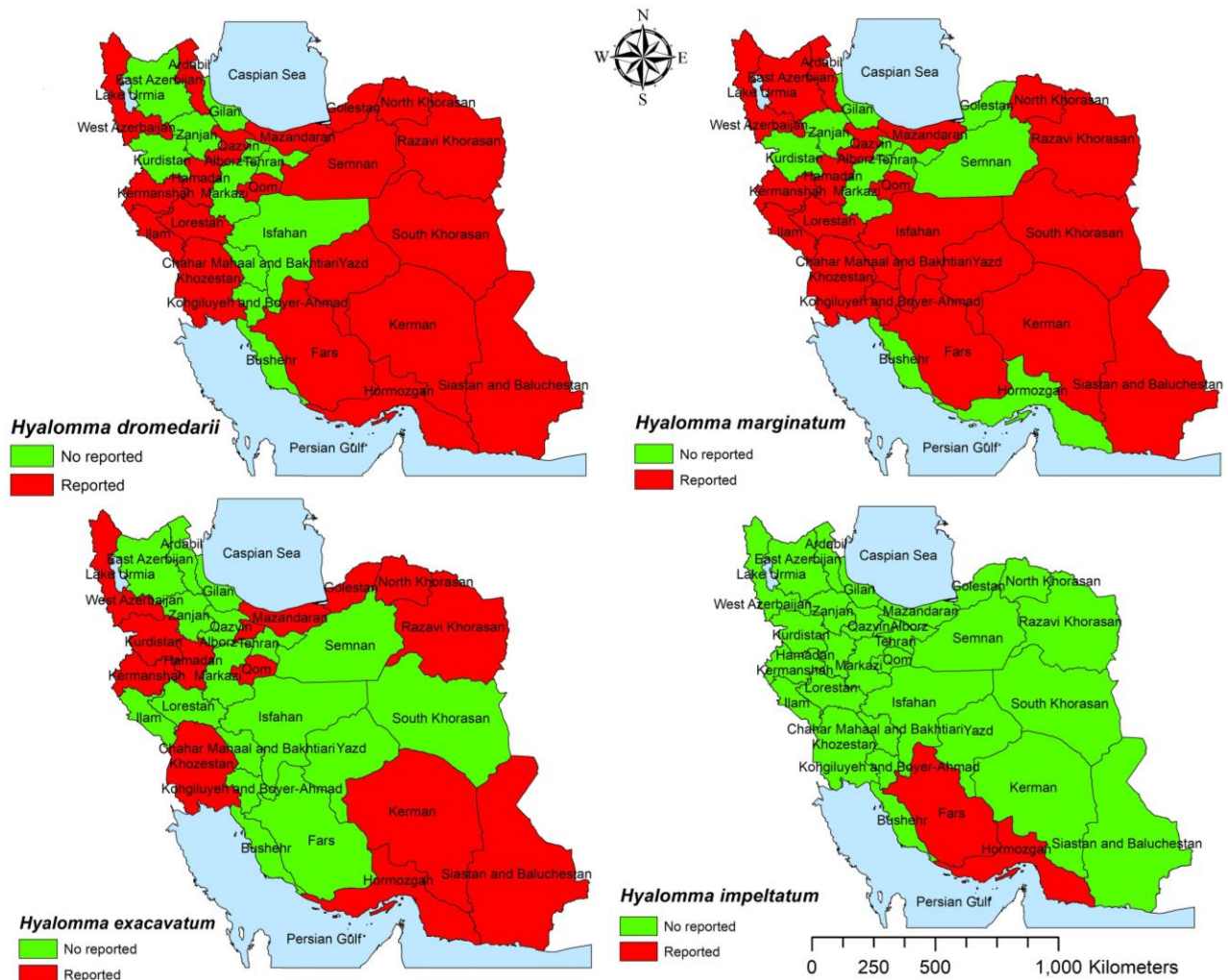


Fig. 6. Presence of *Hyalomma dromedarii*, *Hyalomma excavatum*, (up) and *Hyalomma marginatum* and *Hyalomma impeltatum* (down) report in Iran at the county

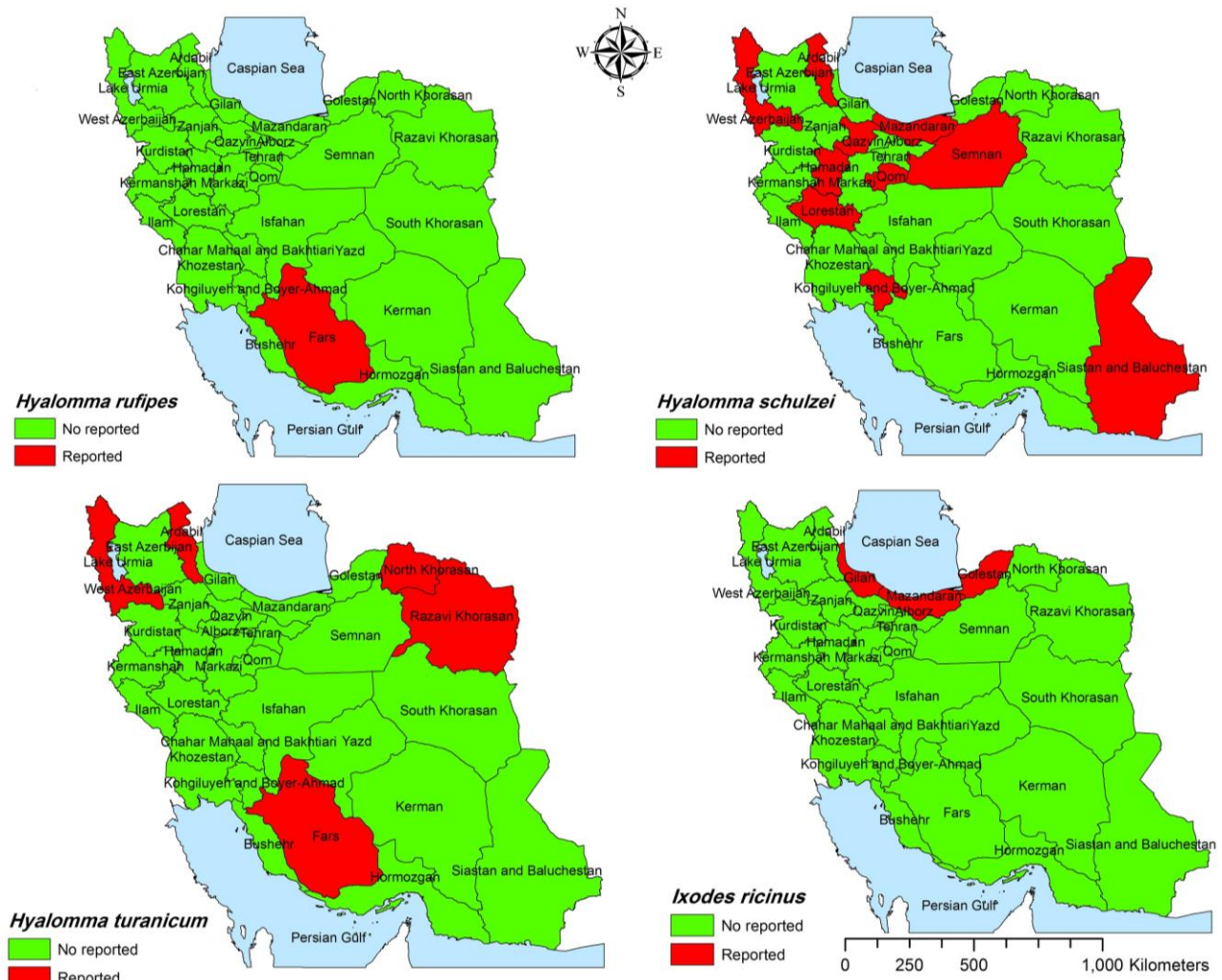


Fig. 7. Presence of *Hyalomma rufipes*, *Hyalomma schulzei*, (up) and *Ixodes ricinus* and *Hyalomma turanicum* (down) report in Iran at the county

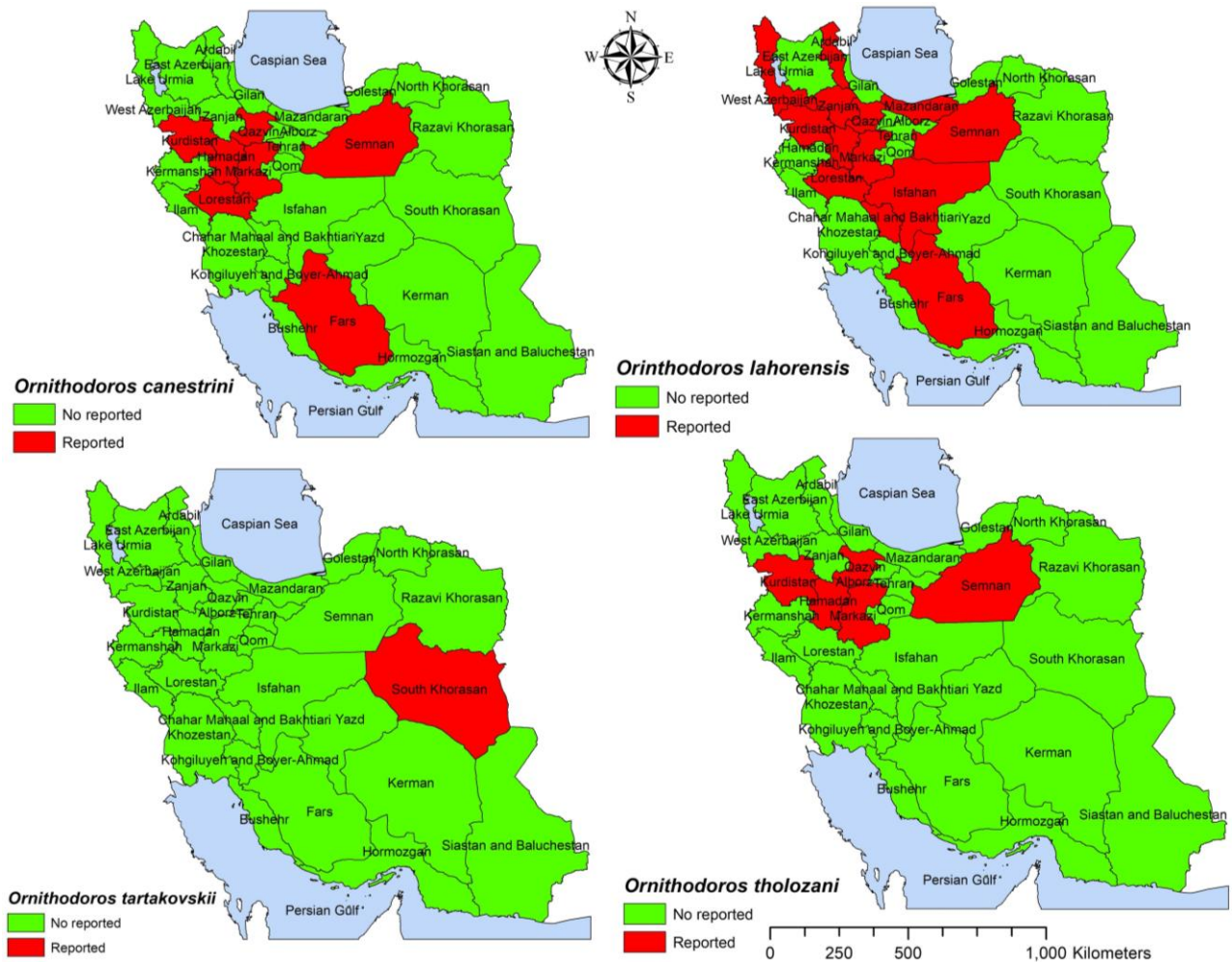


Fig. 8. Presence of *Ornithodoros canestrinii*, *Ornithodoros lahorensis*, (up) and *Ornithodoros tartakovskii* and *Ornithodoros tholozani* (down) report in Iran at the county

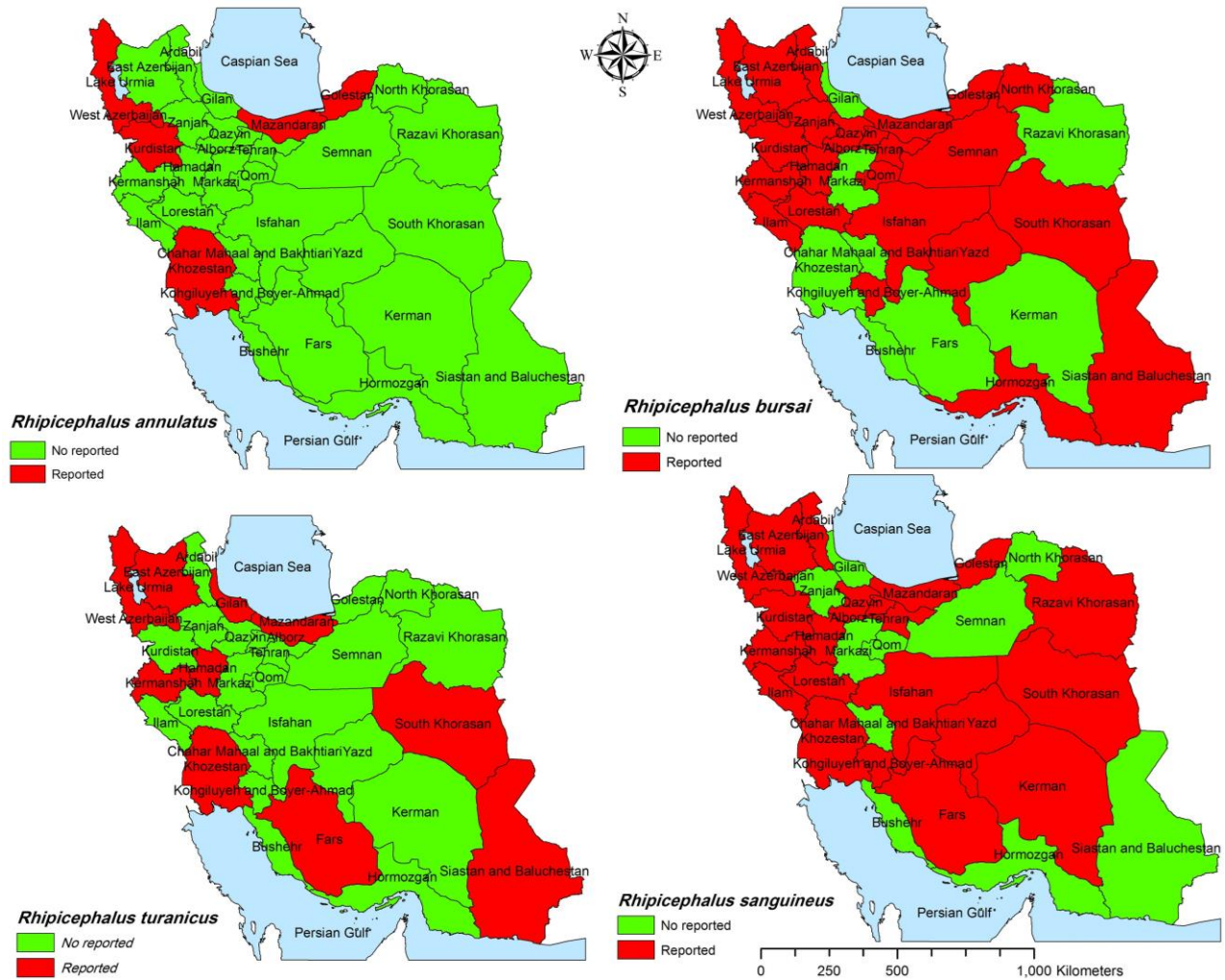


Fig. 9. Presence of *Rhipicephalus annulatus*, *Rhipicephalus bursai*, (up) and *Rhipicephalus sanguineus* and *Rhipicephalus turanicus* (down) report in Iran at the county



Fig. 10. Presence of *Otobius megnini* report in Iran at the county

Discussion

Based on the results of this study, 11 genera and 37 species of hard and soft ticks were reported from Iran, and the infection rate of ticks to the CCHF virus during 1979–2018 was reported in more than 58% of provinces. This indicates that the distribution of the vectors of the CCHF virus in Iran is very wide. Moreover, it was observed that nine species of hard and soft ticks were collected and identified from animals; of these species, the infection with the CCHF virus was detected from four genera of hard ticks (*Hyalomma*, *Haemaphysalis*, *Rhip-*

icephalus and *Dermacentor*) and two genera of soft ticks (*Argas* and *Ornithodoros*) by various methods. Also, the infection with the CCHF virus was reported in more than 66% of the identified ticks in Iran. In India, the infection has been reported from seven genera of hard ticks and three genera of soft ticks, which is more than Iran (31). In a study in Turkey, the total number of soft and hard ticks, distributed in this country, were reported to be 32 species (32), and in Uzbekistan, 11 species have been identified and introduced (33). In China, three gen-

era and seven species of soft ticks and seven genera and 104 species of hard ticks have been identified (about 15% of the world's detected ticks), while the distribution of hard ticks is found to be more than other countries (34). The findings of our study also revealed that the distribution of the *Hyalomma* genus in Iran was more than the rest of the genera, and the most frequent species belonged to this genus. The *H. anatolicum* and *H. marginatum* (the main vectors of CCHF virus) species were reported from 25 and 21 provinces, respectively. They were widely distributed in Iran and reported with great frequency, especially in the eastern and northeast regions of the country. In the case of CCHF transmission, the most important genus was *Hyalomma*, whereas *H. anatolicum* and *H. marginatum* were the most important species (23). Results also demonstrated that the most infection rate in *H. anatolicum* species was 18.18% from Hamedan Province (35), followed by 9.21% in Kermanshah Province (36). As for the CCHF vectors in Iran, the infection rates of *H. anatolicum* and *H. marginatum* in 11 provinces were 11.85% and 14.95%, respectively (37). The infection rate of CCHF in Oman has been reported to be 2.30% on average, and the highest infection rate was reported in the *H. anatolicum* (38). In Kosovo, the infection rate has been estimated to be 11.13%, and the highest contamination has been reported in *Ixodes ricinus* (39). The results of this study showed that although *A. persicus* was the most prevalent species of *Argas* genus, the CCHF virus was detected from *A. reflexus* from Hamadan Province (35). The four species of *Ornithodoros* genus were reported, and *O. lahorensis* was the most frequent one, especially in the northwest, west and center of Iran. Nevertheless, this species was not reported in the northeast and east areas. The *O. tartakovskyi* species of this genus was reported only from South Khorasan Province, and it was infected with the virus in the north and northwest of Iran reported from Ardabil, East Azerbaijan and Mazandaran provinces with an average of 92.6%, 25% and 2.4

%, respectively (37, 40, 41). *Otobius megnini* was reported in three provinces and more frequently observed in central regions with no CCHF infection. A species of the *Boophilus* genus, *B. annulatus*, was mostly reported in the northern and southwestern provinces and was not reported in northeastern regions with no CCHF infection either. The *Dermacentor* genus comprised four species in Iran. The highest number of *D. marginatus* species and the lowest number of *D. silvarum* species were reported from West Azerbaijan, and the highest number of *D. raskemensis* was reported from Razavi Khorasan. In the northwest of Iran, only in East Azerbaijan Province, the infection of *D. marginatus* with the CCHF virus was reported to be 7% from 2008 to 2015 (37, 42). In Turkey, the infestation of *D. marginatus* with the CCHF virus was estimated at 2.74% in 2013 (43). Hence, in comparison, the results show that the infection rate in Iran has been two times more than the rate in Turkey. Six species of *Haemaphysalis* genus were distributed in Iran. *Ha. sulcata* had the highest prevalence and *Ha. erinacei* and *Ha. Parva* had the lowest. Infection with CCHF virus in *Ha. sulcata*, *Ha. punctata* and *Ha. inermis* were % 0/5, %3.5 and %5, respectively from Isfahan, Sistan and Baluchistan, Hamedan and Mazandaran provinces (17, 37, 44, 45). One species of *Ixodes* genus, namely *I. ricinus*, was distributed in the north of Iran and was not reported in other regions. The infection of this genus to the CCHF virus was not reported. Results revealed that there were two species of *Rhipicephalus* genus in Iran. *Rhipicephalus bursa* was the most frequent one in the northwestern, northeastern and central parts of Iran. the infection of *R. bursa* with CCHF virus was reported in four provinces, including Ardabil (13.84%), Hamedan (2%), Southern Khorasan (17%) and Mazandaran (2.4%); yet, the infection of *R. sanguineus* species by CCHFV was reported in nine provinces, including Fars (2%), Isfahan (1.42%), Lorestan (4.3%), Kermanshah (11.11%), Hamedan (4%), Golestan (7%), South Khorasan (11%), North

Khorasan (3%) and Mazandaran (1.7%). In total, the results of this study showed that the distribution of *R. bursa* species in Iran was more than other species, but the infection of *R. sanguineus* with the CCHF virus was more prevalent. Moreover, the severity of *R. sanguineus* infection rate was higher than the rate in other species (35, 46-50). In Turkey, the infection rate was reported to be 1.37% for the *R. bursa* species and 2.74% for the *R. turanicus* species in 2013 (43).

Conclusion

The findings of this study demonstrate that soft and hard ticks were distributed throughout the country, and several identified species belonged to the *Hyalomma* genus. The CCHF virus in Iran infected 16 hard and soft ticks. Yet, the *Hyalomma* genus was the most frequent species in the whole country. The *H. marginatum* and *H. anatolicum* species were also found to be infected in 12 provinces in Iran. Therefore, it can be concluded that these two species are the main vectors of the CCHF virus in Iran. Ethical issues (including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

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