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Climatogeographic Factors Driving the Range Expansion of Ixodes Ticks

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ABSTRACT

Climate change has been a key driver in the spread of important vectors for natural focal infections. Ixodid ticks, known for inhabiting a variety of environments, can thrive in both wooded areas and open meadows or pastures. In recent decades, many parasites, including ticks, have shifted their habitats further north, enabling not only their survival but also the completion of their reproductive cycles in these new regions. This study reviews the existing literature to assess how climatic and geographical changes are affecting the habitat expansion of ixodid ticks. The increase in tick population size, along with the extended spring-to-autumn activity period, has prolonged the epidemic season. This situation is further complicated by the continuous presence and activity of natural foci for arthropod-borne diseases. Various climatic factors, such as temperature, precipitation, and 85% humidity directly affect the life cycle and geographical distribution of ixodid ticks. These changes facilitate the expansion of tick populations into new territories, often carried by birds, wild animals, and rodents that carry ticks. Currently, the northern boundary of areas affected by ixodid-related infections, such as viral tick-borne encephalitis and borreliosis, extends beyond the Arctic. There are indications that these infection zones could shift further north, potentially making parts of the southern Arctic a new risk area for these diseases.

Keywords: Habitat expansion, Ixodid ticks, Climate, Infections, Viability

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Introduction

Ixodes ticks are highly adaptable and can be found in a wide variety of habitats, including deciduous, coniferous, and mixed forests, as well as open areas like meadows, clearings, and even abandoned logging sites [1, 2]. For ticks to thrive in forest ecosystems, certain conditions are essential, such as sparse tree cover, moderate soil moisture, well-developed grass cover, and ample forest litter. Recently, ticks have also been discovered in urban forests and suburban regions, expanding their range [3]. As socio-economic and environmental factors evolve, the number of favorable habitats for tick development is changing. Notably, the range of carriers for tick-borne diseases often exceeds the direct focus of the diseases themselves, primarily due to the higher environmental requirements of the pathogens compared to their hosts. In the last 25 years, significant changes in meteorological conditions and climatic, such as increased average air temperatures in all seasons and high humidity levels, have led to a growth in tick populations and an extended period of activity within their natural habitats [4].

In nature, large herbivores and carnivorous mammals, such as roe deer, moose, wild boars, foxes, badgers, and wolves, serve as primary hosts for ticks. Various smaller mammals, particularly rodents like hares, squirrels, mice, chipmunks, shrews, and hedgehogs, as well as birds, reptiles, and occasionally amphibians, also serve as hosts.

Ticks are capable of parasitizing and transmitting infectious agents to domesticated animals such as sheep, cattle, rabbits, dogs, horses, and cats [4, 5]. Tick-borne diseases, particularly those transmitted by Ixodes ticks, have become a prevalent health concern in urban populations. This increase is attributed to the longer spring-to-autumn tick activity periods and the growing human-nature interactions, particularly as migratory birds spread ticks across urban green spaces, acting as new reservoirs for infections. Additionally, warmer temperatures are causing the shift of more heat-loving plants and parasites to the northeast, with many disease-carrying organisms expanding their range to higher latitudes. Migratory birds play a significant role in the global distribution of infectious agents, often more so than human migration. Birds, as carriers of various pathogens would not show symptoms but transport ectoparasites, including ticks, that harbor arboviruses affecting both animals and humans. Among the ticks, Ixodes species, which are prevalent across the entire Eurasian part of the Palearctic, are of particular significance, and their range is expanding further north due to global warming [6-8].
This study aims to review the literature regarding the impact of climate and geographic changes on the habitat expansion of Ixodes ticks.

Materials and Methods

This research involved a comprehensive review of scientific literature, including book chapters, publications, abstracts, and dissertations, published between 1993 and 2023. The sources used for the literature review included the Russian Scientific Electronic Library, PubMed, Cyberleninka, WoS, and Scopus. This review focuses on investigating how changes in geographical conditions and climatic have affected the expansion of the habitat of Ixodid ticks. A search using key terms such as ixodid ticks, infections, climate, habitat expansion, and viability resulted in 61 relevant entries, of which 48 were in Russian and 13 in English. Various research methods, including systematic, comparative, and analytical approaches, were employed to analyze the selected literature.

Results and Discussion

Impact of abiotic factors on tick distribution

The prevalence of infectious diseases spread through tick bites is significantly influenced by various climatic and natural factors. These factors determine the size of the tick population and the number of infected ticks. One of the most critical factors impacting all stages of tick development is air temperature. This factor dictates the timing of the tick activity season and influences the population size for subsequent years. Temperature plays a key role in preserving the viability of overwintering ticks, the embryogenesis process, and the survival of larvae, which can only thrive within specific temperature ranges [9-11].

Research indicates strong correlations between temperature fluctuations in February, March, April, July, August, and October, and the incidence of tick-borne viral encephalitis. Notably, a high or low incidence of the disease is linked to temperature cycles in these months. Additionally, a significant indirect effect was found between the average monthly temperatures of July and September from the prior year and the number of cases of ixodid tick-borne borreliosis [9, 12].

Interestingly, despite a high tick population after a mild winter, the incidence of tick-borne viral encephalitis may decrease. This phenomenon could be due to the survival of both highly pathogenic and low-virulence strains of the virus, with the latter causing milder, often unreported infections. Only the most virulent strains of the tick-borne viral encephalitis pathogen are capable of surviving extreme cold temperatures [13-16].

Each year, climate conditions are becoming increasingly conducive to the spread of pathogens associated with vector-borne diseases. Warmer winters and earlier springs have led to a higher survival rate of Ixodes ticks during the winter months. During winter, ticks enter diapause and are typically found in forest litter, where they often overwinter in areas such as fallen leaves, grass, moss, compost piles, firewood stacks, brushwood, natural debris, and the ground under tree roots. The temperature beneath the snow in the forest litter remains above 0 °C, enabling ticks to endure the winter in such environments. As the weather warms to around +5-10 °C and nighttime temperatures stay above freezing, ticks become active. This warmer weather triggers their activity, and in turn, leads to an increase in the activity of their hosts as well [17, 18].

One of the contributing factors to this shift is believed to be global warming, as well as the role of migratory birds in transporting ticks across vast distances. In the past, ticks struggled to establish themselves in northern regions, but this is no longer the case. A crucial element in this change is the shorter and milder winters now experienced in many parts of the world. The expansion of tick populations in Norway and Sweden between 1994 and 2008 has seen their range extend over 200 km northward along the Baltic coast. Similarly, in North America, tick populations have moved nearly 1000 km northward when compared to the 1943-1983 period. In the northern Czech Republic, where temperatures have increased by 1.4 °C over the last 40 years, ticks are now found as high as 1300 meters above sea level [14-16].

When examining the climate and geographical factors affecting tick habitats, it is evident that ticks are increasingly moving from rural and forested areas to urban environments, including towns and cities, where they are populating parks and public squares. An analysis of historical data reveals that approximately 50 percent of all reported tick bites on domestic animals (cats, dogs) occurred within these urban green spaces, such as parks and squares. Additionally, ticks have been found in areas with sparse grass and open, sunlit spaces [15-17].

Recent data from the Republic of Belarus on the spread and seasonal patterns of tick activity help explain the increasing frequency of piroplasmosis (babesiosis) in the canine population, which continues to rise each year. Previously, this disease was seen between April and July, with another peak from late August to October. However, in the past few years (2017-2020), piroplasmosis cases have appeared much earlier, with reports in March (2017), February (2018 and 2019), and even as early as January 2020. These trends suggest a significant shift toward year-round risk for piroplasmosis and other tick-borne infections.

Ticks not only affect wild and domestic animals but also pose a considerable risk to humans, as they are vectors for various pathogens, including those responsible for Lyme disease and tick-borne encephalitis. The incidence of tick-borne diseases among the population in Belarus has shown a clear annual increase. Epidemiological surveys indicate that 76% of Belarusians are considered at risk for tick-borne encephalitis, while 92% of the area is considered a risk zone for Lyme borreliosis.

Similar to tick-borne encephalitis, the spread of tick-borne borreliosis in the West Ural taiga region is largely influenced by land clearings, which later regenerate into young aspen-birch and pine-birch forests, fostering the growth of dense grass cover. These regenerated birch forests create ideal conditions for ticks, which act as vectors for the disease. The development of waterlogged areas on gentle slopes and in lowland river valleys, particularly following fires and logging activities, further contributes to the spread of tick-borne borreliosis. Such conditions are especially prevalent in regions where spruce forests, mixed with birch, cedar, and pine, thrive. The shaded environment, high humidity, and moist forest floor, rich in soft humus, provide a conducive habitat for the tick vectors. Additionally, cedar cones serve as a key food source for small rodents, which in turn are crucial for tick sustenance.

Anthropogenic sites, particularly those near taiga settlements, also show high tick populations, as these human-created habitats contribute significantly to the spread of the disease. The majority of active tick foci in the Middle Urals are of the wild type, thanks to the abundance of wild animals that support these foci, often in remote areas with limited human development. Species like moose and bears are widely distributed across these regions, creating uniform conditions that promote tick populations and the spread of borreliosis. Although mountainous areas generally lack natural foci, some localized sites may still harbor ticks. In years marked by cold, extended springs, human-influenced foci tend to present a greater epidemiological threat than wild-type foci. Furthermore, pets, particularly those living near urban or settlement areas, play a significant role in sustaining tick populations in land clearings and nearby habitats.

Recent evidence suggests that the northern boundary of ixodid-borne infections, including viral tick-borne encephalitis and ixodid borreliosis, has extended beyond the Arctic. This shift in the distribution of these diseases indicates a potential northward movement, which could place the southern Arctic region at risk for the transmission of the infections. Notably, significant advancements in ixodid ticks have already been recorded in the northern parts of Russia, particularly in the Komi Republic and Arkhangelsk region [18, 19]. In Norway, the presence of the tick-borne encephalitis virus has been detected as far north as latitude 65.1 °C [20]. Sweden has also observed a notable northward expansion of tick habitats, with increased population sizes and density over an extended period [21].

Natural focal diseases are increasingly influential in determining the health status of populations in the Arctic, where environmental and social conditions differ markedly from those in more temperate southern regions. In the north, climate plays a crucial role in shaping the spread of pathogens, vectors, and disease carriers. As one of the most significant natural factors, climate is fundamental to understanding the medical geography of the region. The ongoing warming of the Arctic, which is advancing more rapidly than in other parts of the world, has become a key topic of debate regarding its impact on infectious and parasitic diseases in the Arctic and subarctic regions [18].

The life cycle and habitat of ixodid ticks are heavily influenced by weather conditions, including precipitation, humidity, and air temperature. These climatic variables contribute to the geographical spread of ticks by altering the habitats of vegetation and wildlife carriers, such as deer, birds, and rodents, which introduce ticks to new areas. For example, the spread of *Ixodes ricinus* ticks into the northern regions of Sweden and Norway has been documented. Furthermore, a rise in the number of tick bites has been linked to increasing annual temperatures. As urbanization leads to more green spaces in cities and as people's behavior shifts—resulting in more outdoor activities, wildlife engagement, and pet ownership—the risk of exposure to tick-borne pathogens has escalated **(Figure 1)** [22, 23].

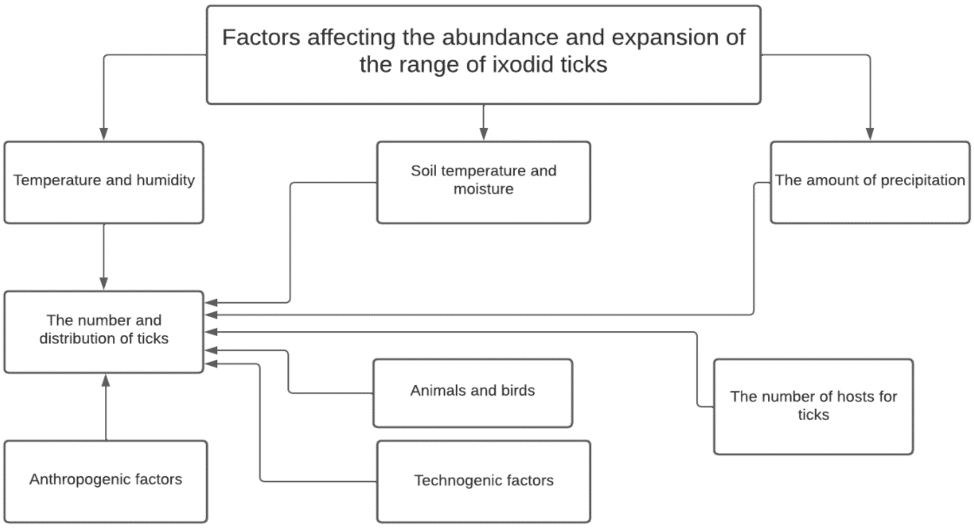

Figure 1. Factors affecting the number and expansion of the range of ixodid ticks

The continuing trend of climate warming in Russia has resulted in higher temperature anomalies across all seasons, which has a favorable impact on the *Hyalomma marginatum* Koch, 1844 ixodid tick population. This warming is also driving the northward expansion of the Crimean-Congo hemorrhagic fever (CCHF) virus. As the carriers of CCHF increase in both number and range, the disease’s prevalence in humans is rising. These climate shifts are thus enhancing the spread and development of *H. marginatum* ticks, contributing to a tense epidemiological situation, particularly in southern Russia.

Recent research underscores the complex interaction between climate factors and the life cycle of *H. marginatum*, highlighting its critical role in the transmission of CCHF. In addition to the well-established impact of temperature on tick development, findings suggest that humidity plays a key role in influencing CCHF outbreaks at various points in the year. The most significant climate factors affecting ticks’ reproductive and developmental processes are the temperatures and rainfall levels during late spring and early summer. Furthermore, overwintering ticks' survival is highly dependent on the temperatures during January and early February.

Therefore, the climate’s multifactorial effects not only determine the length of the active period for ticks but also influence the size of their populations. As climate warming persists, the spread of CCHF is likely to shift further north, potentially involving new regions in the epidemic process [24].

Discussion

The growing concern surrounding tick-borne infections is tied to the increasing spread of blood-feeding arthropods, particularly those that parasitize birds. The migration of bird habitats to northern regions has facilitated not only the survival and reproduction of these vectors but also the completion of the development cycle of tick-borne pathogens, resulting in pathogen invasions. Studies have confirmed that the shifting of blood-sucking ectoparasites and their associated pathogens is directly linked to global climate warming.

The migration of tick-borne encephalitis (IE) and borreliosis to more northern regions is driven by changes in vegetation and increased dryness at the southern limits of these vectors' territories. In mountainous areas, the range of IE vectors is expanding upward, with these vectors now found at higher altitudes. Warmer temperatures have also extended the period during which infected ticks can pose a threat to humans. Additionally, the range of *I. ricinus*, which predominantly carries *Borrelia* species, is expanding, and Ixodes persulcatus is moving northeast into more sparsely populated regions of Russia.

It is important to note that the invasion of new tick-borne pathogens is not only due to the spread of *I. ricinus* but also the introduction of new blood-sucking ixodid species by birds. Climate change has played a key role in enabling the northward movement of southern tick species, such as *H. marginatum* and *Ixodes frontalis*, and these species may eventually become established in new areas. As a result of rising environmental pollution and climate warming, new populations of existing vector species with altered characteristics may emerge [6-8, 25-27].

The impact of climatic conditions across different seasons on the development of *H. marginatum* and the trends in Crimean-Congo hemorrhagic fever (CHF) incidence was examined in the Stavropol Territory. Strong correlations were found between air temperature, precipitation levels during winter and spring of the same year with tick abundance on farm animals, as well as the number of ticks collected during “checker” sampling. The summer period (previous epidemic season) showed a similar correlation with the abundance of larvae and nymphs of *H. marginatum*, as well as an increase in CHF cases [28, 29].

Four species of Ixodes ticks were identified in Stavropol, Russia: *Dermacentor marginatus*, *D. reticulatus*, *I. ricinus*, and *Rhipicephalus sanguineus*. *D. marginatus* becomes active in the spring following its winter diapause, particularly during mid-February thaw periods, as evidenced by reports from medical facilities and pet examinations. Peak parasitism by adult ticks occurs in the third week of April. During the summer (July to mid-August), the adult ticks enter diapause, with their numbers significantly dropping in the fall, but activity resumes by late August. Parasitism on animals and human attacks can occur until November.

R. sanguineus, a common species in the Ixodidae family, parasitizes mainly carnivores and becomes active in March and April. Its peak parasitism occurs in early May, with a lesser autumn peak. Larvae and nymphs are seen parasitizing feeders in June, with a peak in July. *R. sanguineus* is synanthropic, often found on pets such as dogs and cats, and is primarily collected from them. The species is most commonly found in urban areas, private households, open-air kennels, and outbuildings, with some cases of ticks entering residential spaces. These ticks likely travel into homes with pets or people. Cases of human attacks by *R. sanguineus* have also been recorded. Additionally, *Haemaphysalis punctata* ticks have been found in suburban areas near grazing sites, and *H. marginatum* is observed in such areas [30].

The presence of ticks and their potential to transmit infections across vast natural territories necessitates ongoing epizootological monitoring and epidemiological. In 2021, the rate of medical visits in Russia related to tick bites was 309.49 per 100,000 people, with an average of 342.34 per 100,000 over the period from 2014 to 2021 [31].

In recent decades, significant shifts have occurred in the distribution of ixodid ticks, their habitats, and the epidemiological activity associated with them, driven by human influence on natural environments and climatic changes. The ongoing presence and activity of natural foci of vector-borne diseases, combined with the expanding tick population, have worsened the epidemiological situation, yet preventive measures are limited primarily to tick-borne encephalitis and tularemia. This underscores the importance of maintaining up-to-date knowledge of the current tick species composition. Research has shown that the abundance of *Dermacentor* and *Ixodes* ticks is not determined by specific natural habitats, as they can thrive in both forested and open meadow or pasture areas. The findings highlight the necessity for more in-depth investigations into the biological and physiological traits of ixodid ticks, considering their climate and geographical preferences, along with comprehensive monitoring of tick populations, even in areas not typically considered endemic. Such efforts are essential for predicting potential outbreaks of tick-borne diseases, enabling timely interventions and effective prevention and treatment strategies [32].

Conclusion

This study reviews existing literature to assess how climatic and geographical changes influence the habitat expansion of ixodid ticks. The increase in tick population size, along with the extended spring-to-autumn activity period, has prolonged the epidemic season. This situation is further complicated by the continuous presence and activity of natural foci for arthropod-borne diseases. Various climatic factors, such as temperature, precipitation, and 85% humidity directly impact the life cycle and geographical spread of ixodid ticks. These changes facilitate the expansion of tick populations into new territories, often by birds, wild animals, and rodents that carry ticks. Currently, the northern boundary of areas affected by ixodid-related infections, such as viral tick-borne encephalitis and borreliosis, extends beyond the Arctic. There are indications that these infection zones could shift further north, potentially making parts of the southern Arctic a new risk area for these diseases.

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