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## Influence of Climatic Shifts on Ixodid Tick Populations in Stavropol Region

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### ABSTRACT

The parasitism of livestock by ixodid ticks, which transmit blood-borne parasitic diseases, is a major challenge in animal husbandry. This research focuses on how climate change affects the diversity of ixodid tick species. Data from the Kislovodsk meteorological station, including average winter temperature, wind speed, and the variability and trends of the Bodman index (which indicates climate severity), were analyzed. The distribution of ixodid ticks is closely tied to the climatic zones. In the Stavropol region, 16 species of ixodid ticks across 6 genera have been recorded. Monitoring from 1999 onwards reveals a growing number of ixodid tick species. As the region experiences warming temperatures, milder winter conditions have led to an expansion of suitable habitats for ixodid ticks and a corresponding increase in their numbers.

**Keywords:** Stavropol, Insects, Climate change, Parasites

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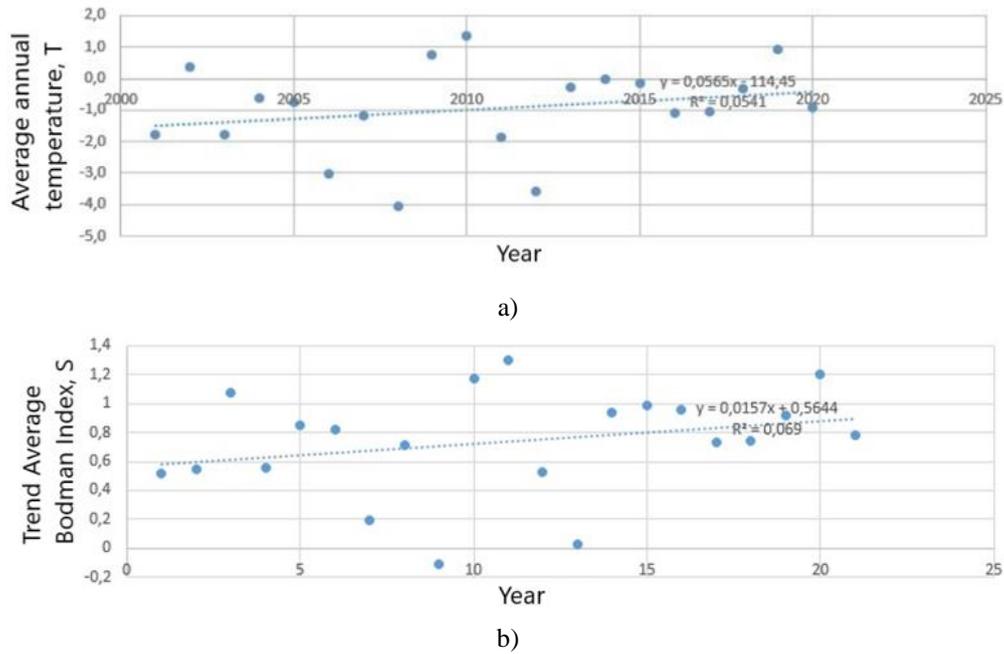
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### Introduction

The Stavropol region is situated in the southern part of Russia, between 43°45' and 46°15' north latitude and 40°50' and 45°40' east longitude. It includes the central section of the Pre-Caucasus, the western Caspian lowlands, and part of the northern slopes of the Greater Caucasus near the Caucasian Mineral Waters [1, 2]. The terrain is characterized by flatlands and foothills, with much of the flat area consisting of the Stavropol upland, parts of the Azov-Kuban lowland, the Kumo-Manych depression (at 20 meters above sea level), and the Caspian lowland [3]. These geographical features and climate create ideal conditions for the development of livestock farming, particularly dairy and beef cattle, and fine-wool sheep. However, one of the major challenges impacting animal husbandry in the region is the infestation of livestock by ixodid ticks, which serve as vectors for various blood parasitic diseases such as piroplasmosis, teileriosis, and anaplasmosis [4].

Temperature and precipitation at the Earth's surface are key climatic factors used to characterize landscapes and serve as indicators of climate change [5]. Experts have noted that the global surface temperature has risen by  $0.6 \pm 0.2$  °C over the past century [6]. This shift in climate has been linked to changes in both ecological and human-driven systems, such as agriculture [7]. Rising temperatures may lead to shifts in climatic zones and an overall increase in average temperature [8]. Additionally, the Stavropol region has experienced a significant warming trend during the winter months (**Figure 1**).

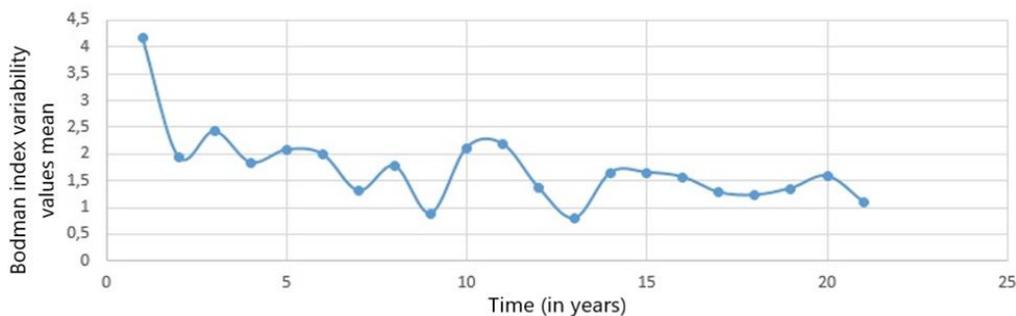


**Figure 1.** Fourier analysis (2001-2020): a) trend of the mean annual temperature, and b) average trend of the Bodman index.

Research has indicated that from 2001 to 2016, the average winter temperature rose by 0.9 degrees Celsius in the northern part of the region, 0.7 °C in Kislovodsk, and 1.1 °C in Stavropol compared to the 1961-2000 period. This upward trend continued through 2017-2020 [9]. Additionally, a significant increase in temperature was observed during the warm season, leading to the necessity for the agricultural sector to implement strategies to adjust crop production to the evolving climate conditions [10].

Some researchers suggest that warming is evident across the entire region, and certain landscapes may now fit into different climate zones based on the moisture conditions, which depend on the ratio of heat and moisture supply [11]. This hypothesis has been supported by subsequent investigations of the Stavropol climate. As the climate continues to change, with both temperature and precipitation rising simultaneously, these shifts are particularly important for dry-steppe ecosystems [12].

In the 21st century, the average start of spring in the Central Caucasus region occurs on February 16, ranging from February 11 in Novoaleksandrovsk to February 25 in Kislovodsk. Throughout the 2000s, the first consistent transition of the daily average temperature above 0 °C happened four times in January, seven times in February, and nine times in March. The earliest spring onset was recorded in 2013 on January 19, and the latest on March 16, 2012, a phenomenon that aligns with global warming trends. While the warming effect is most noticeable in the northern regions, many scientists argue that the primary contributor to the rise in average yearly temperatures in both middle and southern latitudes is the increase in winter temperatures [13].



**Figure 2.** Variability spectrum of the Bodman index.

The evaluation of bioclimatic conditions using the Bodman index, moisture coefficient, and other indices derived from standard climatic parameters will help to identify the connection between climate, landscape characteristics, and the distribution of ixodid ticks (**Figure 2**) [14]. This study examines the impact of climate change on the diversity of ixodid tick species.

### Materials and Methods

Since 1999, ongoing monitoring of ixodid ticks in the Stavropol region has revealed a trend of expanding species diversity, which correlates with conditions that are becoming more conducive to the spread of blood parasitic diseases [15, 16].

The foundation of the research consists of meteorological data collected over the last two decades by the ground network of the Stavropol Center for Hydrometeorology and Environmental Monitoring. Supplementary reference data on temperature patterns and wind speeds at the station's location during two extended periods of the 20th century were also incorporated.

For the research conducted at the Kislovodsk weather station, the following factors were assessed:

- The average temperature during the winter months
- The typical wind speed in winter
- The changes and overall trend of the Bodman index in the Kislovodsk resort reflects the climate's harshness.

To study the ixodofauna, four regions in the zone of sufficient moisture were surveyed: Mineralovodsk, Predgornyy, Georgievsk, and Kirovsk districts, as well as the species composition of ixodid ticks in Kislovodsk. Tick samples were gathered using a standard flag, a light-colored flannel cloth measuring 1 meter in length and 0.6–0.7 meters in width, as well as through direct collection from animals. The tick sampling took place between March and May, July, and August to October from 2016 to 2022. The identification of ixodid ticks was conducted in the veterinary laboratory of the All-Russian Research Institute of Sheep and Goat Breeding, a division of the North Caucasus Federal Scientific Agrarian Center, using a binocular microscope (MBS-2) and following the guidelines for monitoring ixodid ticks in the Stavropol region [17].

### Results and Discussion

In the Stavropol region, sixteen species of ixodid ticks from 6 genera have been found to parasitize [18]. These ticks are highly specialized parasites of terrestrial vertebrates, particularly birds and mammals [19, 20]. The epidemiological and epizootological importance of ixodid ticks lies in their role in transmitting pathogens responsible for a variety of serious vector-borne diseases to both humans and animals, including bacteria, rickettsiae, viruses, protozoa, and spirochaetes [21].

The spread of ixodid tick species is primarily determined by the climatic zones. The region includes four agricultural zones: extremely arid, arid, a zone of unstable moisture, and a zone with adequate moisture [9, 22]. The adequate moisture zone, encompassing the Mineralovodsk, Predgornyy, Georgievsk, and Kirovsk districts, lies across the foothill plains of the Caucasus. The climatic conditions in this zone resemble those of the forest steppe, where the evaporation rate is almost equal to the precipitation, allowing for the evaporation of 500–700 mm of water. The humidity coefficient in this area ranges from 0.7 to 1.0. Winter in the sufficient moisture zone generally starts in late November or December and concludes in early March.

The ixodofauna of this region from 2016 to 2022 is detailed in **Table 1**. An upward trend in the number of ixodid species is evident. In the period from 1999 to 2006, the ixodofauna in these areas consisted of 6 species from 5 genera, whereas by 2016–2022, 12 species from 6 genera were identified. In 2022, Kislovodsk itself saw the presence of 9 species from 5 genera (*Hyalomma*, *Dermacentor*, *Rhipicephalus*, *Ixodes ricinus*, and *Haemaphysalis*) within its biotope.

**Table 1.** Comparison of Ixodofauna in the zone of sufficient humidification of the Stavropol Territory for the periods 1999–2006 and 2016–2022

DISTRICTS	TYPE OF TICKS	
	1999 -2006	2016-2022

Mineralovodsk district	Boophilus calcaratus (annulatus)	Boophilus calcaratus (annulatus)
	Hyalomma marginatum	Hyalomma marginatum
	Dermacentor marginatus	Dermacentor marginatus
	Dermacentor pictus	Dermacentor pictus
	Rhipicephalus sanguineus	Rhipicephalus sanguineus
	Ixodes ricinus	Ixodes ricinus
Predgornyy district		Hyalomma marginatum
	Hyalomma marginatum	Hyalomma anatolicum
	Dermacentor marginatus	Dermacentor marginatus
		Dermacentor pictus
		Dermacentor daghestanicus
Georgievsk district		Boophilus calcaratus (annulatus)
		Hyalomma marginatum
		Hyalomma scupense
		Hyalomma anatolicum
	Boophilus calcaratus (annulatus)	Hyalomma detritum
	Hyalomma marginatum	Dermacentor marginatus
	Dermacentor marginatus	Dermacentor pictus
		Dermacentor daghestanicus
		Rhipicephalus sanguineus
		Rhipicephalus turanicus
	Ixodes ricinus	
Kirovsk district		Boophilus calcaratus (annulatus)
	Boophilus calcaratus (annulatus)	Hyalomma marginatum
	Hyalomma marginatum	Hyalomma anatolicum
	Dermacentor marginatus	Dermacentor marginatus
	Ixodes ricinus	Dermacentor pictus
	Ixodes ricinus	
Kislovodsk city		Hyalomma marginatum
	Hyalomma marginatum	Hyalomma scupense
	Dermacentor marginatus	Hyalomma anatolicum
	Dermacentor pictus	Dermacentor marginatus
	Ixodes ricinus	Dermacentor pictus
		Dermacentor daghestanicus
		Rhipicephalus sanguineus
	Ixodes ricinus	
	Haemaphysalis punctate	

One possible factor behind the widespread distribution of ixodid ticks is the rise in average winter temperatures, which supports the expansion and proliferation of biotopes conducive to ixodid hatching.

## Conclusion

The data analysis indicated that frosts are common in both the autumn and spring seasons in Kislovodsk and throughout the region. A frosty day is defined as one where the minimum air temperature falls below 0 °C on at least one occasion, but the average daily temperature stays positive. The last frost in spring marks the beginning of the frost-free period, while the first frost in autumn marks its end. Despite the general trend of warming temperatures, the frost-free period in the region is expected to lengthen. However, due to increasing climate instability, there could still be late spring frosts and early autumn frosts, which might reduce the overall frost-free period.

Over the past five decades, the growing season for natural vegetation and crops in the northern hemisphere has lengthened by approximately 1 to 4 days per decade, particularly in higher latitudes. The range of plant growth and animal habitats has shifted poleward and to higher elevations. There has been an earlier onset of flowering, bird arrivals, and insect appearances. Additionally, average annual temperatures in the region have risen, primarily due to warming during the colder months. Despite this overall warming trend, some months during the warmer period show a tendency for cooling across most landscape zones.

Research indicates that the ongoing climate warming in the region has led to a reduction in the intensity of bioclimatic conditions, particularly during the winter. This change has contributed to the expansion and growth of biotopes favorable for ixodid ticks.

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**Conflict of Interest:** None

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**Ethics Statement:** None

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