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Research article

A CONCEPTUAL SCHEME OF A PREDICTIVE-ANALYTICAL MODEL FOR DESCRIBING INCIDENCE OF WEST NILE FEVER BASED ON WEATHER AND CLIMATE ESTIMATION (EXEMPLIFIED BY THE VOLGOGRAD REGION)

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The present study focuses on weather and climatic factors influencing the incidence of West Nile fever (WNF) in the Volgograd region. We aimed to describe a relationship between these factors and the WNF incidence and to create a conceptual scheme of a predictive-analytical model for making forecasts how an epidemiological situation would develop in future.

According to this aim, we selected an approach that involved identifying a statistical correlation between the analyzed factors and the WNF incidence in the Volgograd region and estimating the power of this correlation. The study primarily relied on using correlation analysis that was followed by assessing authenticity of the study results. The obtained data made it possible to establish that air temperature was a leading potentiating factor in the Volgograd region. It produced certain effects that varied in their intensity on a whole set of abiotic and biotic factors (water level and temperature, numbers and activity of vectors, how fast the virus amplifies in vectors, etc.).

The study established that use of comprehensive statistical data (average monthly indicators) allowed more precise estimation of correlations. We also considered and confirmed a hypothesis about a delayed effect produced by air temperature on population incidence and numbers of West Nile virus vectors in the Volgograd region; it was the most apparent in years with the maximum numbers of infected people (1999, 2010, and 2012). We revealed a statistical correlation between air temperature and average annual water level and the WNF incidence among population and the number of West Nile virus vectors. There was a strong correlation between the number of vectors and the WNF incidence. A conceptual scheme of a predictive model for determining rate of the WHF incidence in Volgograd region was created based on the statistical analysis results.

Keywords: *West Nile fever, West Nile virus, epidemic situation, predictive-analytical model, factor estimation, weather and climatic peculiarities, correlation analysis, WN virus vectors, Volgograd region.*

West Nile fever (WNF) is an acute transmissible natural focal arboviral disease. Its clinical picture usually involves fever and intoxication; in more severe cases, the disease can affect the central nervous system with appearing meningitis- or encephalitis-like symptoms.

West Nile virus (WNV) is the infectious agent that causes the disease. It belongs to *Flaviviridae* family, *Flavivirus* genus [1]. Mosquitos from *Culex* genus are its primary vectors but the virus can also be carried by mosquitos from *Aedes*, *Coquillettidia*, *Cu-*

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liseta, *Uranotaenia* genus and ticks from *Ixodes*, *Hyalomma*, *Dermacentor* genus [2–4]. The virus is predominantly transmitted by an infected mosquito's bite. Still, there have been some cases when WNV has been transmitted from a mother to a fetus through the placenta, with breast milk as well as by artificial transmission [5–7].

WNF has become a growing concern for public healthcare over the last decades due to its growing nosoarea, occurring outbreaks with severe clinical course and absence of any specific treatment or prevention procedures.

Since WNV was first identified in Uganda in 1937, its nosoarea has grown drastically. At present, WNF incidence is detected in America, Africa, South Asia, Western Pacific region and Europe, the Russian Federation included.

WNF is widely spread in America. Disease cases (between 700 and 3000) are registered annually in more than 48 states in the USA. Most infection cases are neuro-invasive[1].

WNF incidence is registered in 22 European countries; 4218 infected people were identified over 2010–2020. In Russia, the disease has been registered in 30 regions and markers of the infectious agent have been identified in 62 regions [8].

In the Volgograd region, WNF cases have been registered since 1999 and their total number accounts for 44 % of all the cases registered in Russia. WNF incidence is identified in most districts in the region (its maximum rates are detected in Volgograd and Volzhskiy). Given that, it is quite a vital trend in epidemiological studies to identify major factors that have their influence on the WNF incidence in the Volgograd region as well as to examine correlations between them. Data obtained by using tools of statistical and mathematical analysis can provide certain grounds for creating predictive-analytical models. Such models make it possible to estimate how an epidemiological situation as regards WNF would develop in future.

Many researchers believe that it is rather difficult to model and predict outbreaks of transmissible diseases comprising WNF. The major obstacles include complicated transmission mechanisms that involve interactions between an infectious agent, vector and a susceptible host and we should also remember that the whole complex is influenced by variable external factors.

Building up dynamic time series is a common approach applied to model an epidemic process of arboviral diseases. Within this approach, incidence among population is considered a function of delayed environmental indicators [9–11]. An advantage this statistical approach has against imitation models is its relative simplicity. Models can be easily parameterized by using dynamic time series of epidemiological data and data on the environment. However, a major limitation of such models is that they rely on linear approximations for non-linear systems and this leads to multiple simplifying assumptions. In other words, data on external factors are sufficient for calculating a risk of transmission but certain significant effects can be produced by other non-environmental phenomena (for example, after several years when WNF has been intensively transmitted in bird populations, they may develop immunity to it and this, in its turn, can potentially limit WNF transmission [12]). To describe these effects, it is necessary to apply complex non-linear mathematical functions. Nevertheless, a complex approach should be implemented to examine such relationships; it can only be developed after all the factors that influence the intensity of a given epidemiological process have been investigated by using primary tools of statistical analysis, correlation one included.

According to the existing insight into regularities of an epidemic process typical for arboviral infections, it is primarily influenced by nature and climatic factors (air temperature, precipitations, a water level in natural basins and a number of vectors). These factors are typically considered in attempts to predict how an epidemiological situation would develop. In

[1] West Nile virus. Final Cumulative Maps & Data for 1999–2019. *Centers for Disease Control and Prevention*, 2020. Available at: https://www.cdc.gov/westnile/statsmaps/cumMapsData.html (April 14, 2022).

addition, some ecological (air humidity) and social factors (changes in a landscape due to wider use of land, disinsection procedures, local infrastructural peculiarities on a given territory, national habits, etc.) can produce certain effects on transmission of an infectious agent and, consequently, on incidence [13, 14]. Besides, such demographic indicators as infected people's age and sex are potentially connected with severity of an infection and its detectability and can thereby determine intensity of an epidemic process. It is noteworthy that when predictive-analytical models are created, it is important to describe and estimate effects produced by these factors. But, as a rule, such descriptions and estimations require profound mathematical analysis since the analyzed indicators are heterogeneous and can be both quantitative and qualitative. Given that, these groups of indicators have not been given any attention at this stage in our research and have not been analyzed or included into the concept of the model being developed in this study.

To create models for assessing risks of infectious agent transmission (WNF included) it is most common to use retrospective and operative climatic and / or meteorological indicators. However, such a dataset does not always give an opportunity to reliably predict probable time and localization of potential outbreaks [15].

Time invariance is another difficulty in developing such predictive models. Use of time series in analysis is based on an assumption that delayed effects produced by environmental factors on a risk of infection are static (for example, last month precipitations correlate positively with a today risk) and do not change over time (for example, last month precipitations can have a positive correlation with a risk in July but a negative one with a risk in August). The outlined problem concerns WNF as well due to impacts exerted by multiple environmental factors on numbers of the primary vectors, their activity and infection rate and, consequently, on incidence. Certain approaches applied by researchers to predict how an epidemiological situation with WNF would develop were described in one of our previous studies [16].

In this study, our aim was to describe a relationship between natural, climatic and ecological factors and the WNF incidence in the Volgograd region and to create a conceptual scheme of a predictive-analytical model for making forecasts how an epidemiological situation would develop in future.

Materials and methods. We chose an approach that involved identifying statistical correlations between a set of factors and the WNF incidence in the Volgograd region and estimating their intensity. This region of the Russian Federation was selected due to high representativeness of the provided data, which was associated with the infection being registered in the region for a long period and its greatest rates in the Russian Federation (44.0 % of the total number of the cases registered in the country). To achieve our aim, we applied correlation analysis (linear regression was used in all cases) with the subsequent estimation of the obtained results. It is noteworthy, that correlation analysis is a statistical tool and is widely used both in Russian and foreign studies. Results obtained by correlation analysis make it possible to examine correlations between factors by applying proper mathematical procedures at the next stage in the present research.

We selected some factors that could possibly influence WNF transmission, namely, air temperature, the number of vectors and a water level detected at hydrological posts. Given that, we took the following retrospective data:

1) average winter, average summer and average annual temperatures and WNF cases over the period 1999–2019;

2) average annual and average seasonal (spring-autumn period between April and October) numbers of vectors (mosquitoes *Culex spp.*) over the period 1999–2018, average annual water levels and water temperature detected at hydrological posts in Volgograd and the urban settlement of Srednyaya Akhtuba over the period 2001–2017 (we were not able to find data on a longer period in available information sources);

3) average monthly air temperatures and numbers of vectors as well as monthly air temperatures in 1999, 2010, and 2012 (these

years were selected due to a combination of high average seasonal air temperatures and the greatest number of WNF cases registered in the Volgograd region in them).

We performed correlation analysis of effects produced by variable factors on the WNF incidence using Microsoft Excel 2016 16.0.13628.20128 (Microsoft, USA). We applied a free-access JASP software package, version 0.14.1 (The University of Amsterdam, Netherlands) to determine how the analyzed indicators were distributed and to estimate statistical significance.

To determine whether an identified correlation was statistically authentic, we compared the obtained values with critical values of Pearson's rank correlation coefficients (*p*) with statistical significance taken as equal to 0.05.

Prior to the analysis, we checked whether all the data conformed to the normal distribution by using Kolmogorov – Smirnov test. As a result, we established that values of all the analyzed factors were distributed normally; therefore, the further analysis involved calculating Pearson's correlation coefficients.

Results and discussion. We performed multi-factor correlation analysis aiming to identify priority groups of indicators for further investigation. Data used in the analysis included average annual air temperatures, water levels detected at hydrological posts in Volgograd and Srednyaya Akhtuba, numbers of vectors as well as the WNF incidence over the period 2001–2017. Table 1 provides the results.

The obtained values of the correlation coefficient for an annual average air temperature indicate there is a strong correlation between this factor and the WNF incidence. At the same time, correlations between water levels and numbers of vectors were either weak or even very weak.

Therefore, given these results, we can assume that the air temperature is a factor with the most significant influence on the WNF incidence in the Volgograd region. This might be due to effects produced by air temperatures on several other factors such as a development rate, a growth in quantity, activity and infection rate of primary WNV vectors in natural and anthropogenic infection foci as well as levels to which natural and artificial basins heat up; the latter is significant since such basins are major places for mosquito reproduction.

However, use of averaged data in correlation analysis does not fully allow estimating influence produced by each separate factor. Given that, the further analysis with different datasets was performed for each analyzed factor separately.

Estimating intensity of the correlation between air temperature and the WNF incidence. Having estimated influence exerted by average winter (December-February) and average summer (June-August) temperatures on the WNF incidence, we established that the value *R* was negative (-0.094 (p = 0684)) for average winter temperatures. This indicates there is no statistically significant correlation in this case. At the same time, the correlation coefficient value equaled 0.631 ($p = 0.002$) for average summer temperatures and this means there is an average correlation with quite high reliability (Figure 1).

We cannot state that average winter temperatures have zero influence on the WNF incidence in the Volgograd region since they produce certain effects on survival rates of primary vectors. Thus, favorable conditions for mosquito larvae to survive a winter season can persist in basements where air temperatures are higher than outside. In addition, there are data in literature indicating that some mosquito species are able to survive the winter in places of their natural reproduction at temperatures below -10 °C [17]. Given the aforementioned and based on average monthly temperatures in January, February and December and the WNF incidence in the Volgograd region in 1999, 2010, and 2012, we established that average temperatures in February and December had a strong correlation with the WNF incidence (*R* equaled 0.809 for February, $p = 0.4$; 0.824 for December, $p = 0.384$) whereas an average air temperature in January in the same years had only a weak correlation with the WNF incidence ($R = 0.125$, $p = 0.92$). Overall, it is necessary to examine influence exerted by air temperatures in winter on the incidence and number of vectors in greater detail.

For further analysis, we also chose years with the highest WNF incidence and months

Table 1

Results of multi-factor correlation analysis

Influence on the WNF incidence	*R*	*p*
Average annual water level (a hydrological post in Volgograd)	0.086	0.744
Average annual water level (a hydrological post in Srednyaya Akhtuba)	0.135	0.606
Average annual air temperature	0.721	0.001
Average annual number of vectors	0.069	0.792

N o t e : *R* is Pearson's correlation coefficient, *p* is statistical significance.

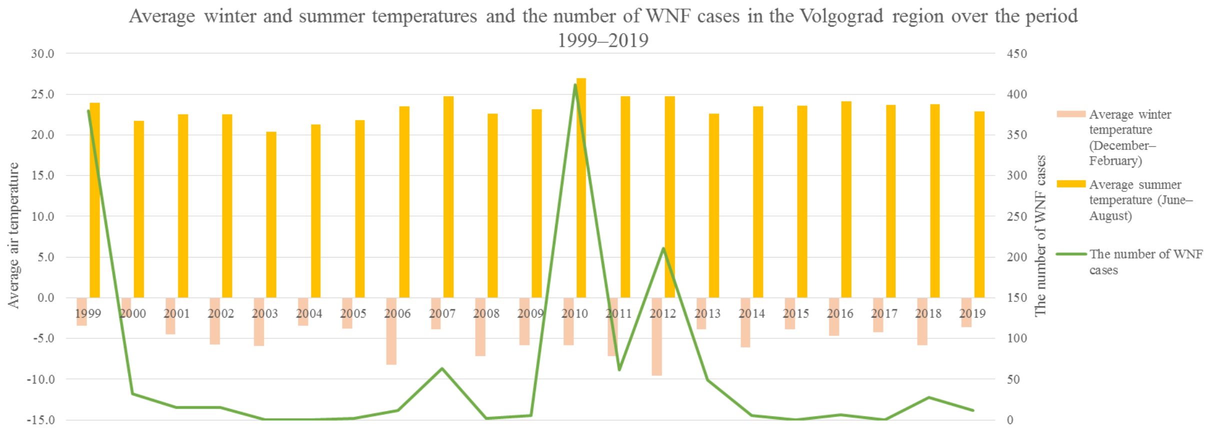


Figure 1. Correlations between average winter and summer temperatures and the WNF incidence

when average air temperatures were above +3...+5 °C thereby helping *Culex* mosquitos, primary WNV vectors, fly away from places where they usually spend the winter [18].

We took data on average monthly air temperatures and registered WNF cases in the Volgograd region over the period between April and October in 1999, 2010 and 2012 and performed correlation analysis; as a result, we established a moderate correlation between these temperatures and the WNF incidence (*R* was within a range between 0.36 and 0.395 (Figure 2A, Table 2)).

Given that the analyzed data were discrete, we considered a hypothesis on a cumulative effect produced by air temperatures on the WNF incidence. In particular, when analyzing time series, we made an assumption that effects produced by temperature on the incidence were delayed, that is, air temperature in the previous month had a positive correlation with the current rate of the WNF incidence. Therefore registered disease cases were shifted one month back along the time scale (Figure 2B). This time delay can be explained, first of all, by a time period necessary for the development cycle of primary vectors to be completed. Thus, according to data available in literature, *Culex pipiens* mosquitos need approximately 30 days under a temperature equals 16 °C for their eggs to develop into the imago stage; if a temperature rises to 24 °C, the full cycle takes approximately 12 days [19]. Second, this delay appears due to a long incubation period (between 3 and 14 days) when a person is infected with the WNF infectious agent.

When correlation analysis was performed considering a time delay (by 12, 21 and 30 days), a correlation became more intense and turned from average to strong and the greatest intensification was detected for the 30-day period (Table 2). Moreover, when we analyzed data within the temperature range between 22 and 29 °C (we considered linear regression), the correlation intensity was very high and became linear with high reliability in 1999 and 2010. In 2012 we detected an insignificant increase in the correlation intensity; this might be due to, among other things, effects produced by other factors during the epidemic season in that year.

The offered hypothesis was extrapolated onto the whole period during which the WNF incidence was registered in the Volgograd region. The delayed effects produced by air

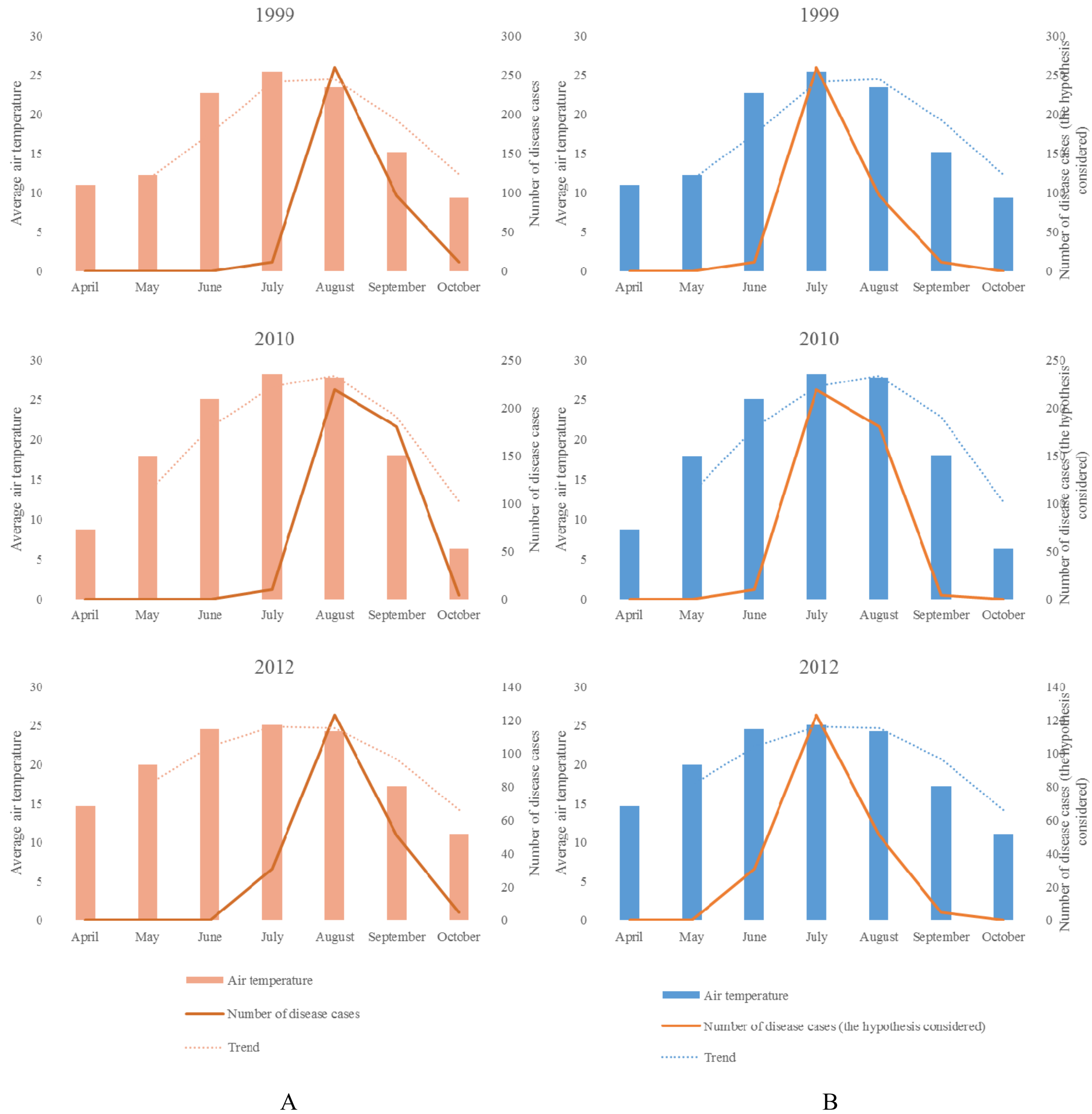


Figure 2. Estimating intensity of correlations between average monthly air temperatures and the WNF: *A* shows average monthly temperatures and the WNF incidence in 1999, 2010, and 2012; *B* shows average monthly temperatures and the WNF incidence (with all the values being shifted 1 month backward) in 1999, 2010, and 2012

Table 2

Results of correlation analysis with its focus on correlations between average monthly temperatures and the WNF incidence

Year	R (p)	R_c (p)	R_d (p)
1999	0.386 (0.393)	0.735 (0.06)	0.998 (0.037)
2010	0.36 (0.427)	0.724 (0.066)	0.998 (0.037)
2012	0.395 (0.38)	0.713 (0.072)	0.832 (0.375)

Note: R_c is the correlation coefficient with the incidence being shifted by 1 month; R_d is the correlation coefficient with the incidence being shifted by 1 month within a temperature range between 22 and 29 °C; p is significance of a correlation.

temperatures on the WNF incidence were identified in all the observed years: the correlation coefficient varied from 0.599 (2013) to 0.837 (2008); the correlation was linear within the temperature range between 22 and 29 °C in those years when the registered WNF incidence was higher than its long-term average rate. Nevertheless, absence of a linear correlation in the remaining years requires exploring a set of factors that mitigate risks of infection.

According to the results, the hypothesis was confirmed for the Volgograd region that air temperatures higher than 22 °C in the current month increase a risk that the WNF incidence would grow next month.

Estimating intensity of a correlation between air temperatures and the number of vectors. Correlation analysis that relied on average annual values of these two indicators over the period 1999–2018 became the first stage in estimating a correlation between air temperatures and the number of vectors (Figure 3).

As a result, we established an authentic absence of statistically significant correlations between the analyzed factors ($R = -0.153$, $p = 0.52$).

Further correlation analysis was performed using data on average monthly temperatures in winter and spring-autumn periods as well as average monthly numbers of vectors in 1999, 2010, and 2012.

Having analyzed average monthly temperatures in January, February and December in 1999, 2010, and 2012 and the average annual number of vectors, we established a very strong correlation between the analyzed factors In January and February as well as absence of any statistically significant correlation between an average monthly temperature and the average annual number of vectors in December in the aforementioned years. The obtained results had high statistical authenticity in all the analyzed cases (Table 3).

We analyzed average monthly ait temperatures and average monthly numbers of vectors in 1999, 2010, and 2012 (Figure 4A, Table 4). The resulting values of the correlation coefficient indicated that the correlation intensity varied between average and strong with high statistical authenticity.

In our further analysis of time series, we considered a hypothesis that average monthly air temperatures had a cumulative effect on the number of WNF vectors in the Volgograd region.

Bearing in mind some specific features of primary vectors' life cycle and the incubation period typical for WNF infection (both were considered in the previous section), we assumed that an air temperature that was observed last month would have a positive correlation with the number of WNF vectors in the current month. To confirm the hypothesis, we shifted monthly numbers of mosquitos in 1999, 2010 and 2012 one month back on the time scale (Figure 4B). In this case the results obtained by correlation analysis with linear regression taken into account established that the analyzed correlation was very strong (Table 4). Having analyzed data within the temperature range above 22 °C, we established that the calculated values had lower statistical significance. This might be due to an

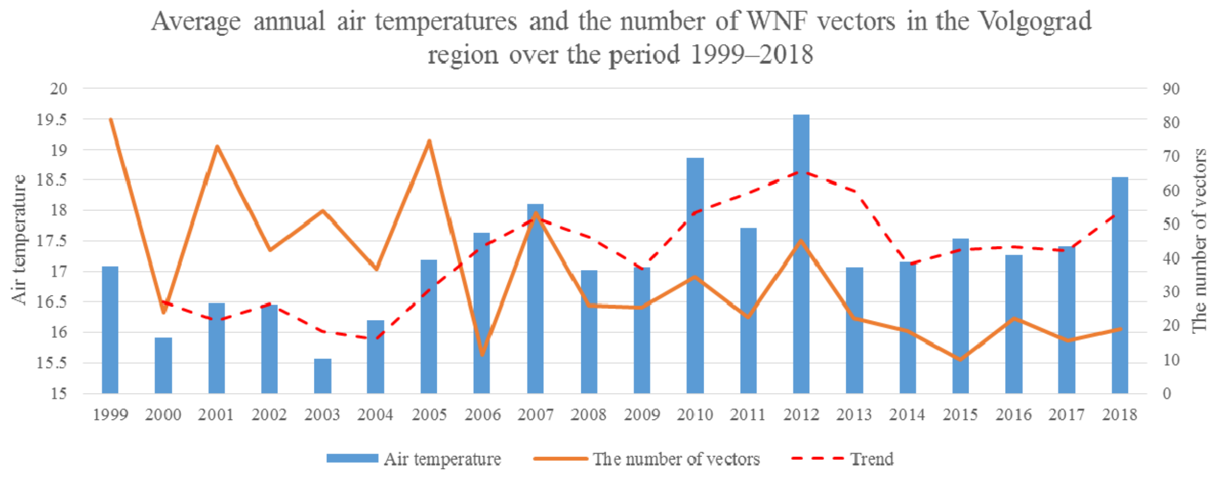


Figure 3. Estimating intensity of a correlation between air temperatures and the average annual number of WNF vectors in the Volgograd region

Table 3

The results of correlation analysis with its focus on average monthly temperatures and the average annual number of vectors

Months	*R*	*p*
January	0.9995	0.019
February	0.706	0.501
December	-0.434	0.714

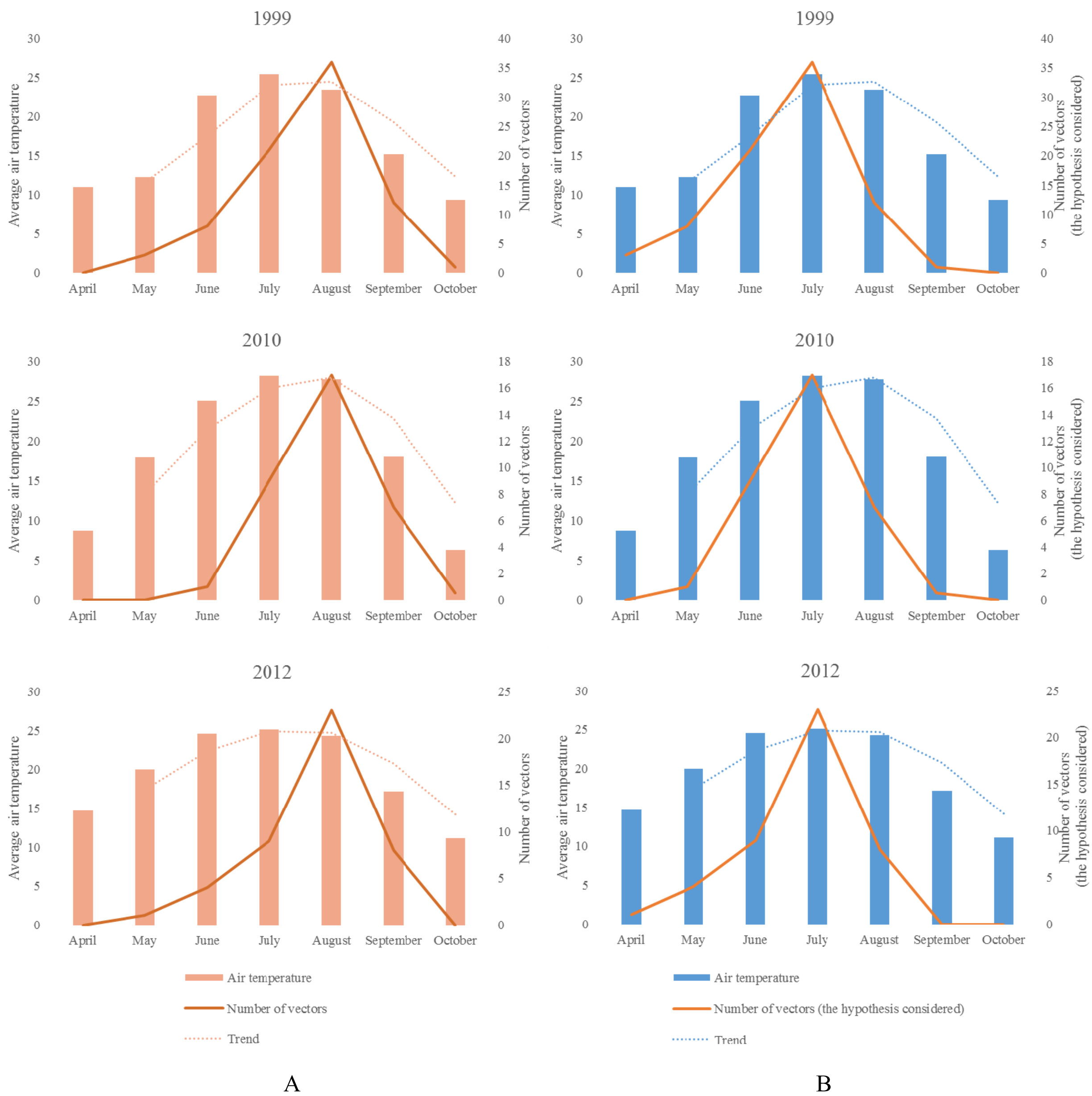


Figure 4. Estimating intensity of the correlation between average monthly air temperatures and the number of WNF vectors in the Volgograd region: *A* shows average monthly air temperatures and the number of WNF vectors in 1999, 2010, and 2012; *B* shows average monthly air temperatures and the number of WNF vectors (with the values being shifted 1 month backward) in 1999, 2010, and 2012

Table 4

The results of correlation analysis with its focus on average monthly temperatures and the number of WNF vectors

Year	*R (p)*	*Rc (p)*	*Rd (p)*
1999	0.784 (0.037)	0.844 (0.017)	0.789 (0.421)
2010	0.672 (0.098)	0.807 (0.028)	0.437 (0.712)
2012	0.596 (0.158)	0.771 (0.042)	0.949 (0.204)

Note: R_c is the correlation coefficient with a 1-month shift of the number of vectors; R_d is the correlation coefficient with a 1-month shift of the number of vectors within the temperature range above 22 °C; *p* is statistical significance of a correlation.

increase in the number of vectors in previous months (April – June).

Therefore, the results obtained by the accomplished analysis are highly reliable and indicate that the hypothesis is true for the Volgograd region: air temperatures higher than 22 °C in the current month have certain effects on an increase in the number of primary WNF vectors in the following month. Influence exerted by air temperatures on the growing number of WNF vectors occurs in a period between April and June when an average monthly air temperature is below 22 °C. This indicates that a threshold temperature level necessary for mosquito populations to grow is lower than a level required for a growth in the WNF incidence. Given that, we examined research articles that addressed a correlation between an air temperature and WNV accumulation as a factor determining the infection rate in vectors.

Estimating intensity of a correlation between air temperatures and the rate of virus accumulation in vectors (based on data available in literature). According to various research data, an air temperature is a basic factor for virus accumulation in vectors. The lowest temperature for the virus development in a mosquito equals +14 °C. A growing temperature makes for faster virus accumulation. Thus, if a temperature equals +14 °C, the quantity of viruses necessary to infect a human is accumulated in 58 days; +18 °C, in 22 days; +23.5 °C, in 15 days; +30 °C, in 11 days [20] (Figure 5A).

We estimated how intense a correlation was between an air temperature and infection rate in vectors; estimations were based on data available in literature. This analysis made it possible to establish an average correlation (within its upper limits). The obtained results were highly reliable (Table 5).

Within further analysis, we excluded air temperatures below +14 °C since it takes the virus about two months to accumulate in a mosquito under such a temperature and in most cases it is longer than an average life span of basic WNV vectors (Figure 5B). Besides, temperatures range between +18 and +25 °C is optimal for vectors' activity.

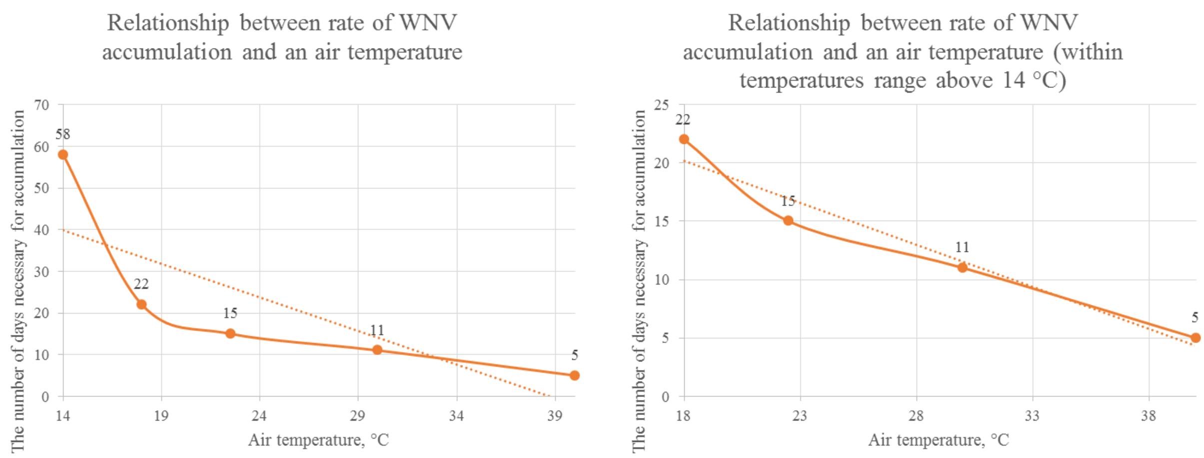
The accomplished correlation analysis (with linear regression) established a string correlation between air temperatures and the rate of WNV accumulation in mosquitos (Table 5).

Therefore, we can assume that if temperatures are above 14 °C, the rate of WNV accumulation in mosquitos will grow; consequently, a risk of infection spread among people will also increase. The higher an air temperature, the higher is a risk of infection. However, more detailed description of this correlation requires further investigation.

Estimating intensity of a correlation between the number of vectors and the WNF incidence. We performed correlation analysis to estimate intensity of a correlation between the number of vectors and the WNF incidence based on average seasonal numbers of mosquitos and data on the annual WNF incidence in the Volgograd region over the period 1999–2018. The analysis revealed a weak correlation and low reliability of the obtained results (Figure 6A).

Further analysis employed data on average seasonal numbers of vectors and the WNF incidence in 1999, 2010, and 2012. The correlation coefficient value indicated the correlation was very weak ($R = 0.081$; $p = 0.948$).

However, despite apparent absence of any correlation between the number of vectors and the WNF incidence, we cannot completely deny its existence since it can be more complicated in its essence and cannot be identified by



A B

Figure 5. Estimating intensity of the correlation between air temperatures and rate of virus accumulation in a mosquito

Table 5

The results of correlation analysis with its focus on the correlation between air temperatures and rate of virus accumulation in a mosquito

Factor	*R*	*p*
Accumulation rate	-0.796	0.107
Accumulation rate within temperatures range above 14 °C	-0.974	0.026

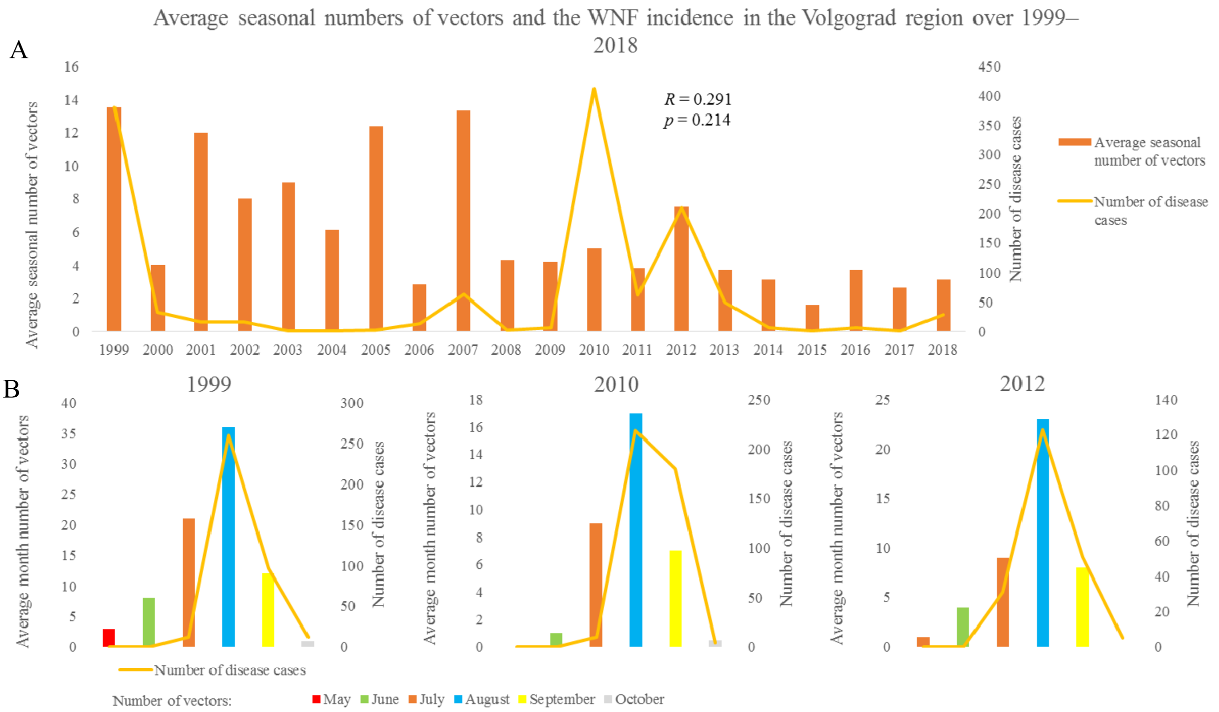


Figure 6. Estimating intensity of the correlation between the number of vectors and the WNF incidence

estimating average seasonal values. Given that, we investigated a correlation between average monthly numbers of mosquitos and monthly WNF incidence in 1999, 2010, and 2012. We established that the correlation intensity varied between high and very high in different years (Figure 6B, Table 6). We should note that this factor made the leading contribution to the WNF incidence rate in 2012.

Given all the obtained data, we can state that the great number of primary vectors increases a risk of people getting infected with WNF in the Volgograd region with high reliability.

Estimating intensity of a correlation between the number of vectors and other natural and climatic factors. Apart from air temperatures, the number of vectors can be influenced by a water level and temperature. Since comprehensive statistical data were not available, we performed our analysis using average annual water levels and temperatures detected at hydrological posts in Volgograd and the urban settlement of Srednyaya Akhtuba over the period 2001–2017 as well as the number of mosquitos in the Volgograd region (Table 7).

The results gave an opportunity to establish a strong correlation between average annual water levels at the hydrological post in Volgograd and average annual numbers of WNF vectors as well as an average correlation between these factors for the hydrological post in Srednyaya Akhtuba. At the same time, average annual water temperatures did not produce any effects on the number of vectors.

Therefore, we can state that an increase in a water level of the Volga River makes for growing numbers of WNF vectors in the Volgograd region. However, more profound examination of correlations between the analyzed factors requires more comprehensive research with wider sets of necessary statistical data.

The conceptual scheme of the predictive-analytical model. Considering all the established correlations between the analyzed factors as well as the offered hypotheses, we developed a conceptual scheme of a predictive-analytical model (Figure 7).

The developed concept requires further mathematical description that would employ various approaches, calculations based on retrospective and operative analytical data as well as estimating predictive value of obtained results.

Conclusion. The performed correlation analysis made it possible to confirm that air temperatures are the most significant factor that influences the WNF incidence in the Volgograd region. Its influence is characterized with combined effects produced on heating of water in natural basins, which are the basic place for WNV vectors' reproduction. This factor also influences the number of mosquito populations, their daily activity and infection rate with WNF infectious agent.

Correlation analysis also allowed us to establish that use of detailed statistical data (such as average monthly air temperatures, average monthly numbers of vectors, etc. against average annual ones) gave an opportunity to

Table 6

The results of correlation analysis with its focus on average monthly numbers of mosquitos and the WNF incidence

Year	*R*	*p*
1999	0.841	0.018
2010	0.811	0.027
2012	0.97	0.001

Table 7

The results of correlation analysis with its focus on the number of vectors, average water levels and average annual water temperatures over the period 2001–2017

Indicators	Hydrological post in Volgograd, *R (p)*	Hydrological post in Srednyaya Ahktuba, *R (p)*
Water level	0.609 (0.009)	0.503 (0.04)
Average annual water temperature	-0.12 (0.645)	-0.172 (0.509)

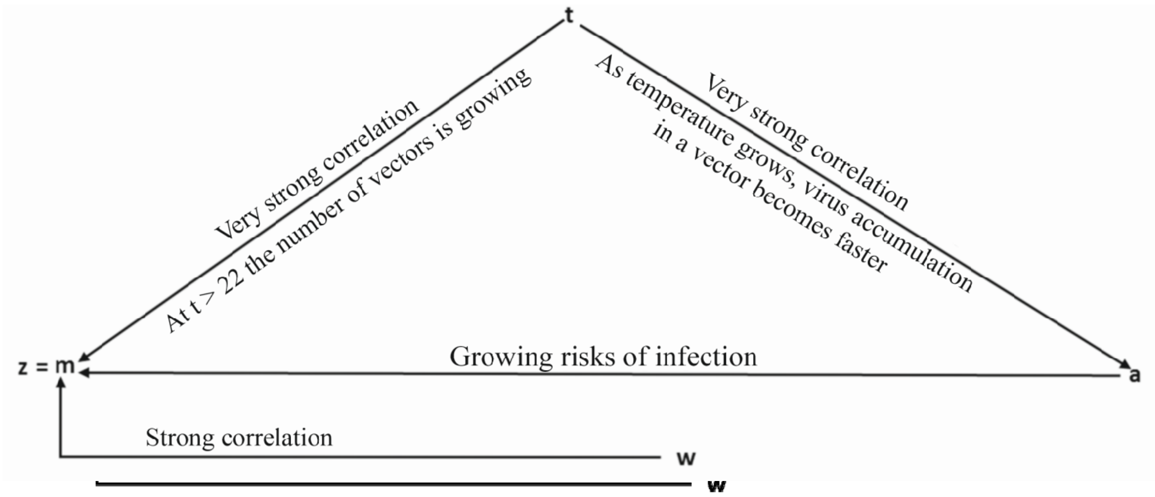


Figure 7. The conceptual scheme of the predictive-analytical model: **z** is the WNF incidence in the current month, **t** is the air temperature in the previous month, **w** is average seasonal water level, **a** is the virus accumulation rate

achieve more precise estimations of correlations between the analyzed factors.

In this study, we were able to confirm the hypothesis on cumulative effects produced by an air temperature on the WNF incidence and the number of WNF vectors in the Volgograd region. These effects were apparent in those years when the WNF incidence rates were the highest (1999, 2010, and 2012).

Also, the study results made it possible to establish correlations between the number of WNF vectors, air temperatures, average annual water level and the WNF incidence; these correlations had different intensity.

Overall, correlations between air temperatures and other factors analyzed in this study are rather complicated since they have different directions (can produce both positive and negative effects on the number of vectors and their natural biotopes); their effects can differ in their intensity, which is determined by existing optimal temperature limits (the number of vectors and infection rate grow faster within them); and influence exerted by air temperatures is delayed over time.

The obtained results gave grounds for developing the conceptual scheme of the predictive-analytical model described above. This model makes it possible to estimate how an epidemiological situation regarding the WNF would develop in the Volgograd region. Our future studies will address mathematical description of the developed scheme together with estimating its predictive value. This will allow achieving more precise forecasts and outlining prospects for this approach to be used in other regions in the Russian Federation.

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