BIOLOGICAL SCIENCES AND EDUCATION IN THE CONTEXT OF EUROPEAN INTEGRATION

SCIENTIFIC MONOGRAPH

2024

СУМСЬКИЙ ДЕРЖАВНИЙ ПЕДАГОГІЧНИЙ УНІВЕРСИТЕТ ІМЕНІ А.С. МАКАРЕНКА

Sumy State Pedagogical University named after A. S. Makarenko

ISMA ANNO1994

ISMA University of Applied Sciences

100 years SPU SUMY PEDAGOGICAL UNIVERSITY 1924 2024

BIOLOGICAL SCIENCES AND EDUCATION IN THE CONTEXT OF EUROPEAN INTEGRATION

Scientific monograph

IZDEVNIECĪBA BALTIJA PUBLISHING

2024

Recommended for printing and distribution via Internet
by the Academic Council of Baltic Research Institute
of Transformation Economic Area Problems according
to the Minutes № 4 dated 30.04.2024

REVIEWERS:

Djakons Romans – Dr.sc.ing., Professor, Academician, President of ISMA University of Applied Sciences;
Lytvynenko Yuliia Ivanivna – Candidate of Biological Sciences, Associate Professor, Head of the Department of Biology and Methods of Teaching Biology, Sumy State Pedagogical University named after A. S. Makarenko;
Genkal Svitlana Eduardivna – Candidate of Pedagogical Sciences, Associate Professor, Associate Professor at the Department of Biology and Methods of Teaching Biology, Sumy State Pedagogical University named after A. S. Makarenko;
Mironets Liudmyla Petrivna – Candidate of Pedagogical Sciences, Associate Professor, Associate Professor at the Department of Biology and Methods of Teaching Biology, Sumy State Pedagogical University named after A. S. Makarenko.

Biological sciences and education in the context of European integration: Scientific monograph. Riga, Latvia : "Baltija Publishing", 2024. 284 p.

ISBN 978-9934-26-443-6

CONTENTS

SCIENTIFIC AND TECHNICAL POTENTIAL OF BIOLOGICAL SCIENCES IN UKRAINE IN THE CONTEXT OF EUROPEAN INTEGRATION

HISTORICAL ASPECTS OF THE DEVELOPMENT OF BIOLOGICAL SCIENCE AND EDUCATION IN EUROPE

01

SECTION

PRIORITY AREAS FOR THE DEVELOPMENT OF BIOLOGICAL SCIENCES IN THE CONTEXT OF EUROPEAN INTEGRATION

Chapter 4

DYNAMICS OF CLIMATIC PREDICTORS OF A POSSIBLE INVASION OF EPIDEMIOLOGICALLY DANGEROUS BLOOD-SUCKING MOSQUITOES (DIPTERA: CULICIDAE) INTO NORTH-WESTERN BLACK SEA COAST AREAS

Rudik V. A., Korzhov Ye. I.
DOI https://doi.org/10.30525/978-9934-26-443-6-4

INTRODUCTION

Blood-sucking mosquitoes of the Culicidae family are one of the numerous and ecologically plastic groups of living organisms. During their evolutionary development, they were able to adapt to highly variable abiotic conditions in their habitats, thanks to which they spread throughout the world[1]. Due to physiological hematophagy, blood-sucking mosquitoes have vector competence for many pathogens (arboviruses, protists, helminths, etc.), due to which they pose a significant threat to public health.

In recent decades, the world has faced an urgent problem of the emergence of known outbreaks and the emergence of new infectious and parasitic diseases, the vectors of which are blood-sucking mosquitoes. The processes of globalization and climate change create new ecological spaces, the conditions of which fit into a wide range of ecological plasticity of some tropical mosquito species. This complex of transformational processes leads to the appearance of vectors exotic for certain territories, and with them dangerous diseases for which there is currently no specific treatment.

The spread of exotic species in Europe is evidenced by the constantly growing list of countries where vector invasion has been detected. Expansion of the boundaries of the ranges of blood-sucking mosquitoes can be carried out both at the expense of their introduction and by natural distribution. Human activity in the ongoing globalization processes, namely mass migration of the population, developed intercontinental transport flows and overpopulated urban coenoses, creates new opportunities for the spread of invasive vectors, which are realized by their transportation over long

[1] Becker N. Life strategies of mosquitoes as an adaptation to their habitats. In: *Bull. Soc. Vector Ecol*. 1989, Vol. 14, Nr. 1, p. 6-25.

distances. Against the background of global climate changes, more favorable conditions for the adaptation of invasive vectors in temperate latitudes arise. The continuous manifestation of vectors in combination with climatic changes in the environment increases the probability of their establishment in new habitats.

Aedes mosquitoes (Meigen, 1818) stand out among invasive mosquitoes. In the last 40 years, five introduced invasive mosquito species of this genus have been registered in Europe: *Aedes aegypti* (Linnaeus, 1762) (origin from Africa), *Aedes albopictus* (Skuse, 1895) (origin from the tropical forests of Southeast Asia), *Aedes atropalpus* (Coquillett, 1902) (origin from North America), *Aedes japonicus* (Theobald, 1901) (origin from East Asia), *Aedes koreicus* (Edwards, 1917) (origin from Northeast Asia). A single case of identification of another species of *Aedes triseriatus* (Say, 1823) (origin from North America) took place in France[2].

Among the listed invasive species, the most common Asian tiger mosquito *Ae. albopictus*, which can transmit 26 viruses [3]. The distribution of this mosquito species poses an epidemiological risk due to its ability to transmit medically difficult arboviruses, including chikungunya (CHIKV), dengue (DENV), Zika (ZIKV), and yellow fever virus. Also the species *Ae. albopictus* is a spreader of malaria and infectiously dangerous filarial nematodes of the genus *Dirofilaria*[4].

Among the species of the Culicidae family indigenous to Ukraine, widespread malaria mosquitoes of the genus *Anopheles* of the subfamily *Anopheles* (Meigen, 1818) pose high epidemiological risks. Cryptic species of the complex are known in the country south *Anopheles maculipennis sensu lato*: *Anopheles atroparvus* (van Thiel, 1927), *Anopheles maculipennis sensu strico* (Meigen, 1818), *Anopheles messeae* (Falleroni, 1926) have a special epidemiological importance as the main specific carriers of malarial plasmodia. It was these vectors of the complex, in the presence of the causative agent in the ecosystem, that supported the epidemic process of three-day malaria caused by *Plasmodium vivax* (Grassi & Feletti, 1890) in

[2] Medlock J. M., Hansford K. M., Schaffner F., Versteirt V., Hendrickx G., Zeller H., & Van Bortel W. 2012. A review of the invasive mosquitoes in Europe: ecology, public health risks, and control options. *Vector borne and zoonotic diseases (Larchmont, N.Y.)*, *12*(6), 435–447. https://doi.org/10.1089/vbz.2011.0814

[3] Paupy C., Delatte H., Bagny L., Corbel V. & Fontenille, D. 2009. Aedes albopictus, an arbovirus vector: from the darkness to the light. *Microbes and infection*, *11*(14-15), 1177–1185. https://doi.org/10.1016/j.micinf.2009.05.005

[4] Cancrini, G., Scaramozzino, P., Gabrielli, S., Di Paolo, M., Toma, L., & Romi, R. 2007. Aedes albopictus and Culex pipiens implicated as natural vectors of Dirofilaria repens in central Italy. *Journal of medical entomology*, 44 (6), 1064–1066. https://doi.org/10.1603/0022-2585(2007)44[1064:aaacpi]2.0.co;2

Ukraine until the middle of the last century[5, 6]. Other available species of the genus *Anopheles*, which are not part of the complex: *Anopheles claviger* (Meigen, 1904), *Anopheles hyrcanus* (Pallas, 1771), *Anopheles plumbeus* (Stephens, 1828) have secondary epidemiological importance as malaria vectors due to ecological features, primarily due to their exophilicity.

In South-Eastern Europe there are representatives of another species: *An. maculipennis s.l.*: *Anopheles labranchiae* (Falleroni, 1926), *Anopheles melanoon* (Hackett, 1934) i *Anopheles sacharovi* (Favre, 1903), and a representative of the subfamily *Cellia* (Theobald) *Anopheles superpictus* (Grassi, 1899)[7]. Caution regarding *An. sacharovi* and *An. superpictus* due to their high tolerance, except for *Pl. vivax*, strains of *Plasmodium falciparum* (Welch, 1897). The presence of these epidemiologically significant malaria mosquitoes in Europe and their geographical proximity to the borders of Ukraine creates high risks regarding their natural and anthropogenic spread to the studied territory. An increase in the species diversity of competent vectors will lead to an increase in the already dangerous vector potential.

In our work, we analyzed the climatic prerequisites for the emergence of epidemiologically dangerous blood-sucking mosquitoes in the Northwestern Black Sea region, in particular mosquitoes of the genera *Aedes* and *Anopheles*. Climate change is also assessed in terms of its impact on the local malaria mosquito fauna and the associated risks of malaria returning to the region.

The conducted research is based on information on individual climate indicators of available observation stations of the North-Western Black Sea region obtained from the relevant regional hydrometeorology centers located within the research region. In general, average daily data of air temperature and precipitation amounts for a multi-year period from eight ground observation stations of the region were analyzed: Odesa (1899-2021), Sarata (1948-2021), Izmail (1946-2021), Vylkove (1951-2021), Mykolaiv (1899-2021), Kherson (1899-2021), Khorly (1951-2021), Henichesk (1899-2021). All observation stations are located within the Black Sea Lowland geographic feature (Fig. 1).

[5] Rudik V. A. Analysis of species composition, distribution and seasonal ratio of malaria mosquitos of northwestern region of Black Sea Coast // Pryrodnychyi Almanakh (biological sciences), 2019. – 26. – P. 157-170. DOI: https://doi.org/10.32999/ksu2524-0838/2019-26-15

[6] Rudik V. The Risk of the Spread of Malaria in Anophelogenous Southern Ukraine Against the Backdrop of Global Climate Change // Fourth Annual BTRP Ukraine Regional One Health Research Symposium (20-24 May 2019). – Kyiv, Ukraine. – P. 193. URL: https://dspace.ksaeu.kherson.ua/handle/123456789/9043

[7] Becker, N., Petric, D., Zgomba, M., Boase, C., Madon, M., Dahl, C., & Kaiser, A. 2010. Mosquitoes and their Control. (2 ed.) Springer. https://doi.org/10.1007/978-3-540-92874-4

Fig. 1. Location of hydrometeorological observation stations within the eastern and western parts of the North-Western Black Sea Coast area

Among the existing land-based hydrometeorological stations that conduct regular monitoring observations, two were chosen as the base (reference) points of research: Odesa and Kherson. They are equidistantly located within the studied territory, have the longest series of observations and characterize the distribution of meteorological values in the eastern and western halves of the North-Western Black Sea Coast (see Fig. 1). Analysis and processing of materials of hydrometeorological observations were carried out according to generally accepted methods[8].

1. Prerequisites for the invasion of blood-sucking mosquitoes tropical species in the research region

The prerequisites for the invasion of tropical species of mosquitoes on the territory of modern Europe began to form at the end of the last – beginning of the current century[9, 10, 11]. At that time, from the moment of the first appearance of the species *Ae. albopictus* in Albania in 1979, then in Italy in

[8] Школьний Є. П., Лоєва І. Д., Гончарова Л. Д. 1999 Обробка та аналіз гідрометеорологічної інформації: підручник (підручник). К.: Міносвіти України, 1999. – 538 с.

[9] Becker N. 2008. Influence of climate change on mosquito development and mosquito-borne diseases in Europe. Parasitol Res 103(Suppl 1): S19–S28

[10] Caminade C., Medlock J.M., Ducheyne E. et al. 2012. Suitability of European climate for the Asian tiger mosquito Aedes albopictus: recent trends and future scenarios. J R Soc Interface. 2012 Oct 7;9(75):2708-17. https://doi:10.1098/rsif.2012.0138

[11] Kraemer M.U., Sinka M.E., Duda K.A. et al. 2015 The global distribution of the arbovirus vectors Aedes aegypti and Ae. albopictus. Elife. 2015 Jun 30;4:e08347. https://doi.org/10.7554/eLife.08347

1990 and France in 1999, tropical invasive species were registered in 20 European countries[2].

With the appearance of the species *Ae. albopictus* at the beginning of the 21st century in Europe, epidemiologists began to record outbreaks of transmissible diseases. Among the most large-scale cases, outbreaks of chikungunya fever in Italy and France, dengue fever in Croatia, Belgium, Germany and others can be highlighted[12].

If the main inducers of the spread of blood-sucking mosquitoes on a global scale are human activity and the adaptation mechanisms of vectors, then among the main predictors of the rooting and further spread of invasive vectors on the territory of Europe, most researchers single out climatic factors, namely the global increase in air temperature and the regional increase in the amount of atmospheric precipitation[11, 12, 13]. In this regard, we, in order to determine the risks of invasion of blood-sucking mosquito species, primarily *Ae. albopictus*, on the territory of the North-Western Black Sea coast and to identify changes in the living conditions for local malaria vectors, the dynamics of these climatic indicators over a long period of time and in the modern period were analyzed.

The first findings of mosquitoes invasive species coincide with the activation of the global warming process in the world, which began in the 80s of the last century and continues at the present time. The transition to a stable phase of climate warming occurs unevenly on a regional scale and is influenced by local weather conditions (proximity to the sea, presence of mountainous landscapes, etc.). As the analysis of data from observations of land-based hydrometeorological stations and posts showed, the course of air temperature within the research region is characterized by a consistent change of warm and cold periods of different durations (Fig. 2).

[12] Рудік В.А. Перші знахідки тропічного виду Aedes Albopictus в межах міста Одеса / Сучасна гідроекологія: місце наукових досліджень у вирішенні актуальних проблем: зб. наук. праць матеріали VI наук.-практ. конф. молодих вчених (Київ, 2023. 10–11 жовтня 2023 р.). Київ: Інститут гідробіології НАН України, 2023. С. 75-77. URL: https:// http://dspace.onu.edu.ua:8080/handle/123456789/36922

[13] Bonizzoni M., Gasperi G., Chen X., James A.A. The invasive mosquito species Aedes albopictus: current knowledge and future perspectives. Trends Parasitol. 2013; 29(9):460–8. https://doi:10.1016/j. pt.2013.07.003

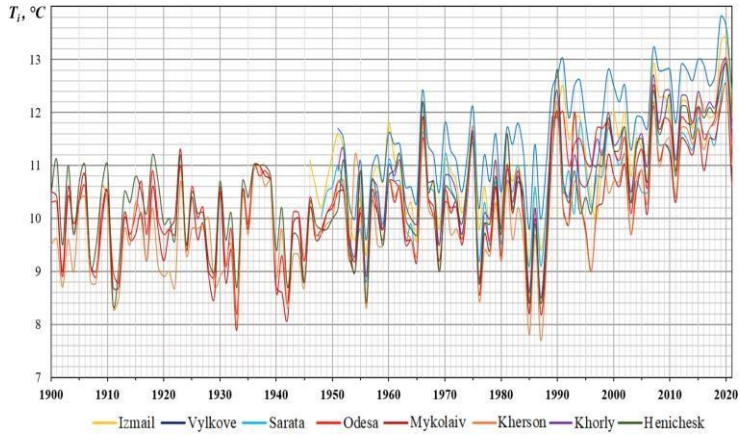

Fig. 2. Dynamics of air temperature at the main observation points within the North-Western Black Sea Coast area

Warm and cold periods have a short-term (2–3 years) and long-term (5–7 years) duration and change on a multi-year scale alternately. The annual temperature series of the main observation stations practically repeat each other, which is confirmed by the rather large positive values of the correlation coefficients between them (Table 1).

Table 1

Matrix of pairwise correlation coefficients of average annual air temperature series within North-Western Black Sea Coast area

Observation points	Odesa	Sarata	Izmail	Vylkove	Mykolaiv	Kherson	Henichesk	Khorly
Odesa	1.00	0.91	0.92	0.95	0.91	0.88	0.91	0.93
Sarata	0.91	1.00	0.91	0.92	0.88	0.84	0.88	0.90
Izmail	0.92	0.91	1.00	0.97	0.89	0.84	0.87	0.88
Vylkov	0.95	0.92	0.97	1.00	0.90	0.83	0.89	0.91
Mykolai	0.91	0.88	0.89	0.90	1.00	0.89	0.93	0.94
Khersor	0.88	0.84	0.84	0.83	0.89	1.00	0.89	0.91
H niche	0.91	0.88	0.87	0.89	0.93	0.89	1.00	0.98
Khorly	0.93	0.90	0.88	0.91	0.94	0.91	0.98	1.00

The close correlation between the series of observations indicates that they belong to one regional climate zone and the homogeneity of the temperature field spatial distribution within the selected research region.

In order to periodize data on atmospheric air temperature in the North-Western Black Sea Coast, we constructed integral curves of annual air temperature deviations (T_i, °C) from normal (T_n, °C) separately for each of the main ground points of the Southern Ukraine hydrometeorological observations network (Fig. 3).

The analys of the data is show that the most clear transition of the average annual values of the air temperature into the phase of steady increase is noted at the Odesa, Mykolaiv, Kherson, Izmail, Sarata, and Vylkove stations. Steady transition to the phase of climate warming according to the integral curves shown in fig. 3 falls on 1988.

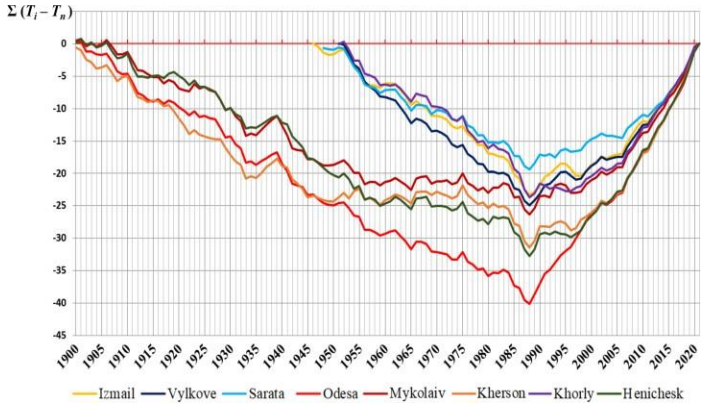

Fig. 3. Integral curves of average annual air temperature deviations from normal at the main observation points within the North-Western Black Sea Coast area

At the Henichesk and Khorly stations, the beginning of the warming period also falls in this year, but the gradients of annual upward changes in air temperature are not clear until the end of the 90s of the last century, which is explained by the influence of local weather conditions and the geographical features of the location of these observation points.

Because of this, it can be considered that the peak year of the temperature regime transition of the research region towards warming is 1988.

Thus, using the method of constructing integral curves based on temperature indicators, we distinguished two climatic periods within the North-Western Black Sea Coast region:

1) the period before climate warming – from the beginning of instrumental observations at a separate point until 1987;

2) the modern (technogenic) period of warming – from 1988 to the present time.

The first period is characterized by the predominance of negative deviations of average annual air temperatures from the long-term average according to data from all hydrometeorological observation stations in the region. The average values of the deviations ranged from –0.29° to –0.66° depending on the location of the individual observation point.

The average values of the annual air temperature in the period before the climate warming in the region were within 9.7-10.3° and in the southernmost observation points (Izmail, Vylkove) reached values of about 11.0° (Table 2).

Table 2

Individual characteristics of the atmospheric air temperature regime periods in the North-Western Black Sea Coast region by main observation points

Observation points	Period before warming			Modern (technogenic) period		
	$\frac{\overline{T}}{T_{mn}\text{-}T_{mx}}$	N, years	$(T_i - \overline{T})_{cp}$	$\frac{\overline{T}}{T_{mn}\text{-}T_{mx}}$	N, years	$(T_i - \overline{T})_{cp}$
Odesa	9.9 8.2- 11.5	89	–0.44	11.5 9.8- 13.0	34	+1.16
Sarata	10.2 8.8- 11.6	40	–0.47	11.2 10.1- 13.0	34	+0.60
Izmail	10.6 9.1- 11.8	42	–0.54	11.8 10.0- 13.4	34	+0.66
Vylkove	11.0 9.6- 12.4	37	–0.66	12.4 11.0- 13.8	34	+0.71
Mykolaiv	9.8 7.9- 11.9	89	–0.29	10.9 9.0- 12.5	34	+0.75
Kherson	9.7 7.7- 11.8	89	–0.34	10.9 9.0- 12.5	34	+0.90
Henichesk	10.1 8.4- 12.2	89	–0.36	11.4 9.5- 12.9	34	+0.93
Khorly	10.3 8.5- 12.2	37	–0.61	11.6 9.7- 12.9	34	+0.66

Note: $\overline{T}$, T_{mn}, T_{mx} – the multi-year average, the lowest and the highest value of the average annual air temperature; N – the length of the period in years

For the modern period of warming, which began in the territory of the North-Western Black Sea in 1988 and continues to the present time, sharp positive deviations of the average annual air temperatures from the average of the multi-year period are characteristic. Their values for individual points are in the range of 0.60-1.16°, which indicates a fairly sharp increase in air temperature in the research region from year to year during the second period. The average values of the annual air temperature in the current period of climate warming are within 11.0–12.0° and above, which in some years can reach 13.8° (see Table 2).

Analyzing the absolute values of average temperature deviations for individual periods, it was established that their values in the current period, which has a duration of 34 years, exceed the same values for the previous one, which was longer in duration (37-89 years). Moreover, according to individual observation stations, temperature deviations from long-term averages in the modern period exceed the values of the previous period by 2.0-2.6 times. Such a rapid increase in air temperature in the modern period is explained by the fact that natural cyclical changes in the temperature regime are now additionally enhanced by anthropogenic influence on the atmosphere. Because of this, the current period of climate warming can also rightly be called technogenic.

2. Analysis of air temperature and precipitation distribution fields over a multi-year period

The homogeneity and close correlation between the series of spatio-temporal distribution of atmospheric air temperature within the North-Western Black Sea Coast region made it possible to single out typical observation points for characterizing the temperature field of the studied area. As mentioned above, the most characteristic for the climate of the western part of the research region is the distribution of meteorological values at the Odesa observation station, for the eastern part – Kherson.

The climate of the North-Western Black Sea Coast, particularly its eastern part, is mostly temperate continental with mild winters, hot summers and relatively long spring and autumn periods. For the western part of the region, located mainly in the coastal zone of the Black Sea Lowland, the climate acquires the characteristics of a moderate maritime climate.

The atmospheric air temperature fields constructed by us demonstrate characteristic changes in the intra-annual distribution of warm and cold periods that have occurred over many years (Fig. 4).

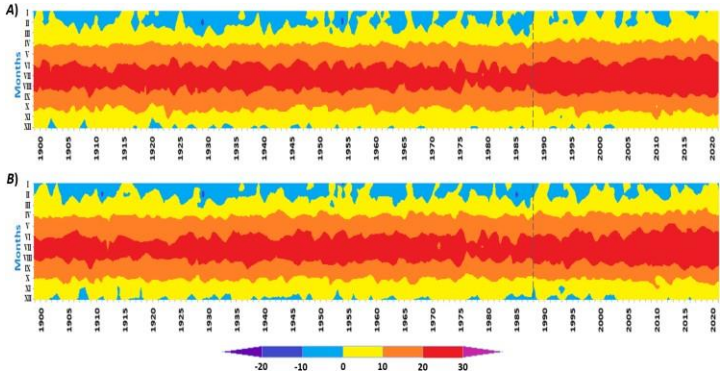

Fig. 4. Fields of air temperature (°*C*) within the limits of the cities of Odesa (*A*) and Kherson (*B*) for the period 1899-2021. The dotted line marks the year of the climate transition to the modern phase of warming within the North-Western Black Sea Coast area

In the modern period of climate warming, the beginning of which can be considered 1988, a sharp reduction in the duration of the cold period and an increase in the warm period became characteristic of the annual distribution of air temperatures. Centers of cold within the North-Western Black Sea Coast shifted from December-January to February-March, or disappeared altogether. Particular attention is drawn to the data of the last decades. Since 2010, meteorological winter was recorded only in 2012 and 2017, in other years it was not observed.

At the current stage of climate change, the decrease in the cold period of the year was compensated by an increase in the warm period. This process is most pronounced for the duration of temperatures with a range above 20° (see Fig. 4). Compared to the years before warming, the duration of this temperature range increased by 1.5–2.6 times. The gradual expansion of the warm period band is proportionally accompanied by the disappearance of cold spots in the cold period of the year for intervals of 2-4 years in a row.

In the distribution of atmospheric precipitation in the studied territory, as the second most important climatic factor affecting the blood-sucking mosquitoes distribution and existence, pronounced changes are also observed (Fig. 5).

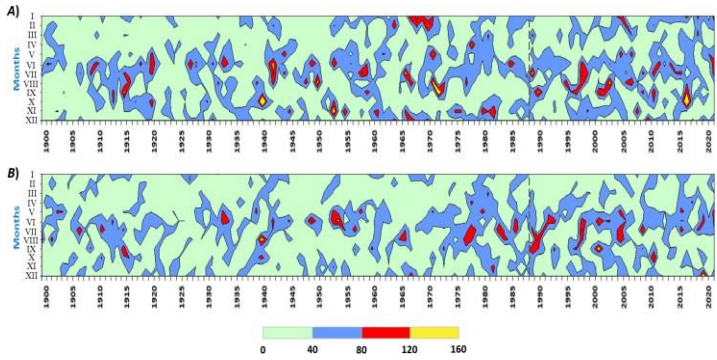

Fig. 5. Fields of atmospheric precipitation amounts (mm/month) within the limits of the cities of Odesa (*A*) and Kherson (*B*) for the period 1899–2021. The dotted line marks the year of the climate transition to the modern phase of warming within the North-Western Black Sea Coast area

In the modern period of climate warming, the total amount of atmospheric precipitation that falls during the year in the studied territory has increased[14, 15]. In the intra-annual distribution, the number of months with the amount of precipitation exceeding 40 mm/month increased.

In the summer period of the year, months with the amount of precipitation of 80 mm/month or more became more frequent. Precipitation became mainly torrential with the greatest intensity in the summer months.

The winter months have become drier with the majority of monthly precipitation amounts below 40 mm. Long winter snow peaks, which in the 70s and 80s exceeded the value of 80 mm/month in intensity, are almost not noted at the present stage.

The shifting of the humidification peaks of the studied territory and the nature of atmospheric precipitation from the winter period to the summer months create extremely favorable ecological and climatic conditions in the

[14] Kutishchev P. S., Korzhov Ye. I., Honcharova O. V. Retrospective analysis and forecast of the main abiotic factors of the environmental conditions of ichtyofauna of the Dnipro-Buh estuary ecosystem / Topical issues of the development of veterinary medicine and breeding technologies: Scientific monograph. Riga, Latvia : «Baltija Publishing», 2022. – Pp. 476-497. DOI: https://doi.org/10.30525/978-9934-26-258-6-14

[15] Коржов Є. І., Гончарова О. В. Формування режиму солоності вод Дніпровсько-Бузької гирлової області під впливом кліматичних змін у сучасний період / Actual problems of natural sciences: modern scientific discussions: Collective monograph. Riga: Izdevniecība «Baltija Publishing», 2020. – P. 315-330. DOI: https://doi.org/10.30525/978-9934-588-45-7.18

region for the invasion, adaptation and subsequent successful spread of tropical mosquito species.

The analysis of the fields of distribution of air temperature and atmospheric precipitation within the North-Western Black Sea Coast region for many years and at the current stage indicates a significant redistribution of climatic factors towards the formation of more favorable conditions for the invasion of epidemiologically dangerous blood-sucking mosquitoes in the studied territory. This is also supported by our findings of the invasive species *Ae. albopictus* in the Odesa region in 2023, which was not observed here until this year[12, 16].

According to the considered climate changes in the territory of the North-Western Black Sea region, the presence of a wide range of conditions and a significant number of suitable breeding places for southern species of malaria mosquitoes, including within the boundaries of megacities, forms the prerequisites for the expansion of their habitats boundaries and creates risks of a possible outbreak and spread of malaria and other epidemiologically dangerous diseases.

3. A general analysis of the most significant climatic factors affecting the distribution of tropical blood-sucking mosquitoes

In order to identify the total influence of the air temperature and atmospheric precipitation regime on the distribution and adaptation of blood-sucking mosquitoes within the North-Western Black Sea Coast, we took two consecutive intervals of equal duration from the periods before the climate warming (1955–1987) and modern (1988–2021), which in general form a continuous series of 66 years (Fig. 6).

[16] Rudik V., Levchenko V. Monitoring of Blood-sucking Mosquitoes by Means of Homemade Electromechanical Light-emitting Diode Traps in Southern Ukraine // 2021 INTERNATIONAL BIOTHREAT REDUCTION SYMPOSIUM. BTRP Ukraine (29 June – 2 July 2021). – Kyiv, Ukraine. – P.216. URL: https://dspace.ksaeu.kherson.ua/handle/123456789/9044

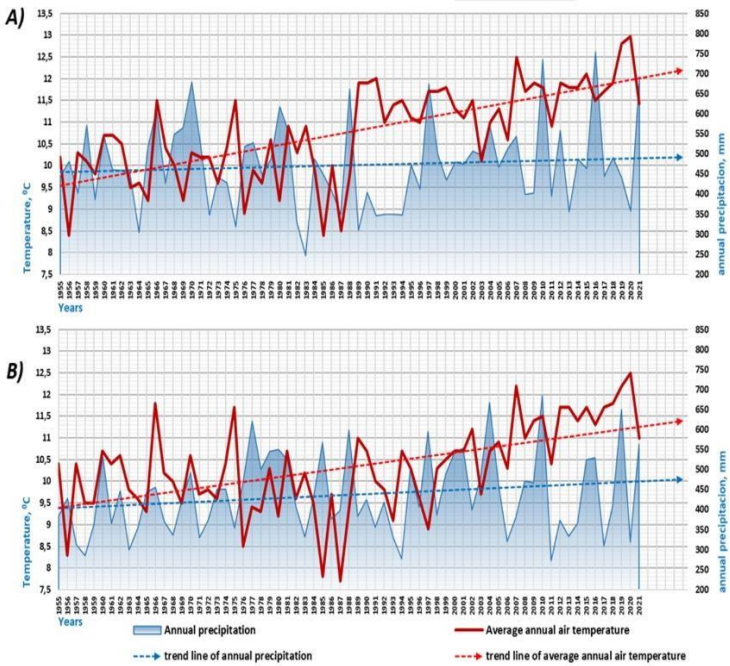

Fig. 6. Long-term dynamics of the average annual air temperature and annual amounts of atmospheric precipitation within the limits of the cities of Odesa (*A*) and Kherson (*B*) for the period 1955–2021

Trends in changes in air temperature and the amount of atmospheric precipitation in the territory show that the North-Western Black Sea Coast region is becoming hotter and more humid. In the western part of the region, over the past almost 70 years, the average annual air temperature has increased by 3.0°, in the eastern part by 2.2°. On the contrary, the increase in annual amounts of atmospheric precipitation in the eastern part of the region is more significant and amounts to an additional 80 mm, in the western part – 50 mm.

The long-term distribution of atmospheric precipitation has become more unstable after the manifestation of global warming processes in the region. The years with their minimum number and maximum values have become more frequent. The limits within which the annual amount of precipitation can fluctuate have increased significantly. If in the period before the warming, the difference between the minimum and maximum value of the annual precipitation amount was 384 mm, now it has increased by 1.4 times and is 542 mm. The alternation of dry and significantly wet periods has also

become more pronounced and uneven both on an intra-annual and multi-year scale (see Fig. 6).

It should be noted that the region still has a significant influence of local weather conditions, which are formed under the influence of features of the relief, roughness of the terrain, proximity to the sea and other local factors. If the mentioned features do not have a significant effect on the temperature regime, then the spatial distribution of atmospheric precipitation at individual points may not correspond to general large-scale trends. An example of such points is the Henichesk and Izmail border observation stations (Fig. 7).

Within these cities, general trends in air temperature changes persist. The temperature increase for Henichesk is 2.2° for the selected periods, for Izmail – 2.8°, which is typical for the eastern and western parts of the region. However, the amounts of annual precipitation for these cities, on the contrary, are decreasing in the modern period. For example, over the past almost 70 years, this indicator has decreased by 17 mm within Henichesk and by 41 mm in Izmail.

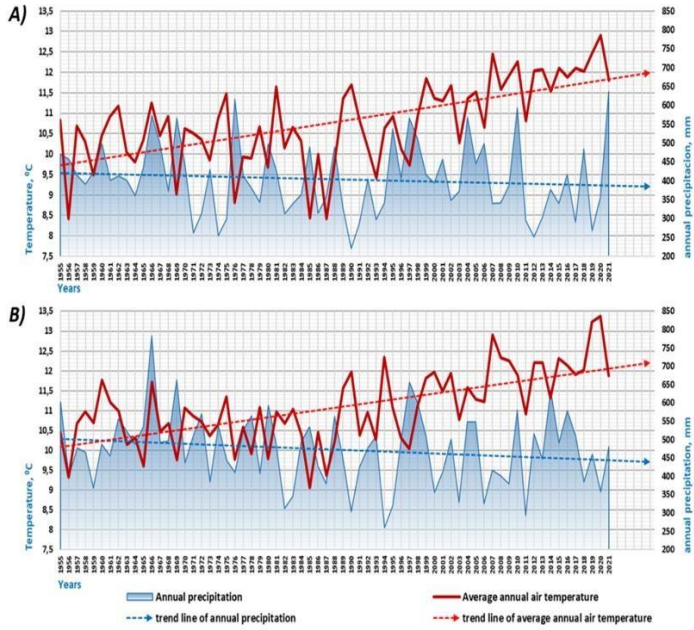

Fig. 7. Long-term dynamics of the average annual air temperature and annual amounts of precipitation within the cities of Henichesk (*A*) and Izmail (*B*) for the period 1955–2021

These cities are characterized by an increase in the number and frequency of years with low amounts of precipitation compared to previous climatic periods. This is explained by the marginal location of Henichesk and Izmail within the North-Western Black Sea Coast region, due to which there is an increased influence on the specified territories of adjacent climatic zones and local weather-forming factors.

Without excluding the mosaic of the cumulative manifestation of the most significant climatic factors, which form a significant diversity of ecological conditions before the invasion of epidemiologically dangerous blood-sucking mosquitoes, the general tendency to increase the air temperature and increase the humidity of the territory of the North-Western Black Sea Coast region allows us to consider these changes favorable for the spread and further successful adaptations of insects of the genera *Aedes* and *Anopheles*.

The presence of these epidemiologically significant blood-sucking mosquitoes in Europe and the geographical proximity of ranges to the borders of Ukraine creates high risks of their natural and anthropogenic spread to the study area. Increasing the species diversity of competent vectors will lead to an increase in the already dangerous vector potential.

CONCLUSIONS

The territory of the North-Western Black Sea Coast is a transition zone between a temperate and subtropical climate according to climatic indicators. The eastern part has a mostly temperate continental climate with mild winters, hot summers and quite long spring and autumn periods. For the western part of the region, which is located mainly in the coastal zone of the Black Sea Lowland, the temperate marine climate gradually acquires the characteristics of subtropical.

Due to the intermediate position and the instability of the climate in the modern period, the studied territory is favorable for the invasion of dangerous carriers of exotic diseases – blood-sucking mosquitoes of the genera *Aedes* and *Anopheles*. Among the main climatic factors that can contribute to the invasion of these vectors, we single out the general climate warming and an increase in the amount of atmospheric precipitation, especially in the warm period of the year.

The analysis of surface meteorological observation data showed that global climate changes, the active manifestation of which in the studied area began at the end of the 80s of the last century, affected both of the most significant factors that can contribute to the active invasion and adaptation of dangerous mosquito species within the North-Western Black Sea Coast region.

Thus, using the method of constructing integral curves of the distribution of average annual air temperatures, we established two climatic periods:

1) the period before climate warming – from the beginning of instrumental observations to 1987;

2) the modern (technogenic) period of warming – from 1988 to the present time.

The first period is characterized by the predominance of negative deviations of average annual air temperatures from the multi-year average according to data from all hydrometeorological observation stations in the research region. The second period is characterized by sharply positive deviations of these values. The average annual air temperature in the period before the climate warming in the region was in the range of 9.7–10.3° and in the southernmost observation points (Izmail, Vylkove) reached values close to 11.0°. In the modern period of climate warming, they fluctuate between 11.0–12.0° and above, which in some years can reach 13.8°.

A significant difference in the spatio-temporal distribution of air temperature during the selected periods had a corresponding effect on the redistribution of atmospheric precipitation fields, as the second most important climatic factor affecting the distribution and existence of epidemiologically dangerous blood-sucking mosquitoes within the study region.

In the intra-annual distribution, the number of months with the amount of precipitation exceeding 40 mm/month increased. During the summer season, months with precipitation of 80 mm/month or more became more frequent. Precipitation became mainly torrential with the greatest intensity in the summer months. The winter season has become drier with the majority of monthly precipitation amounts below 40 mm. Long winter snow peaks, which in the 70s and 80s of the last century exceeded the value of 80 mm/month in intensity, are practically not noted now.

The investigated changes in the fields of air temperature and atmospheric precipitation confirm the presence of favorable conditions for invasion, adaptation and further spread within the North-Western Black Sea Coast region of tropical blood-sucking mosquitoes (Diptera: Culicidae) of the genera *Aedes* and *Anopheles*. Increasing the species diversity of competent vectors will lead to an increase in the already dangerous vector potential.

SUMMARY

The scientific work analyzes the climatic prerequisites for the emergence of epidemiologically dangerous blood-sucking mosquitoes of the genera *Aedes* and *Anopheles* in the territory of the North-Western Black Sea Coast. Among the most significant climatic factors that create favorable conditions for the spread of tropical mosquitoes, an increase in air temperature and an increase in the amount of precipitation in the region were singled out. It is shown that the combined action of these factors at the current stage of climate change creates favorable conditions for the spread and rooting of epidemiologically dangerous mosquito species: *Aedes aegypti* (Linnaeus, 1762), *Aedes albopictus* (Skuse, 1895), *Aedes atropalpus* (Coquillett, 1902), *Aedes japonicus* (Theobald, 1901), *Aedes koreicus* (Edwards, 1917). Among the listed invasive species, the most widespread is *Aedes albopictus*, the first

individuals of which were recorded by researchers in the Northwestern Black Sea region in mid-2023. The geographic proximity to the borders of Ukraine of the epidemiologically significant malaria mosquitoes areas present in Europe: *Anopheles labranchiae* (Falleroni, 1926), *Anopheles melanoon* (Hackett, 1934) and *Anopheles sacharovi* (Favre, 1903), as well as a representative of the subfamily *Cellia* (Theobald) *Anopheles superpictus* (Grassi, 1899) creates high risks regarding their natural and anthropogenic spread to the studied territory.

Bibliography

1. Becker N. Life strategies of mosquitoes as an adaptation to their habitats. In: Bull. Soc. Vector Ecol. 1989, Vol. 14, Nr.1, p. 6-25.

2. Medlock J. M., Hansford K. M., Schaffner F., Versteirt V., Hendrickx G., Zeller H., & Van Bortel W. 2012. A review of the invasive mosquitoes in Europe: ecology, public health risks, and control options. Vector borne and zoonotic diseases (Larchmont, N.Y.), 12(6), 435–447. DOI: https://doi.org/10.1089/vbz.2011.0814.

3. Paupy C., Delatte H., Bagny L., Corbel V. & Fontenille, D. 2009. Aedes albopictus, an arbovirus vector: from the darkness to the light. Microbes and infection, 11(14-15), 1177-1185. DOI: https://doi.org/10.1016/j.micinf.2009.05.005.

4. Cancrini, G., Scaramozzino, P., Gabrielli, S., Di Paolo, M., Toma, L., & Romi, R. 2007. Aedes albopictus and Culex pipiens implicated as natural vectors of Dirofilaria repens in central Italy. Journal of medical entomology, 44 (6), 1064–1066. DOI: https://doi.org/10.1603/0022-2585(2007)44[1064:aaacpi]2.0.co;2.

5. Rudik V. A. Analysis of species composition, distribution and seasonal ratio of malaria mosquitos of northwestern region of Black Sea Coast // Pryrodnychyi Almanakh (biological sciences), 2019. 26. P. 157-170. DOI: https://doi.org/10.32999/ksu2524-0838/2019-26-15.

6. Rudik V. The Risk of the Spread of Malaria in Anophelogenous Southern Ukraine Against the Backdrop of Global Climate Change // Fourth Annual BTRP Ukraine Regional One Health Research Symposium (20-24 May 2019). – Kyiv, Ukraine. – P. 193. URL: https://dspace.ksaeu.kherson.ua/handle/123456789/9043.

7. Becker N., Petric D., Zgomba M., Boase C., Madon M., Dahl C. & Kaiser A. 2010. Mosquitoes and their Control. (2 ed.) Springer. DOI: https://doi.org/10.1007/978-3-540-92874-4

8. Школьний Є. П., Лоєва І. Д., Гончарова Л. Д. 1999. Обробка та аналіз гідрометеорологічної інформації: підручник (підручник). К.: Міносвіти України, 1999. 538 с.

9. Becker N. 2008. Influence of climate change on mosquito development and mosquito-borne diseases in Europe. Parasitol Res 103(Suppl 1): S 19–S28.

10. Caminade C., Medlock J.M., Ducheyne E. et al. 2012. Suitability of European climate for the Asian tiger mosquito Aedes albopictus: recent

trends and future scenarios. J R Soc Interface. 2012 Oct 7;9 (75) : 2708-17. DOI: https://doi:10.1098/rsif.2012.0138.

11. Kraemer M.U., Sinka M.E., Duda K.A. et al. 2015. The global distribution of the arbovirus vectors Aedes aegypti and Ae. albopictus. Elife. 2015 Jun 30;4:e08347. DOI: https://doi.org/10.7554/eLife.08347.

12. Рудік В.А. Перші знахідки тропічного виду Aedes Albopictus в межах міста Одеса / Сучасна гідроекологія: місце наукових досліджень у вирішенні актуальних проблем: зб. наук. праць матеріали VI наук.-практ. конф. молодих вчених (Київ, 2023. 10–11 жовтня 2023 р.). Київ: Інститут гідробіології НАН України, 2023. С. 75-77. URL: http://dspace.onu.edu.ua:8080/handle/123456789/ 36922.

13. Bonizzoni M., Gasperi G., Chen X., James A.A. The invasive mosquito species Aedes albopictus: current knowledge and future perspectives. Trends Parasitol. 2013; 29(9):460–8. DOI: https://doi:10.1016/ j. pt.2013.07.003.

14. Kutishchev P. S., Korzhov Ye. I., Honcharova O. V. Retrospective analysis and forecast of the main abiotic factors of the environmental conditions of ichtyofauna of the Dnipro-Buh estuary ecosystem / Topical issues of the development of veterinary medicine and breeding technologies: Scientific monograph. Riga, Latvia : «Baltija Publishing», 2022. – Pp. 476-497. DOI: https://doi.org/10.30525/978-9934-26-258-6-14.

15. Коржов Є. І., Гончарова О. В. Формування режиму солоності вод Дніпровсько-Бузької гирлової області під впливом кліматичних змін у сучасний період / Actual problems of natural sciences: modern scientific discussions: Collective monograph. Riga: Izdevniecība «Baltija Publishing», 2020. – P. 315-330. DOI: https://doi.org/10.30525/978-9934-588-45-7.18.

16. Rudik V., Levchenko V. Monitoring of Blood-sucking Mosquitoes by Means of Homemade Electromechanical Light-emitting Diode Traps in Southern Ukraine // 2021 International biothreat reduction symposium. BTRP Ukraine (29 June – 2 July 2021). – Kyiv, Ukraine. P. 216. URL: https://dspace.ksaeu.kherson.ua/ handle/123456789/9044.

Information about the authors:
Rudik Vitalii Anatoliiovych,
Postgraduate Student at the Department of Molecular Biology, Biochemistry and Genetics
Odessa I. I. Mechnikov National University
2, Dvoryanska str., Odesa, 65082, Ukraine

Korzhov Yevhen Ivanovych,
Candidate of Geographic Sciences,
Associate Professor at the Department of Aquatic Bioresources and Aquaculture
Kherson State Agrarian and Economic University
23, Stritenska str., Kherson, 73006, Ukraine

The project was implemented with the support of

CENTER
for Ukrainian and European
Scientific Cooperation

The Center for Ukrainian and European Scientific Cooperation is a non-governmental organization, which was established in 2010 with a view to ensuring the development of international science and education in Ukraine by organizing different scientific events for Ukrainian academic community.

The priority guidelines of the Centre for Ukrainian and European Scientific Cooperation

1. **International scientific events in the EU**

Assistance to Ukrainian scientists in participating in international scientific events that take place within the territory of the EU countries, in particular, participation in academic conferences and internships, elaboration of collective monographs.

2. **Scientific analytical research**

Implementation of scientific analytical research aimed at studying best practices of higher education establishments, research institutions, and subjects of public administration in the sphere of education and science of the EU countries towards the organization of educational process and scientific activities, as well as the state certification of academic staff.

3. **International institutions study visits**

The organisation of institutional visits for domestic students, postgraduates, young lecturers and scientists to international and European institutes, government authorities of the European Union countries.

4. **International scientific events in Ukraine with the involvement of EU speakers**

The organisation of academic conferences, trainings, workshops, and round tables in picturesque Ukrainian cities for domestic scholars with the involvement of leading scholars, coaches, government leaders of domestic and neighbouring EU countries as main speakers.

Contacts:
Head Office of the Center for Ukrainian and European Scientific Cooperation:
88000, Uzhhorod, 25, Mytraka str.
+38 (099) 733 42 54
info@cuesc.org.ua

www.cuesc.org.ua

НОТАТКИ

НОТАТКИ

НОТАТКИ

Izdevniecība “Baltija Publishing”
Valdeķu iela 62 – 156, Rīga, LV-1058
E-mail: office@baltijapublishing.lv

Iespiests tipogrāfijā SIA “Izdevniecība “Baltija Publishing”
Parakstīts iespiešanai: 2024. gada 1. maijs
Tirāža 150 eks.