UDC 574.589 (477.74)
DOI https://doi.org/10.32782/2226-0099.2025.143.1.42

MODERN CLIMATIC CHANGES WITHIN THE NORTH-WESTERN BLACK SEA REGION AS A FACTOR IN THE GROWTH OF ICHTHYOPATHOLOGICAL AND INVASIVE THREATS

Korzhov Ye.I. *– PhD in Geography,*
Associate Professor at the Aquatic Bioresources and Aquaculture,
Kherson State Agrarian and Economic University
orcid.org/0000-0003-2677-5296
Honcharova O.V. *– PhD in Agriculture,*
Associate Professor at the Aquatic Bioresources and Aquaculture,
Kherson State Agrarian and Economic University
orcid.org/0000-0002-9702-7458

The article presents the impact of climate warming in the North-Western Black Sea Coast region on the possible exacerbation of the ichthyopathological situation in the region's water bodies. The virulence of pathogens in the aquatic environment depends on several factors, including water flow, organic matter, and physical and chemical conditions. The most important factor is the temperature, which determines the development of helminths, fungal pathogens, viruses and affects the physiological and immune properties of fish.

Climate warming in the region leads to an increase in critical water temperatures in the summer and autumn, which complicates the sanitary and epidemiological situation and causes disease outbreaks among the fish fauna during these periods of the year. According to the analysis of long-term observation data from the main monitoring stations in the North-Western Black Sea Coast region, stable manifestations of climate warming began to be observed here after 1988.

The method made it possible to identify two main periods: before climate warming (from the beginning of instrumental observations until 1987) and the current (man-made) warming period – from 1988 to the present. In the first period, negative deviations of average annual air temperatures from the long-term norm were observed, ranging from –0.29° to –0.66° depending on the observating location. The period of modern warming is characterised by sharply positive deviations of average annual temperatures from the long-term norm, ranging from +0.6 to +1.2°, indicating a stable increase in temperature from year to year. The average annual temperature in the region before climate warming was in the range of 9.7-10.3°, after warming – 11.0-12.0° and in some years can reach 13.8°C.

An increase in water temperature above 20-25°C increases the risk of epizootics in fish. In particular, due to climate warming and an increase in water temperatures during critical periods throughout the year, an increase in infectious, helminthic, invasive, fungal and bacterial diseases can be expected.

Among the water bodies that, under the influence of the factor of increasing air and water temperatures, have conditions of increased ichthyopathological and invasive hazard are water bodies located within the lower reaches of the Danube (Izmail, Bilhorod-Dnistrovskyi districts of Odesa region) and water bodies in the southern part of Kherson region (Skadovsk, Henichesk districts, Syvash), as these regions are currently experiencing the greatest manifestation of climate warming.

Key words: *fish diseases, species invasion, climate warming, land water bodies, North-Western Black Sea Coast region.*

Коржов Є.І., Гончарова О.В. Сучасні кліматичні зміни в межах Північно-Західного Причорномор'я як фактор зростання іхтіопатологічних та інвазійних загроз

В статті розглянуто вплив потепління клімату в межах Північно-Західного Причорномор'я на можливе загострення іхтіопатологічної обстановки на водних об'єктах регіону. Вірулентність патогенів у водному середовищі залежить від кількох факторів, зокрема проточності води, органічних речовин та фізико-хімічних умов. Найважливішим

є температурний фактор, який визначає розвиток гельмінтів, грибкових патогенів, вірусів та впливає на фізіологічні й імунні властивості риби.

Потепління клімату в регіоні призводить до збільшення критичних температур води в літньо-осінній період, що ускладнює санітарно-епідеміологічну ситуацію і викликає спалахи хвороб серед іхтіофауни саме в ці періоди року. Згідно аналізу даних спостережень за багатолітній період по основним моніторинговим станціям в межах Північно-Західного Причорномор'я стабільні прояви потепління клімату тут почали спостерігатись після 1988 року.

Метод дозволив виділити два основні періоди: до потепління клімату (від початку інструментальних спостережень до 1987 року) та сучасний (техногенний) період потепління – з 1988 р. по нинішній час. У першому періоді спостерігалися від'ємні відхилення середніх річних температур повітря від багаторічної норми, які коливались від –0,29° до –0,66° залежно від місця спостереження. Період сучасного потепління характеризується різко достатніми відхиленнями середніх річних температур від багаторічної норми, які коливаються від +0,6 до +1,2°, що вказує на стабільне підвищення температури від року в рік. Середні значення річної температури повітря у період до потепління клімату в регіоні знаходились в межах 9,7-10,3°, після потепління – 11,0-12,0° та в окремі роки можуть сягати 13,8°.

Підвищення температури води вище 20-25°С збільшує ризик епізоотій у риб. Зокрема, через потепління клімату і збільшення температур води у критичні періоди впродовж року, можна очікувати збільшення інфекційних, гельмінтозних, інвазійних, а також грибкових і бактеріальних захворювань.

Серед водних об'єктів, які, під дією фактору збільшення температур повітря та води, мають умови підвищеної іхтіопатологічної та інвазійної небезпеки є водойми розташовані в межах нижньої течії Дунаю (Ізмаїльський, Білгород-Дністровський райони Одеської області) та водойми південної частини Херсонської області (Скадовський, Генічеський райони, Сиваш), оскільки саме у цих регіонах на сучасному періоді відмічається найбільший прояв потепління клімату.

Ключові слова: *хвороби риб, інвазія видів, потепління клімату, водні об'єкти суші, Північно-Західне Причорномор'я.*

Problem statement. The regional manifestations of global warming have a wide range of impacts on biotic and abiotic components of aquatic ecosystems. The increase in average annual air and water temperatures, the expansion of the boundaries of the autumn and spring seasons, which together form a long warm period of the year within the North-Western Black Sea Coast region, directly affect the deterioration of the ichthyopathological situation in natural water bodies of the region and their general ecological condition [1, 5, 8, 12]. Due to the close dependence of the development of pathogens and vectors of fish diseases on the temperature factor of the environment, climate warming within the study area significantly worsens the sanitary and epidemiological state of water bodies. Such processes are especially active in water bodies with low flow and low self-purification potential [4, 7, 13], which, along with the temperature factor, are also favorable for the development of epizootics in natural water bodies.

Analysis of recent research and publications. The virulence of pathogens in the aquatic environment depends on a number of factors, such as the flow of a water body, the saturation of water with organic matter, physicochemical resistant conditions for the reproduction and existence of pathogens and viruses, etc. [2-4, 7, 8, 13]. Among these factors, the temperature factor is crucial. According to a number of studies, water temperature is not only the limit of the beginning and end of the development of helminths, fungal pathogens, infusoria, flagellates, viruses and other pathogens, but also affects the state of the fish body itself, its physiological and immune properties [1, 2, 8, 10, 12].

A direct consequence of climate warming in water bodies in the study area is an increase in the frequency of critical water temperatures in the summer and autumn. Under the influence of elevated temperatures in certain water bodies during this period, not only

does the sanitary and epidemiological situation become more complicated, but outbreaks of diseases are also frequent, leading to the death of a significant number of fish fauna. For this reason, the study of the impact of climate warming on the development of ichthyopathological processes in natural reservoirs is becoming an increasingly urgent issue among specialists and scientists in the field of fisheries and veterinary medicine.

Materials and methods of research. In analyzing the changes in the temperature field within the North-Western Black Sea Coast region, we used data from long-term observations at the main hydrometeorological stations in the region: Odesa, Mykolaiv, Kherson, Henichesk – 1899-2021, Izmail – 1946-2021, Sarata – 1948-2021, Vylkove – 1951-2021 and Khorly – 1951-2021.

The periodization of climate change was carried out based on the data of atmospheric air temperature within the North-Western Black Sea Coast region by constructing integral curves of annual deviations of air temperature (*Ti*, °C) from the normal annual temperature (*Tn*, °C) separately for each of the main ground points of the hydrometeorological observation network in the South of Ukraine.

Statistical data processing was performed according to generally accepted methods and guidelines [6, 11].

Summary of the main research material. The first manifestations of global climate warming in the North-Western Black Sea Coast region began to appear in the 1980s [15, 18]. This is clearly demonstrated by the integrated deviation curves of long-term air temperature series at the main observation stations, which we have constructed (Fig. 1).

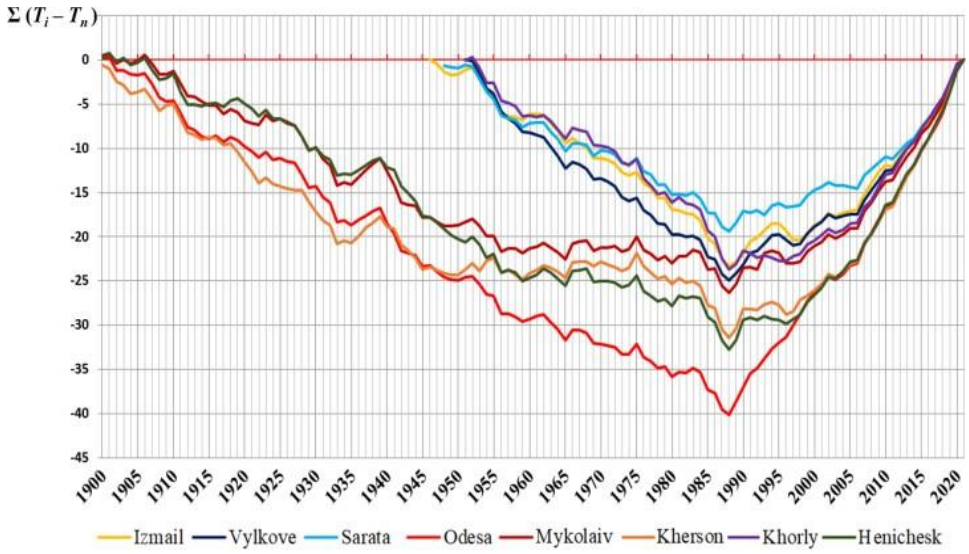

Fig. 1. Integral curves of changes in annual air temperatures within the North-Western Black Sea Coast region

The data analysis shows that at Odesa, Mykolaiv, Kherson, Izmail, Sarata and Vylkove stations, the transition of mean annual air temperature values to the phase of steady increase was quite clear. The steady transition to the phase of climate warming according to the presented integral curves occurred in 1988. At Genichesk and Khorly stations,

the beginning of the warming period also falls on this year, but the gradients of annual temperature changes are unclear until the end of the 1990s, which is explained by the geographical features of the locations of the observation points and the influence of local weather conditions on large-scale synoptic processes. Therefore, it can be argued that the year of the transition of the temperature regime within the North-Western Black Sea Coast region towards warming is 1988.

Thus, using the method of constructing integral curves for temperature indicators within the North-Western Black Sea Coast region, we have identified two climatic periods [18]:

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

2) modern (anthropogenic) warming period – from 1988 to the present.

The first period is characterised by a predominance of negative deviations of average annual air temperatures from the long-term average at all hydrometeorological observation stations in the region. The average value of the deviations ranged from -0.29° to -0.66°, depending on the location of the individual observation point (Table 1).

Table 1

Some characteristics of the periods of atmospheric air temperature regime in the North-Western Black Sea Coast region

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

Notes: T, Tmn, Tmx – values of the average long-term, lowest and highest mean annual air temperature at a particular point, °C; n – length of the observation series

The average annual air temperature in the period before climate warming in the region was in the range of 9.7-10.3° and in the southernmost observation points (Izmail, Vilkovo) reached values of about 11.0°.

The current warming period, which began in the North-Western Black Sea Coast region in 1988 and continues to the present day, is characterised by sharply positive

deviations of average annual air temperatures from the long-term average. Their values at certain locations are in the range of 0.6-1.2°, which indicates a sharp increase in air temperature during the second period from year to year.

The average annual air temperature in the current period of climate warming is in the range of 11.0-12.0° and above, which in some years can reach 13.8° with maximum absolute values of up to +42°C (see Table 1). Such periods in the annual context are particularly dangerous for the development of epizootics and ichthyopathological threats.

Analysing the absolute values of the average temperature deviations for individual periods, it is clear that their values in the current period, which lasts 34 years, exceed the same values for the previous period, which was longer and lasted 37-89 years. At the same time, at some stations, the deviation of temperatures from the long-term average in the current period is about 2,6 times higher than in the previous period. Such a rapid increase in air temperature in the modern period is explained by the fact that natural cyclical changes in the temperature regime in the current period are further exacerbated by active negative anthropogenic impact on the atmosphere. For this reason, the current period of climate warming can also be fairly called man-made.

These climatic changes, which have been observed within the study area for almost 40 years, can create a deterioration in the ichthyopathological and sanitary-epidemiological situation in regional water bodies.

The development and extinction of epizootics occurs in a certain sequence. Several stages are distinguished: pre-epizootic, developmental, maximum growth, extinction, and post-epizootic period. This sequence is most clearly observed in natural reservoirs and in cases where the epizootic is not interrupted by anti-epizootic measures. Between individual epizootics there is a more or less long dormant period, called the inter-epizootic stage, when sporadic cases of disease are observed, which maintains the presence of the pathogen in the water body. The duration of the inter-epizootic stage depends on the nature of the pathogen, its biology, the availability of conditions for its preservation in the environment, and the immune-physiological state of the fish organism, but in most cases, the temperature factor is decisive in the outbreak of certain diseases [3].

In the case of salmon furunculosis, the pathogen Aeromonas salmonicida is shed from abscesses directly into the water environment, and in the intestinal form – with excrement. If the pathogen is found in the environment, the most favourable conditions for its preservation are water temperatures between 20° and 28°C. Aeromonads pathogenic to fish are often found in the intestines of carp or pond water in an avirulent form, without causing sporadic disease. In migratory salmonids, furunculosis is most common during spawning migrations to freshwater rivers. The most susceptible fish are over two years of age. The mortality rate of affected fish can reach 100%. The disease is triggered by non-compliance of the growing conditions with technological requirements, such as over-compacted plantings, inadequate feeding, reduced oxygen dissolved in water, organic pollution of water bodies and increased water temperature. The causative agent of furunculosis is found both in the body of sick fish and in contaminated water, actively multiplying as a saprophyte, the active phase of which also begins at 20-22° [3].

Fish mortality from yersiniosis can reach 55-65% and depends on a number of factors, including temperature, stocking density, and immune-physiological state of the organism. Thus, at water temperatures of 15-18°, the course of yersiniosis is complicated, and when it decreases to 10°, fish mortality decreases [9].

Unlike warm-blooded animals, the temperature optimum for the development of pathogens of infectious diseases of fish is quite wide. It starts from the limit of 10°C and

reaches 25°C and higher for some viruses. The virulence of pathogens decreases with decreasing air temperature, and, accordingly, water and fish body temperature.

Most often, outbreaks of spring viremia of carp are observed in the spring-summer period with an increase in water temperature to 13-17°, which subside at temperatures of 20°C and above. The virus is transmitted through water, silt, fish farming equipment, and can be carried by blood-sucking parasites of fish – leeches, argulus. It persists for more than a month in water at a temperature of 10° and in dry silt at temperatures of 4-20°.

Carp pox with subsequent infectious gill necrosis occurs in pond farms in most of Europe and Asia in the warm season at water temperatures of 19-22°, fish of all age groups are affected, but more often one- and two-year-olds.

Mass disease of fry and yearlings with ichthyobodosis is observed in spring and summer in spawning and rearing ponds, in pools, when the water temperature is most favorable for the mass development of parasites (16-25°). In the autumn period, the invasion gradually fades. Low temperatures negatively affect the development of the pathogen, but with a significant crowding of fish, enzootics of ichthyobodosis can also occur in wintering ponds and pools of wintering complexes at water temperatures of 2-7°C. The reproduction of the pathogen and the development of the disease are facilitated by an acidic environment (pH not higher than 5,0-5,5), deterioration of the hydrological, hydrochemical and gas regimes in ponds and pools, and the general zoohygienic condition of the reservoir. Ichthyobodo necatrix, as a specialized parasite, dies outside the fish body after 1-7 hours [9].

The course of myxosomiasis is affected by the temperature of the water in the reservoir. At relatively low water temperatures in coastal areas (14-16°), the disease lasts longer and is usually more severe. At higher temperatures, young trout grow intensively, as a result of which ossification and densification of its skeleton occurs faster, therefore the pathogenic effect of the parasite decreases. Enzootics of myxosomiasis are recorded mainly in the summer (June-early July). At this time, the greatest intensity of invasion and mass death of sick fish are observed. At the end of summer (August), the number of sick fish decreases, but they remain carriers of the pathogen and a potential reservoir of invasion.

The pathogen of branchiomycosis shows significant virulence at water temperatures above 20°, and at lower temperatures the disease has a chronic or subacute course. The development of outbreaks of the disease is facilitated by the saturation of water with organic compounds (according to the permanganate oxidation index >20 mgO_2/dm^3), the presence of ammonia in a concentration higher than 10 $\mu g/dm^3$, significant silt deposits, significant overgrowth of the bed with aquatic vegetation and the lack of flow [9]. The decomposition of organic residues creates favorable conditions for nutrition, growth, development and reproduction of the pathogen of branchiomycosis.

The pathogens of saprolegniosis and achliosis are lower mold fungi (phycomycetes) from the genera Saprolegnia and Achlia. The most pathogenic are the following species: S. parasitica, S. monica, S. mixta, S. ferax, A. flagelata. All of them are saprophytes. They are distributed in slow-flowing water bodies whose waters are rich in organic matter. Development occurs at any time, individual species appear in different seasons depending on the temperature: S. monica occurs in October-December and in April-June at a water temperature of 5-16°, S. mixta, S. ferax in the autumn and spring at a temperature of 5-16°, and S. parasitica throughout the year.

Ichthyophonosis (drunken disease) is a dangerous disease that affects marine, freshwater and aquarium fish. The causative agent is the fungus Ichthyophonus hoferi from the class of zygomycetes. The growth of the fungus is observed at a temperature of 23-26°. Rainbow trout is extremely susceptible to infection.

Protozoa are the most common group of invasive fish diseases, the causative agents of which are parasitic protozoa (over 500 species), usually unicellular organisms, which are classified as subkingdom Protozoa. Among fish parasites, there are representatives of all types of protozoa, including sarcomastigophora, apicomplexa, myxosporidia, microsporia, and ciliated ciliates.

Bothriocephalosis is a common helminthic disease of fish caused by the cestodes Bothriocephalus acheiognathi (B. gowkongensis) and B. opsariichthydis from the Bothriocephalidae family, which parasitize the intestinal tract of many fish species, including carp, common carp, grass carp, catfish, and silver carp. The increase in the number of helminths is facilitated by water temperatures above 25°, which accelerates its development. In this regard, a special problem arises when growing fish in warm waters of thermal power plants and nuclear power plants [9].

In addition to the dangerous ichthyological effect on aquatic organisms, climate warming also expands the distribution of dangerous and aggressive invasive species of flora and fauna [14, 16, 17].

Thus, the pathogens of almost all fish diseases have their own temperature optimum, and, mainly, these are elevated temperatures. The conditions for the course of epizootics are worsened by such accompanying factors as organic pollution of natural water bodies, an increase in their trophic level, a low content of dissolved oxygen in water, and low flow. In the context of the effect of climate warming within the North-Western Black Sea Coast region, additional warming of the water masses of the region above 22° can significantly complicate the sanitary and epidemiological state of natural water bodies. These processes are especially dangerous in the summer-autumn period, when waters in slow-flowing water bodies are maximally saturated with organic substances, deoxygenated, and have temperatures above 25°.

Conclusions. The close relationship between the temperature factor and the development of pathogenic flora and fauna in water bodies, invasion of alien species, increased virulence of the environment and the likelihood of epizootics indicates that climate warming is a factor that complicates the ichthyological situation in places of its active manifestation.

An increase in water temperature above 20-25°C creates an increased threat to the occurrence of epizootics associated with infectious, helminthic, invasive diseases of fish, as well as fungal and bacterial invasions. The virulence of infectious pathogens decreases with a decrease in water and fish body temperature.

Analysis of long-term series of air temperature observations in the North-Western Black Sea Coast region showed that the most potentially pathogenic and invasively dangerous for aquatic fauna are water bodies located within the lower reaches of the Danube (Izmail and Bilhorod-Dniester districts of Odessa region) and water bodies in the southern part of Kherson region (Skadovsk, Genichesk districts, Syvash). During the modern warming period, the beginning of which we took 1988, it was in these areas that the greatest increase in air and surface water temperature was noted.

REFERENCES:

1. Білик Г. В., Коржов Є. І. Огляд основних аспектів впливу кліматичних змін на сучасний стан іхтіофауни Дніпровсько-Бузької гирлової області. *Наукові читання, присвячені Дню науки. Екологічні дослідження Дніпровсько-Бузького регіону.* 2019. Вип. 12. С. 3-10.

2. Воліченко Ю. М., Безпалова Л. Е., Оліфіренко В. В. Сезонні зміни гельмінтофауни деяких промислових риб дельти Дніпра. *Таврійський науковий вісник.* 2011. Вип. 77. Т. 2. С. 191-194.

3. Іхтіопатологія: конспект лекцій для студентів першого (бакалаврського) рівня вищої освіти спеціальності 207 «Водні біоресурси та аквакультура» / Н. Є. Гриневич та ін. Біла Церква.2021. 127 с.

4. Коржов Є. І., Кучерява А. М. Формування кількісних показників бактеріопланктону заплавних водойм пониззя Дніпра з різною інтенсивністю зовнішнього водообміну. *Водні і наземні екосистеми та збереження їх біорізноманіття – 2019*: Збірник наукових праць. Житомир: ЖНАЕУ. 2019. С. 236-237.

5. 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.

6. Методи гідроекологічних досліджень поверхневих вод / О. М. Арсан та ін.; за ред. В. Д. Романенка. Київ. 2006. 108 с.

7. Овечко С. В., Коржов Є. І., Гільман В. Л. Науково-практичні рекомендації щодо покращення екологічного стану слабопроточних водойм пониззя Дніпра. Херсон. 2015. 28 с.

8. Оліфіренко В. В. Залежність гельмінтофауни риб від екологічних особливостей водойми. *Таврійський науковий вісник.* 2011. Вип. 77. Т. 1. С. 195-199.

9. Орехова Г. А. Кишковий ієрсиніоз тварин (актуальність, епізоотологія, діагностика) (огляд літератури). *Ветеринарна медицина.* 2015. Вип. 101. С. 125-129.

10. Цуркан Л. В., Воліченко Ю. М., Кутіщев П. С., Шерман І. М. Динаміка змін основних рибничо-біологічних показників рибопосадкового матеріалу коропа та рослиноїдних риб як реакція на клімат сучасної зими півдня України. *Таврійський науковий вісник.* Вип. 109. 2019. С. 225-232.

11. Школьний Є. П., Лоєва І. Д., Гончарова Л. Д. Обробка та аналіз гідрометеорологічної інформації : підручник. Київ. 1999. 538 с.

12. Honcharova O., Korzhov Ye. Transformation of the climatic factor influence on the parameters of the fish organism in ontogenesis. *Scientific progress: innovations, achievements and prospects*: Proceedings of the 5th International scientific and practical conference. February 6-8, 2023. Munich, Germany. 2023. P. 40-46.

13. Korzhov Ye. I. Ecohydrological investigation of plain river section in the area of small hydroelectric power station influence. *Collective monograph: Current state, challenges and prospects for research in natural sciences*. Lviv-Toruń. 2019. P. 135-154.

14. Krasnovyd V., Kvach Yu., Drobiniak O. The Parasite Fauna of the Gobiid Fish (Actinopterygii, Gobiidae) in the Sukhyi Lyman, Black Sea. *Вестник зоологии*. 2012. Т. 46, № 6. С. 483–490.

15. 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. 2022. P. 476-497.

16. Kvach Yu., Kutsokon Yu., Stepien C., Markovych M. Role of the invasive Chinese sleeper Perccottus glenii (Actinopterygii: Odontobutidae) in the distribution of fish parasites: New data and a review. *Biologia.* Vol. 71. 2016. P. 941-951.

17. Rudik V. A., Korzhov Ye. I., Chebotar S. V. Assessment of overwintering and local reproduction conditions of the epidemiologically dangerous mosquito species Aedes albopictus (Diptera: Culicidae) in south of Ukraine. *SWorldJournal* (Svishtov, Bulgaria). 2024. Issue 26, Part 1. P. 99-109.

18. Rudik V. A., Korzhov Ye. I. Dynamics of climatic predictors of a possible invasion of epidemiologically dangerous blood-sucking mosquitoes (Diptera: Culicidae) into North-Western Black Sea Coast areas. *Biological sciences and education in the context of European integration:* Scientific monograph. Riga, Latvia. 2024. P. 63-80.