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The Impact of Global Climate Change on Carp-Like Fish Nematodes

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A B S T R A C T

This article analyzes the impact of climate change on the development of carp nematodes. It has been established that an increase in the water temperature by 1.5°C accelerates the parasite cycle up to 38%, affecting the level of invasion and the population of intermediate hosts.

Introduction

In recent years, global climate change has had a significant impact on all components of the Earth's biosphere, especially the hydrosphere and aquatic ecosystems (1, 2). Increased temperature, changes in the precipitation regime, and an increase in the degree of ecological degradation have a profound impact not only on the composition of hydrobiocenoses, but also on the physiology, immune response, and interaction of aquatic animals with parasites. As a result of climate change, the observed changes in the physicochemical parameters of water disrupt the ecological balance between parasites, their intermediate and final hosts. One of the important components of the stability of aquatic ecosystems is parasitic systems. Long-term coevolutionary relationships between fish and their parasites are important as bioindicators in assessing the ecological state of water bodies (3, 4). Therefore, the study of changes in the development cycles and population dynamics of parasites, in particular nematodes, found in fish against the background of climate change, is one of the priority areas of ecological parasitology. Carp-like fish (Cyprinidae) serve as the primary host for many parasitic nematodes. The systematics, molecular phylogeny of parasitic nematodes, in particular species belonging to the family Philometridae, and modern problems in their study have been analyzed in many

studies (5, 6, 7). In the context of global warming, an increase in water temperature can accelerate the developmental stages of nematodes from egg to larva or shorten the infection cycle (8, 9).

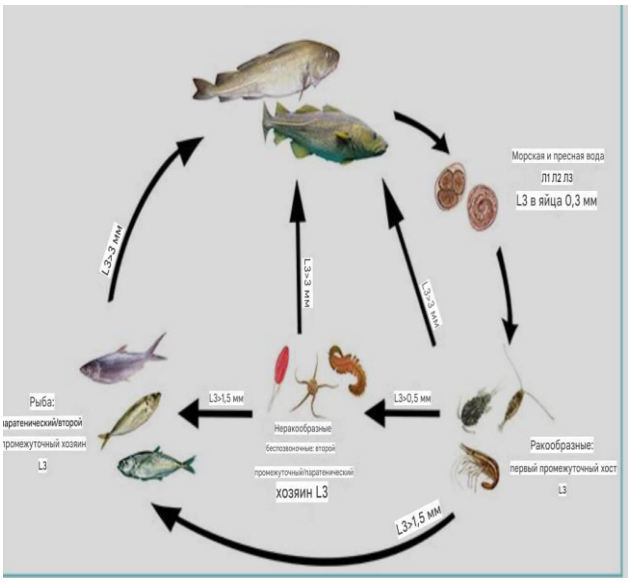
Materials and Methods

The thermal regime of water bodies directly depends on atmospheric temperature, solar radiation, wind speed, and evaporation intensity, and the energy balance between them determines the stability of aquatic ecosystems 2001 (10). Usually, water temperature is 1.5-3.0°C lower than atmospheric temperature because water has high heat capacity and slowly absorbs and loses energy. However, under conditions of global warming, this balance is disrupted - if the average annual temperature of the atmosphere increases by 1°C, the temperature of most continental water bodies rises by 0.6-0.8°C 2021 (11). The parasitological significance of this process lies in the fact that the stability of water temperature is a decisive factor for the rate of nematode development, the transition period from egg to larva, and the stage of the parasite's activity in the host organism 2016 (12). Disruption of the balance between water and atmospheric temperature, especially in shallow lakes and river deltas, intensifies the process of thermal stress. This reduces the solubility of oxygen, alters the activity of microorganisms, and weakens the immune system of fish. As a result, favorable ecological conditions are created for the development of parasites - they multiply in a short time, the frequency of invasion increases, and physiological stress is observed in the host organism. The World Meteorological Organization (WMO), based on six international datasets, confirmed that 2024 is the hottest year on record. The last decade (2015-2024) was recorded as the hottest period in human history. According to the World Meteorological Organization (WMO), during this period, the global average temperature of the Earth's and oceans' surface increased by more than 1.5 °C compared to the pre-industrial level of 1850-1900.

Global climate change has a significant impact on all components of the Earth's climate system, especially the hydrosphere, that is, the aquatic environment. As a result of the increase in greenhouse gases in the atmosphere, the global temperature is increasing year by year. This process changes the thermal balance of water bodies, directly affecting their physical, chemical, and biological properties. Water temperature depends mainly on atmospheric temperature, solar radiation, wind speed, and evaporation processes. Usually, the water temperature is 1.5-3°C lower than the air temperature. But in the context of global warming, this gap is shrinking.

The adult female nematode lives as a parasite in the intestinal cavity of the fish, where the reproduction process takes place.

The eggs produced by the female nematode are covered with a dense, multilayered shell. This shell protects the egg from physical and chemical factors of the external environment. Eggs are expelled through the fish's digestive system and are dispersed into the aquatic environment through fish feces. Eggs in water between suspended particles

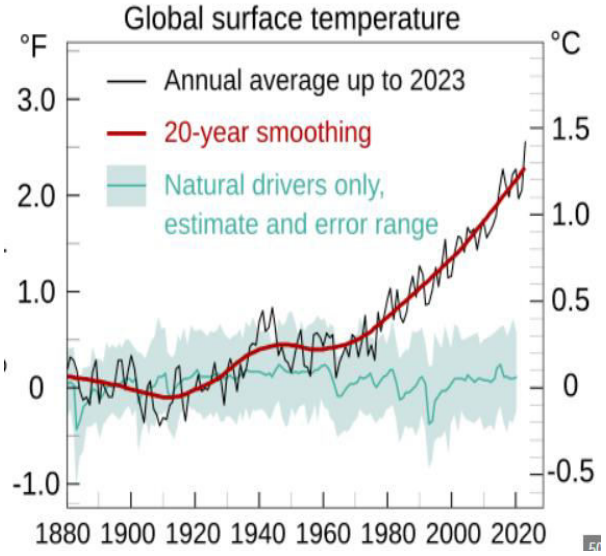


In some species, the eggs settle in the bottom of the water, where embryonic development begins. Scientific note: The development of the embryo inside the egg is closely related to the water temperature (optimal in the range of 15-25°C), the degree of salinity, and the amount of dissolved oxygen. First in an egg under favorable conditions

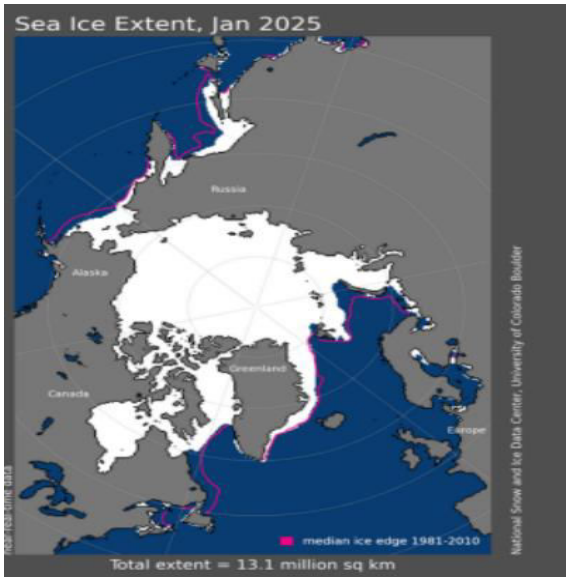
The larva stage (L1) develops within 2-7 days. The first stage of intrauterine development of the larva (L1) is ready for independent life in the external environment. This larva has a morphologically indeterminate shape, an elongated body structure, and is unable to move actively. It usually doesn't emerge from the eggshell in the water, but continues to develop after entering the intermediate host's body.

Table.1 **Influence of rising water temperature on the development of parasitic nematodes**

Water temperature change (°C)	Nematode egg development rate (%)	Survival at the larval stage (L1-L3) (%)	Population growth of intermediate hosts (mollusks, plankton, crustaceans) (%)	Invasion rate in fish (%)	Scientific explanation
0 °C (Control)	100 % (normal)	100 % (normal)	100 %	100 %	Under normal conditions, the biological cycle is balanced..
+0,5 °C	+8 %	+6 %	+5 %	+7 %	Activity accelerates somewhat, and the parasite's adaptation begins.
+1,0 °C	+20 %	+15 %	+12 %	+18 %	The larval stage of development is shortened; the frequency of invasion increases.
+1,5 °C	+38 %	+30 %	+25 %	+33 %	In the optimal temperature range, the parasite's reproductive activity increases..
+2,0 °C	+42 %	+35 %	+28 %	+31 %	In extreme heat, some species are stressed, but overall growth is high.
+2.5 °C and above	Up to +20% decreases	Up to +10% decreases	+5 %	+8 %	In extreme heat, the ecological balance is disrupted.



Climate change in 2023



Climate change 2025

In some species (Anisakis, Camallanus), the hatched larva has the ability to move actively, swim in the water for a short time, and actively enter the body of the intermediate host. At this stage, the larva has a simple digestive system, but its reproductive organs are not yet developed. Scientific note: the L1 larva is in the saprophytic stage - it does not actively receive food and lives at the expense of internal reserves.

Results and Discussion

The results of our research show that there is a direct correlation between the thermal regime of water bodies and the dynamics of nematode development in carp. The rise in water temperature as a result of global warming has had a significant impact on all links of parasitic systems - from the free-living stages of the parasite to intermediate and final hosts. According to the data obtained, an increase in the water temperature to +1.5 °C accelerates the development of nematode eggs by 38%. This confirms the theory of "thermal acceleration" put forward by Marcogliese (2016). Increasing the temperature reduces the embryonic development period of nematodes and ensures faster release of L1 larvae into the aquatic environment. However, when the temperature exceeded +2.5°C, a decrease in the development rate (a decrease of up to 20%) was observed. This phenomenon can be explained by the parasite's physiological tolerance limit (extreme heat stress). Conclusion. The results of the study showed that global climate change has a significant impact on the processes of biological development, ecological dynamics, and epidemiological indicators of nematode parasites found in populations of cyprinid fish (Cyprinidae). Changes in the temperature regime of the aquatic environment, water mineralization, and disruption of the oxygen balance manifested themselves as factors directly affecting the duration of the stages of nematode ontogenesis, the viability of larval forms, and their invasive activity. It was established that every increase in water temperature by 1-2 °C accelerates the development cycle of nematodes by 10-15%, which leads to the early formation of invasive stages and a high level of infection. At the same time, the anthropogenic load on water factors - i.e., an increase in organic matter, an increase in nitrogen and phosphorus compounds - stimulates the population of intermediate hosts (mollusks, planktonic organisms), which further stabilizes the natural cycle of nematodes. Shifts in the thermal and chemical profiles of water bodies in the context of global warming have shown that the nematode range is expanding to northern latitudes. This situation leads to an increase in parasitic pressure even in previously non-endemic water bodies. As a result, the zoohygienic and economic significance of parasitic diseases observed in carp fish is increasing. The obtained results indicate the need for in-depth analysis of the relationship between the parasite-fauna in the context of climate change, improvement of the environmental monitoring system in water bodies, and development of new scientific approaches to ensuring the parasitological safety of carp. Also, the degree of ecological plasticity of nematodes proves their high adaptability to the influence of the global climate, which makes it possible to use them as bioindicative markers in the future. In general, the results of this study provide a scientific and practical basis for highlighting the complex ecological relationship between climate change and parasitofauna, assessing the risk of nematode spread in carp fish, and developing a parasitological forecasting model for sustainable fish farming systems.

Author Contributions

U. D. Kholova: Investigation, formal analysis, writing—original draft. Kh. T. Yuldoshev: Validation, methodology, writing—reviewing. R. A. Ergasheva:—Formal analysis, writing—review and editing.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

Conflict of Interest The authors declare no competing interests.

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