DOI: 10.3750/AIEP/02979

ASSESSMENT OF THE OCCURRENCE OF MICROORGANISMS AND OTHER FISH PARASITES IN THE FRESHWATER AQUACULTURE OF UKRAINE IN RELATION TO THE AMBIENT TEMPERATURE

Nataliia MATVIENKO[1], Anna LEVCHENKO[2], Oleksii DANCHUK[2], and Yuriy KVACH*[2, 3]

[1]*Institute of Fisheries of the National Academy of Agrarian Sciences, Kyiv, Ukraine*

[2]*Odessa State Agrarian University, Odessa, Ukraine*

[3]*Institute of Marine Biology, National Academy of Sciences of Ukraine, Odessa, Ukraine*

Matvienko N., Levchenko A., Danchuk O., Kvach Y. 2020. Assessment of the occurrence of microorganisms and other fish parasites in the freshwater aquaculture of Ukraine in relation to the ambient temperature. Acta Ichthyol. Piscat. 50 (3): 333–348.

Background. The climate changes observed in the world over the past several decades strongly affect global aquaculture and fisheries. Ukraine is among the 24 countries, whose aquaculture and inland fisheries are currently facing medium stress, and will be potentially under higher stress in the future. The purpose of our work was to find a relation between air temperature and its impact on the spreading of infectious in freshwater aquaculture of Ukraine in the context of global climate change.
Material and methods. During 2011–2017, an epizootiological survey on experimental fishery farms of different patterns of ownership was conducted. The objects of research were the clinically healthy and diseased freshwater fish of different age groups, as well as parasites and bacteria of different etiological groups that affect aquatic organisms. A review of the clinical and parasitological study of different age groups and hybrids of silver carp, *Hypophthalmichthys molitrix* (Valenciennes, 1844) and bighead carp, *Hypophthalmichthys nobilis* (Richardson, 1845), common carp, *Cyprinus carpio* Linnaeus, 1758, and some cultured rainbow trout, *Oncorhynchus mykiss* (Walbaum, 1792), and brown trout, *Salmo trutta Linnaeus*, 1758 were conducted. Research methods common for ichthyopathology, microbiology, and fisheries were used.
Results. The study on fish diseases was conducted both in aquaculture and natural waters, in particular in the reservoirs of the Dnieper Cascade. Not only the growth and development of fish but also the signs and the course of various diseases appeared to depend on water temperature. The resistance of the fish and other hydrobionts to the influence of threshold temperatures depends on their adaptation to particular factors. In the years with a relatively warm vegetation period, the infection rates significantly increased to 25% and above. A significant broadening of the spectrum of parasitic infections over the last decade has been noted. An ecological misbalance in the ecosystems, an increase in the level of organic pollution of water, and, as a result, in the number of pathogenic microorganisms that may be harmful to fish and human health were registered.
Conclusion. Taking into account the results of the analytical studies regarding climate change in Ukraine, we can predict outbreaks of bacterial and parasitic diseases in fish in the years to come, which may cause significant economic damage to aquaculture farms.

Keywords: fish farms, pisciculture, aquaculture, inland waters, global warming

INTRODUCTION

The climate changes observed all over the world in the past several decades strongly affect global aquaculture and fisheries (Cochrane et al. 2009, Morgan and Wall 2009). This is caused by different factors, such as the degradation of habitats, changes in aquatic ecosystems, and the introduction of non-indigenous biota (Kriticos et al. 2003, Yazdi and Shakouri 2010). The influence of global warming on the risk of the development of some diseases in aquatic animals has already been registered (Karvonen et al. 2010).

There are 24 countries in the world, whose aquaculture and inland fisheries are facing medium, and will potentially be under higher stress in the future (Harrod et al. 2019). Among the European countries, there are Finland, Germany, Poland, Sweden, and Ukraine. At the current stage of the economic development of Ukraine, one of the most important tasks is to improve the living standards of the population, to provide necessary foods, and to ensure the safety of raw materials and food products (Andrûŝenko et al. 2014). The rising production and consumption of fish,

* Correspondence: Dr Yuriy Kvach, Institute of Marine Biology, National Academy of Science of Ukraine, Vul. Pushkinska 37, 65048 Odessa, Ukraine, phone/fax: +38 (048) 725-09-18, e-mail: (YK) *yuriy.kvach@gmail.com*, (NM) *mnarine73@ukr.net*, (AL) *annlevchenko22.12@gmail.com*, (OD) *olexdan@ukr.net*, ORCID: (YK) 0000-0002-6122-4150, (NM) 0000-0001-8849-0099.

which is currently two times lower compared to the level in 1990 (Matvienko et al. 2015), is of great importance in solving these problems.

In terms of nutritional value, the fish flesh is inferior to the meat of domestic animals, but the assimilation rate in the human body far exceeds that of beef (Olìjnik unpublished*). Increasing the volume of fish, fish products, and ensuring a high quality of fish as food depends on the animal health status of fish farms and on climatic conditions. However, in recent years a continued increase and conservation of commercial and pond fish stocks has been largely hindered by almost annual outbreaks of new and poorly known bacterial and parasitic fish diseases that caused mass mortalities (Davydov et al. 2012). The traditional aquaculture species in Ukraine is common carp, *Cyprinus carpio* Linnaeus, 1758, however, recently, rainbow trout, *Oncorhynchus mykiss* (Walbaum, 1792); sturgeons (fam. Acipenseridae); and Philippine catfish, *Clarias batrachus* (Linnaeus, 1758), are actively cultivated in closed water bodies (Matvienko et al. 2015).

The territory of Ukraine is rich with different types of water bodies. The human population which inhabits the river banks is commonly suffering from annual floods, with extremely abnormal ones in the Danube at 2005, in the Dniester and Transcarpathian rivers at August 2008, as well extreme snowing in the western and central Ukraine in December 2009 and March 2013, affecting the economy of the regions (Diduh 2014). Thus, Ukraine fully experiences the effects of climate changes, in particular, those recorded for the western and southern regions of Ukraine.

The rapid growth of aquaculture is primarily driven by a significant decline in natural fish stock and the development of inland water resources, as well as the need to provide valuable food to the population (Mansfield 2010). Year after year, the epizootic situation in Ukraine in both specialized farms and natural water bodies has been worsening. Among the important factors for the emergence and spread of fish diseases under modern environmental conditions are changes in climatic conditions with relatively warm winters and hot summers with high water temperatures, which contribute to an accumulation of organic matter in water reservoirs; the development of pathogens of fish diseases; as well as the increase of anthropogenic load in aquatic ecosystems accompanied by the release of various contaminants into reservoirs (Evtušenko et al. 2015). Thus, the purpose of our work was to find a relation between the air temperature and its impact on the spreading of infectious in freshwater aquaculture of Ukraine in the context of global climate change.

MATERIALS AND METHODS

The epizootiological surveys in experimental fish farms with different ownership profiles were conducted in 12 administrative regions (oblasts) of Ukraine within 2011–2017 (Table 1). A total of 777 fish representing 14 species-level taxa and two hybrids were studied for parasites and pathogens in pond aquaculture. The study covered two species of sturgeons (Acipenseridae) and one hybrid, three species of salmonids (Salmonidae), 8 species and one hybrid of cyprinids (Cyprinidae), and one esocid (Esocidae) (Table 1). The following fish species were examined: *Acipenser gueldenstaedtii* Brandt et Ratzeburg, 1833; *Acipenser ruthenus* Linnaeus, 1758; *Huso huso* (Linnaeus, 1758) × *Acipenser ruthenus*; *Carassius gibelio* (Bloch, 1782); *Ctenopharyngodon idella* (Valenciennes, 1844); *Cyprinus carpio*; *Hypophthalmichthys molitrix* (Valenciennes, 1844); *Hypophthalmichthys nobilis* (Richardson, 1845); *Hypophthalmichthys molitrix* × *Hypophthalmichthys nobilis*; *Hypophthalmichthys* spp.; *Rutilus rutilus* (Linnaeus, 1758); *Tinca tinca* (Linnaeus, 1758); *Esox lucius* Linnaeus, 1758; *Oncorhynchus mykiss*; *Salmo trutta* Linnaeus, 1758; *Salvelinus fontinalis* (Mitchill, 1814) (Table 1). The fish were sampled in different aquaculture and fisheries farms monthly from April to September. The trout aquaculture farms were studied only in three regions of Ukraine (Chernivtsi, Lviv, and Zakarpattia oblasts), the sturgeon farms—in two regions (Chernihiv and Odessa oblasts), in all other regions, carp farms were studied.

The data from the annual reports of the Institute of Fisheries, Kyiv (Matvìênko and Vaŝenko unpublished**) on studies of fish parasites in the reservoirs of the Dnieper River Cascade (Kamyanske, Kaniv, and Kyiv Reservoirs), in the Yavoriv Reservoir, and the Vistula River basin (Table 2) were used. These represent data on 440 fish related to 15 taxa, including 10 cyprinid taxa, one catfish (Siluridae), one esocid (Esocidae), one goby (Gobiidae), and two percids (Percidae): *Abramis brama* (Linnaeus, 1758); *Blicca bjoerkna* (Linnaeus, 1758); *Carassius gibelio*; *Cyprinus carpio*; *Hypophthalmichthys* spp.; *Leuciscus aspius*

---

* Olìjnik [Oliynyk] O.B. 2018. Krustaceozi koropodih rib: posirennâ, dìagnostika ta lìkuval′no-profìlaktičnì zahodi. [Carp fish Crustacean diseases: Spreading, diagnostics and medioprophylactic measures.] Abstract of PhD Thesis in Parasitology. National University of Life and Environmental Sciences of Ukraine, Kiïv, Ukraine. [In Ukrainian with English summary.]

** Matvìênko [Matvienko] N.M., Vaŝenko [Vashchenko] A.V. 2015. Zvìt pro naukovo-doslìdnu robotu za zavdannâm 28.00.02.02F "Doslìditi bìologìčnì ta ekologo-geografìčnì osoblivostì poširennâ zbudnikìv hvorob promislovih vidìv rib i vprovaditi molekulârnì metodi doslìdžennâ vidìlennih patogenìv (2011–2015 roki)". [Report of Scientific Research Study on the task 28.00.02.02F "To study the biological and eco-geographical traits of spread of pathogens of commercial fish species and to provide molecular methods of the study of isolated pathogens (2011–2015)".] Institut rybnogo gospodarstva NAAN, Kiïv, Ukraine. [In Ukrainian.]

Matvìênko [Matvienko] N.M., Vaŝenko [Vashchenko] A.V. 2016. Zvìt pro naukovo-doslìdnu robotu za zavdannâm 33.00.00.04F "Doslìditi mehanìzmi poširennâ ìnvazìjnih ta infekcìjnih zahvorûvan′ rib v umovah prìsnovodnoï akvakulturi Ukraïni. Etap 2016 roku: Doslìditi osoblivostì poširennâ ìnvazìjnih ta infekcìjnih zahvorûvan′ rib v umovah prìsnovodnoï akvakulturi Ukraïni". [Report of Scientific Research Study on the task 33.00.00.04F "To study the triggers of spread of parasitic and infection diseases of fish under conditions of freshwater aquaculture in Ukraine. Stage 2016: To study the traits of spread of parasitic and infection diseases of fish under conditions of freshwater aquaculture in Ukraine".] Institut rybnogo gospodarstva NAAN, Kiïv, Ukraine. [In Ukrainian.]

Matvìênko [Matvienko] N.M., Vaŝenko [Vashchenko] A.V. 2017. Zvìt pro naukovo-doslidnu robotu za zavdannâm 33.00.00.04F "Doslìditi mehanìzmi poširennâ ìnvazìjnih ta infekcìjnih zahvorûvan′ rib v umovah prìsnovodnoï akvakulturi Ukraïni. Etap 2017 roku: Ocìniti situacìû ščodo poširennâ ìnvazìjnih zahvorûvan′ osnovnih promislovih vidìv rib u vnutrìšnih vodojmah Ukraïni". [Report of Scientific Research Study on the task 33.00.00.04F "To study the triggers of spread of parasitic and infection diseases of fish under conditions of freshwater aquaculture in Ukraine. Stage 2017: To evaluate the situation with the spread of parasitic diseases of main commercial fish species in inland water bodies of Ukraine".] Institut rybnogo gospodarstva NAAN, Kiïv, Ukraine. [In Ukrainian.]

Table 1

The commercial fish species and their numbers (*N*), studied for parasite and pathogens in aquaculture farms in different regions of Ukraine

Administrative region	Sampling coordinates	Fish species	N
Chernihiv Oblast	51°26′00.9″N, 31°15′22.4″E	*Acipenser ruthenus*	6
		Cyprinus carpio	15
Chernivtsi Oblast	48°21′16.9″N, 25°18′35.7″E	*Oncorhynchus mykiss*	40
	48°09′17.5″N, 25°18′23.8″E	*Salmo trutta*	20
		Salvelinus fontinalis	12
	48°21′55.7″N, 22°48′45.7″E	*Cyprinus carpio*	6
Dnipropetrovsk Oblast	48°49′42.9″N, 34°48′29.8″E	*Ctenopharyngodon idella*	30
		Cyprinus carpio	15
		Hypophthalmichthys spp.	15
Donetsk Oblast	48°51′02.1″N, 37°31′53.5″E	*Carassius gibelio*	25
	48°52′21.1″N, 37°32′15.0″E	*Cyprinus carpio*	30
	48°56′39.4″N, 37°26′26.3″E	*H. molitrix* × *H. nobilis*	10
	48°58′59.9″N, 37°26′20.9″E		
Kharkiv Oblast	49°53′35.6″N, 36°15′45.5″E	*Cyprinus carpio*	10
		Hypophthalmichthys molitrix	10
Kherson Oblast	46°27′10.2″N, 32°22′45.6″E	*Cyprinus carpio*	10
		Ctenopharyngodon idella	10
		Hypophthalmichthys molitrix	10
		Hypophthalmichthys nobilis	10
Kyiv Oblast	50°06′11.9″N, 29°56′00.9″E	*Carassius gibelio*	25
	50°18′08.7″N, 30°27′09.7″E	*Ctenopharyngodon idella*	10
	50°28′40.5″N, 30°04′55.2″E	*Cyprinus carpio*	25
		Hypophthalmichthys nobilis	10
		Rutilus rutilus	10
		Tinca tinca	5
		Esox lucius	5
Lviv Oblast	49°23′28.8″N, 23°38′39.6″E	*Oncorhynchus mykiss*	40
	49°53′33.9″N, 23°45′23.9″E		
	49°43′40.0″N, 23°42′54.2″E	*Carassius gibelio*	20
	49°27′56.5″N, 23°54′38.4″E	*Ctenopharyngodon idella*	10
		Cyprinus carpio	40
		H. molitrix × *H. nobilis*	30
		Tinca tinca	6
Odessa Oblast	45°27′31.7″N, 29°33′02.2″E	*Acipenser gueldenstaedtii*	6
		Acipenser ruthenus	6
		Huso huso × *Acipenser ruthenus*	6
		Ctenopharyngodon idella	10
		Cyprinus carpio	30
		Hypophthalmichthys molitrix	10
		Hypophthalmichthys nobilis	10
Rivne Oblast	50°18′32.7″N, 26°08′11.3″E	*Oncorhynchus mykiss*	25
	50°12′08.2″N, 25°41′19.7″E	*Carassius gibelio*	16
	50°12′31.1″N, 25°19′36.5″E	*Ctenopharyngodon idella*	15
		Cyprinus carpio	12
		H. molitrix × *H. nobilis*	10
		Esox lucius	15
Zakarpattia Oblast	48°43′44.3″N, 22°49′59.5″E	*Oncorhynchus mykiss*	30
	48°21′55.7″N, 22°48′45.7″E	*Cyprinus carpio*	30
		Hypophthalmichthys molitrix	30
		Hypophthalmichthys nobilis	20
Zhytomyr Oblast	50°10′56.4″N, 29°13′36.5″E	*Carassius gibelio*	10
		Ctenopharyngodon idella	5
		Cyprinus carpio	6
		H. molitrix × *H. nobilis*	5

(Linnaeus 1758); *Leuciscus idus* (Linnaeus, 1758); *Rutilus rutilus*; *Scardinius erythrophthalmus* (Linnaeus, 1758); *Tinca tinca*; *Silurus glanis* Linnaeus, 1758; *Esox lucius*; *Neogobius fluviatilis* (Pallas, 1814); *Perca fluviatilis* Linnaeus, 1758; *Sander lucioperca* (Linnaeus, 1758) (Table 2).

The research methods used are common/established for ichthyopathology, microbiology, and fisheries domains (Pritchard and Kruse 1982, Bauer 1987, Davydov et al. 2012). The parasites were preserved as permanent slides and studied in light microscopy to identify species. The epizootic survey of the aquaculture farms was conducted as a planned inspection of fish farms adopted in ichthyopathology (Gaevs′ka 2004). The microbiological studies were provided in three stages:

- Preliminary sowing on tryptone-soya agar (TSA), which was then incubated at 26°C for 24 h.
- obtaining pure cultures of the microorganisms and study of their morphological features.
- determination of DNAse activity of obtained stains (Bauer et al. 1981).

Standard examination for fish parasites was conducted according to Buchmann (2007). Fresh mucus smears were separately collected from gills, skin, and fins to identify protozoan parasites by microscopic examination (Lom and Dykova 1992). Morphological identification of the protozoan parasites was performed directly on wet mounts of gills, skin, and fins mucus under a microscope at 10× to 40× magnification.

Collected parasites were fixed in 70% ethanol for subsequent identification. As regards the parasitic diseases, the infection levels were evaluated by the parasitological parameters, i.e., the prevalence (PR) [%] which is the number of infected hosts divided by the number of examined hosts (×100); the mean intensity of infection (MI) which is the total number of collected parasites divided by the number of infected hosts; and the intensity range (IR) which is the number of parasites in one infected host body, were calculated according to Bush et al. (1997). The standard deviation (SD) was calculated for mean parameters.

The identification was carried out following the generally accepted recommendations by Bergey's manual of systematic bacteriology (Krieg and Holt 1984). The express identification of bacteria was made using API 20E

Table 2

Commercial fish species and its number (*N*) studied for parasites in different dam reservoirs in Ukraine

Reservoir	Sampling coordinates	Fish species	N
Kamyanske Reservoir	48°33′06.6″N, 34°29′38.1″E	*Abramis brama*	23
		Rutilus rutilus	20
		Sander lucioperca	10
		Esox lucius	10
		Perca fluviatilis	25
Kaniv Reservoir	49°58′33.7″N, 31°03′32.3″E	*Abramis brama*	35
		Blicca bjoerkna	15
		Leuciscus aspius	15
		Rutilus rutilus	25
		Sander lucioperca	10
		Scardinius erythrophthalmus	10
		Tinca tinca	10
		Silurus glanis	6
		Esox lucius	6
		Perca fluviatilis	15
Kyiv Reservoir	50°52′11.3″N, 30°33′59.8″E	*Abramis brama*	20
		Blicca bjoerkna	10
		Leuciscus aspius	10
		Leuciscus idus	10
		Rutilus rutilus	25
		Sander lucioperca	10
		Scardinius erythrophthalmus	10
		Esox lucius	6
		Perca fluviatilis	12
		Neogobius fluviatilis	30
Yavoriv Reservoir	49°56′43.9″N, 23°28′18.7″E	*Carassius gibelio*	10
		Cyprinus carpio	12
		Hypophthalmichthys spp.	10
		Rutilus rutilus	8
		Tinca tinca	6
		Esox lucius	6
		Perca fluviatilis	10

standardized test system (BioMerieux, France) based on 21 biochemical tests. The cultures were incubated for 18–24 h. The results were analyzed visually and assessed using the color key table. The mean air temperatures for the growing season (April–September) were used in the analysis.

The temperature regime is one of the most important factors among the climatic and meteorological conditions affecting the formation of the natural food base, development, and growth of fish. Based on the number of days in the year with the effective aquaculture air temperature above 15°C, the territory of Ukraine was divided into 4 aquaculture (fisheries) zones (Table 3). The pond aquaculture areas in Ukraine are shown in Fig. 1.

All the zones are characterized by a temporary continental climate. Then, we provide the characteristics of individual zones in accordance with Osipčuk (2008). The zone A (Polesie) has a relatively high level of precipitation, 500–600 mm per year. Droughts are rare, the warmest month (July) features air temperatures from 17 to 19°C. Zone B (Forest steppe and Carpathians) compose up to 34% of Ukraine territory. The January air temperatures are from –5 to –8°C, the July ones from 18 to 22°C. The precipitation values range from 550–750 mm in the west to 450 mm in the east. In the Carpathians, the precipitation is 800–2000 mm and more. The vegetation period is 200–210 days per year. The steppe zone in Ukraine comprises 39.7% of the territory and is divided into two parts: Zone C (Northern Steppe) and Zone D (Southern Steppe). The precipitation is about 300–450 mm per year and droughts are frequent. The period without frosts comprises 160–220 days while the active vegetation from 160 to 195 days. The mean annual air temperatures increase from the northern-east (Zone C; +7.5°C at summer and –7°C at winter) to the south-west (Zone D; +11°C at summer and 0°C at

Table 3

The aquaculture/fisheries zones of Ukraine in relation to the number of warm days per year (the zones shown on the map, Fig. 1)

Code	Aquaculture/fisheries zone	Warm days number	Administrative regions of Ukraine
A	Polesie	91–105	Khmelnytskyi Oblast, Kyiv Oblast (northern part), Lviv Oblast, Rivne Oblast, Sumy Oblast, Ternopil Oblast, Volyn Oblast, Zhytomyr Oblast
B	Forest steppe and Carpathians	106–120	Cherkassy Oblast, Chernivtsi Oblast, Ivano-Frankivsk Oblast, Kharkiv Oblast, Kyiv Oblast (southern part), Poltava Oblast, Vinnytsia Oblast, Zakarpattia Oblast
C	Northern Steppe	121–135	Dnipropetrovsk Oblast, Donetsk Oblast, Kirovohrad Oblast, Luhansk Oblast, Zaporizhzhia Oblast (northern part)
D	Southern Steppe	136–150	Crimea, Kherson Oblast, Mykolaiv Oblast, Odessa Oblast, Zaporizhzhia Oblast (southern part)

Warm days number = number of days per year with an air temperature higher than 15°C.

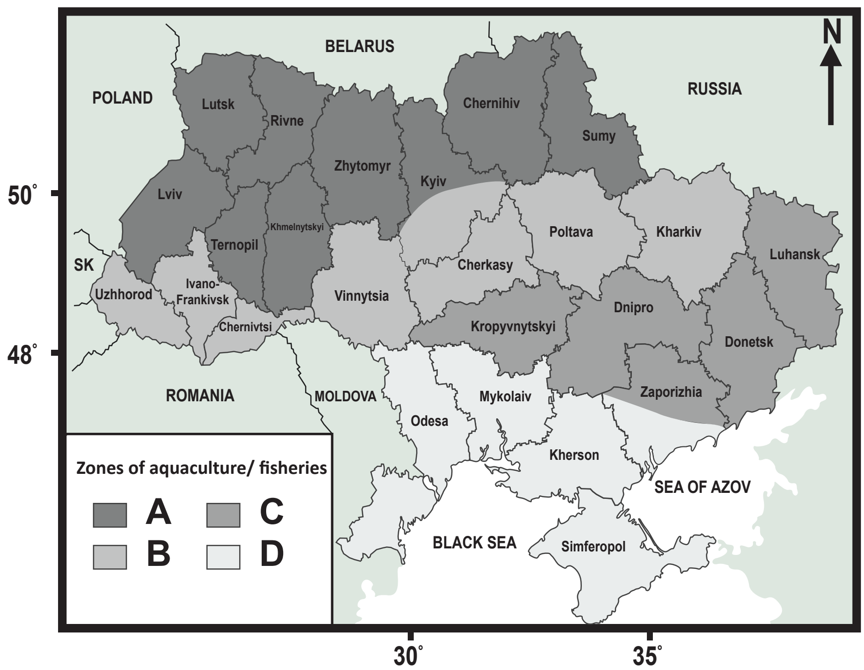

Fig. 1. The map of aquaculture/fisheries zones of Ukraine territory. See Table 3 for zones codes

winter). Mean diel air temperatures in July increased in a spectacular way from +21.5°C to +23°C).

The analysis of the dependence of the cases of parasitic and bacterial diseases on the mean air temperature in different years was carried out in four different aquaculture/fisheries zones (Table 3, Fig. 1). The air temperature data by months were provided by the Ukrainian Hydrometeorological Center and used in the analysis for each related zone of fisheries. Two regions were chosen as representative samples for each zone, except for Zone C (where only Dnipropetrovsk oblast was representative). For Zone A Kyiv and Lviv oblasts were used, for Zone B, Kharkiv and Zakarpattia oblasts, and for Zone D, Kherson and Odessa oblasts. All statistical analyses were conducted using the Quantitative Parasitology 3.0 web application (Rózsa et al. 2000).

RESULTS

A total of 19 parasite species was found in pond aquaculture in Ukraine (Table 4). 24% of the present parasites were ciliates *Apiosoma piscicola* (Blanchard, 1885), *Chilodonella cyprini* (Moroff, 1902), *Ichthyophthirius multifiliis* Fouquet, 1876, *Trichodina* spp. (Fig. 2). Four parasite taxa were presented by crustaceans, namely *Argulus* sp., *Ergasilus* sp., *Lernaea cyprinacea* Linnaeus, 1758, *Sinergasilus major* (Markevich, 1940), *Sinergasilus polycolpus* (Markevich, 1940), which in total accounted for 23% of the infection cases. The digeneans (17%) are presented by *Diplostomum* spp., *Posthodiplostomum cuticola* (von Nordmann, 1832), the cestodes (15%) by *Caryophyllaeus fimbriceps* Annenkova-Chlopina, 1919, *Khawia sinensis* Hsü, 1935, *Ligula intestinalis* (Linnaeus, 1758), *Schyzocotyle acheilognathi* (Yamaguti, 1934), *Triaenophorus nodulosus* (Pallas, 1781), and the monogeneans (15%) represented by *Dactylogyrus vastator* Nybelin, 1924, and *Gyrodactylus* spp. The remining parasitic infections (8%) were caused by the nematodes *Philometroides* sp. and leeches *Piscicola geometra* (Linnaeus, 1761) (Fig. 2).

Furthermore, the epizootic situation in aquaculture farms involved in the artificial reproduction of salmonid fish was studied. We registered the mortality of the trout fry caused by the infection with saprogenic fungi and the ciliate *Ichthyophthirius multifiliis*; in the older age groups of the trout. A detailed study revealed the infection with metacercariae of *Diplostomum* spp. (Table 4).

The highest number of parasite taxa (9) occurred in the fish from the Kyiv Reservoir, where 8 fish species (*Abramis brama*, *Leuciscus idus*, *Rutilus rutilus*, *Sander lucioperca*, *Esox lucius*, *Perca fluviatilis*, *Neogobius fluviatilis*) were found to be infected, but three other species (*Blicca bjoerkna*, *Leuciscus aspius*, *Scardinius erythrophthalmus*) were not infected (Table 5). The most prevalent parasite was the ciliate *Ichthyophthirius multifiliis* (PR = 85.7%), found in skin and fins of *Abramis brama* and the nematode Eustrongylides *excisus* Jägerskiöld, 1909 (PR up to 85%), found in the viscera and mesenteries of *Sander lucioperca*, *Perca fluviatilis*, and *Neogobius fluviatilis*. In the Kamyanske Reservoir and the Kaniv Reservoir, we registered 5 and 4 taxa of disease agents, respectively (Table 5). *Diplostomum* spp. was found to be the most prevalent in both water bodies. Metacercariae of the opistorchid *Pseudamphistomum truncatum* (Rudolphi, 1819) from the muscles of *Abramis brama* only in the Kamyanske Reservoir with low prevalence. Only three taxa of the disease agents infecting three different fishes (*Carassius gibelio*, *Cyprinus carpio*, *Hypophthalmichthys* spp.) were registered in the Yavoriv Reservoir (Table 5).

With regards to bacterial diseases, the microbiological study of both water and fish showed a wide species spectrum of microorganisms: *Aeromonas* (PR = 40%), *Pseudomonas* (PR = 28%), and less frequently *Edwardsiella*, *Proteus*, *Yersinia*, *Flavobacterium*, and *Micrococcus* (Table 6). In particular, the bacteria of genera *Aeromonas* and *Flavobacterium* were isolated mainly from fry and fingerlings of rainbow trout (*Oncorhynchus mykiss*), while *Pseudomonas*, *Aeromonas* were detected in cyprinids, i.e., common carp (*Cyprinus carpio*), and *Yersinia* recovered from sturgeons (Table 6). The general situation with the presence of fish bacterial diseases is shown in and Fig. 3.

Psychrophilic bacteria belonging to the genera *Pseudomonas, Aeromonas*, and *Flavobacterium* prevailed in fish studied in the cold season. In the warm season, the microflora of the skin and internal organs was represented by mesophilic microorganisms, i.e., various types of bacteria of the genus *Micrococcus*, and *Corynebacterium*. The representatives of the genus *Proteus* (i.e. *Proteus morganii*) and the Enterobacteriaceae family (i.e., *Escherichia coli*) were also identified as indicators of pollution of the water bodies.

Among bacterial diseases of fish, the erythroderma-like disease of carp (caused by *Aeromonas, Pseudomonas*) and the bacterial disease of trout (caused by *Aeromonas, Flavobacterium, Yersinia*, and *Renibacterium*) were recorded in fish farms under consideration. In young sturgeons, diseases associated with an unbalanced diet and bacterial infections were reported. The erythroderma-like disease of carp was registered in examined fish from Lviv, Sumy, and Kyiv oblasts (Table 6). Also, we registered the necrosis of gills (Lviv Oblast), the chronic form of swim bladder inflammation in carp (Rivne Oblast), and a bacterial disease in young trout (Chernivtsi and Zakarpattia oblasts).

The analysis of parasitic and bacterial disease cases revealed a dependence on the mean air temperature in all representative regions for each of the four aquaculture zones of Ukraine (Fig. 4–7). Having analyzed the situation from both the quantitative and species viewpoints, we confirmed a trend to increase of parasites numbers and their species composition during the observation period, i.e., from 11 main groups in 2006–2010 to 17 in 2011–2017 (Fig. 8).

DISCUSSION

The fish production obtained from the natural forage base depends on the condition of the water body and consumption by the fish (Eggers et al. 1978). The material and energy basis of all subsequent stages of the production process in the water body implies the forming of organic matter using minerals in the course of the producents' life.

Table 4

Parasites registered in aquaculture fish in different regions of Ukraine

Fish species	Parasite species	PR	IR	MI
	Chernihiv Oblast			
Acipenser ruthenus	*Lernaea cyprinacea*	60	3–5	2.6±1.9
Cyprinus carpio	*Schyzocotyle acheilognathi*	10	1–3	1.7 ± 0.8
	Piscicola geometra	10	2–3	2.2 ± 0.4
	Chernivtsi Oblast			
Oncorhynchus mykiss	*Apiosoma piscicola*	7	1–2	1.4 ± 0.5
	Dactylogyrus vastator	40	10–15	12.5 ± 1.8
	Gyrodactylus sp. 1	60	10–12	11.0 ± 0.8
Salmo trutta	*Gyrodactylus* sp. 2	25	5–7	6.0 ± 0.8
Salvelinus fontinalis	*Argulus* sp.	30	3–5	4.0 ± 0.9
Cyprinus carpio	*Caryophyllaeus fimbriceps*	40	6–15	10.2 ± 3.6
	Khawia sinensis	20	3–5	4.0 ± 0.8
	Dnipropetrovsk Oblast			
Ctenopharyngodon idella	*Ligula intestinalis*	8	1–2	1.5 ± 0.5
	Sinergasilus major	40	1–5	2.5 ± 1.6
Cyprinus carpio	*Khawia sinensis*	30	1–4	2.1 ± 1.3
	Schyzocotyle acheilognathi	10	1–2	1.4 ± 0.5
Hypophthalmichthys molitrix	*Posthodiplostomum cuticola*	20	1–3	1.6 ± 0.8
	Donetsk Oblast			
Carassius gibelio	*Ichthyophthirius multifiliis*	60	5–30	13.5 ± 8.8
Cyprinuscarpio	*Ichthyophthirius multifiliis*	65	15–40	23.8 ± 9.0
	Schyzocotyle acheilognathi	10	1–4	2.1 ± 1.3
H. molitrix × *H. nobilis*	*Posthodiplostomum cuticola*	50	5–13	9.2 ± 2.9
	Kharkiv Oblast			
Cyprinus carpio	*Ichthyophthirius multifiliis*	60	3–15	8.8 ± 4.5
	Lernaea cyprinacea	50	5–7	5.8 ± 0.8
Hypophthalmichthys molitrix	*Posthodiplostomum cuticola*	50	5–8	6.4 ± 1.3
	Kherson Oblast			
Cyprinus carpio	*Trichodina* spp.	20	3–15	8.0 ± 4.4
Ctenopharyngodon idella	*Sinergasilus major*	60	10–25	15.7 ± 5.2
Hypophthalmichthys molitrix	*Posthodiplostomum cuticola*	50	7–11	9.0 ± 1.5
Hypophthalmichthys nobilis	*Diplostomum* spp.	60	2–6	3.3 ± 1.4
	Kyiv Oblast			
Carassius gibelio	*Schyzocotyle acheilognathi*	30	1–2	1.4 ± 0.5
Ctenopharyngodon idella	*Sinergasilus major*	25	10–15	11.8 ± 1.8
Cyprinus carpio	*Chilodonella cyprini*	30	1–10	4.5 ± 3.0
	Ichthyophthirius multifiliis	80	5–17	10.2 ± 4.9
	Dactylogyrus vastator	70	5–25	11.6 ± 6.4
	Khawia sinensis	25	3–12	6.5 ± 3.5
	Philometroides sp.	7	2–5	3.0 ± 1.0
	Argulus sp.	70	8–10	8.7 ± 0.8
	Lernaea cyprinacea	40	6–10	7.4 ± 1.5
Hypophthalmichthys nobilis	*Sinergasilus major*	20	7–12	8.7 ± 1.8
	Posthodiplostomum cuticola	40	7–30	15.7 ± 9.9
Rutilus rutilus	*Khawia sinensis*	30	3–5	3.8 ± 0.8
Tinca tinca	*Lernaea cyprinacea*	50	1–5	2.8 ± 1.7
Esox lucius	Not found			
	Lviv Oblast			
Carassius gibelio	*Lernaea cyprinacea*	70	7–11	8.3 ± 1.4
Ctenopharyngodon idella	*Argulus* sp.	30	2–7	4.0 ± 1.6
Cyprinus carpio	*Ichthyophthirius multifiliis*	70	5–18	10.1 ± 4.0
	Dactylogyrus vastator	60	3–15	6.7 ± 3.8
	Caryophyllaeus fimbriceps	40	7–15	9.6 ± 2.5
	Lernaea cyprinacea	90	5–24	11.0 ± 5.5

Table continues on next page.

Table 4 cont.

Fish species	Parasite species	PR	IR	MI
H. molitrix × *H. nobilis*	*Posthodiplostomum cuticola*	40	5–12	8.0 ± 2.4
Tinca tinca	Not found			
Oncorhynchus mykiss	*Ichthyophthirius multifiliis*	60	7–21	11.6 ± 2.5
	Diplostomum spp.	70	10–12	10.6 ± 0.9
	Gyrodactylus sp.	60	7–20	13.3 ± 4.3
	Odessa Oblast			
Acipenser gueldenstaedtii	Not found			
A. ruthenus	Not found			
Huso huso × *A. ruthenus*	*Argulus* sp.	7	1–3	1.7 ± 0.8
Ctenopharyngodon idella	*Argulus* sp.	20	1–3	2.3 ± 0.8
	Sinergasilus major	80	7–30	15.7 ± 7.3
Cyprinus carpio	*Ichthyophthirius multifiliis*	80	20–40	26.8 ± 7.1
	Caryophyllaeus fimbriceps	45	7–17	10.9 ± 3.1
	Khawia sinensis	30	3–6	4.8 ± 1.0
	Lernaea cyprinacea	90	15–30	20.2 ± 4.8
Hypophthalmichthys molitrix	*Posthodiplostomum cuticola*	40	5–12	8.5 ± 2.3
Hypophthalmichthys nobilis	*Diplostomum* spp.	30	3–4	3.5 ± 0.52
	Rivne Oblast			
Carassius gibelio	*Argulus* sp.	35	3–5	4.0 ± 0.8
Ctenopharyngodon idella	*Sinergasilus polycolpus*	30	5–10	7.5 ± 1.8
Cyprinus carpio	*Ichthyophthirius multifiliis*	40	11–17	12.8 ± 2.2
	Lernaea cyprinacea	30	5–7	5.7 ± 0.8
Esox lucius	Not found			
H. molitrix× *H. nobilis*	*Diplostomum* spp.	15	2–4	3.1 ± 0.9
Oncorhynchus mykiss	*Apiosoma piscicola*	12	5–20	11.4 ± 5.3
	Trichodina spp.	80	5–20	9.8 ± 4.9
	Gyrodactilus sp.	30	5–15	8.8 ± 3.3
	Zakarpattia Oblast			
Oncorhynchus mykiss	*Ichthyophthirius multifiliis*	30	7–25	11.5 ± 5.5
	Gyrodactylus sp.	60	7–20	12.7 ± 4.2
	Diplostomum spp.	40	10–12	10.4 ± 0.6
Cyprinus carpio	*Caryophyllaeus fimbriceps*	30	10–12	10.3 ± 0.6
	Khawia sinensis	15	1–2	1.4 ± 0.5
Hypophthalmichthys molitrix	*Posthodiplostomum cuticola*	40	5–8	5.9 ± 0.9
Hypophthalmichthys nobilis	*Lernaea cyprinacea*	50	7–15	9.4 ± 2.6
	Zhytomyr Oblast			
Carassius gibelio	*Trichodina* spp.	60	8–17	11.1 ± 2.9
Ctenopharyngodon idella	*Sinergasilus polycolpus*	60	8–10	8.9 ± 0.9
Cyprinus carpio	*Ichthyophthirius multifiliis*	40	7–12	9.0 ± 1.6
	Khawia sinensis	30	3–7	4.4 ± 1.6
	Ergasilus sp.	18	3–10	5.5 ± 2.4
H. molitrix × *H. nobilis*	*Diplostomum* spp.	20	3–5	3.6 ± 0.9

PR = prevalence (%), IR = intensity range, MI = mean intensity (± standard deviation).

In Ukraine, fisheries-related calculations are based on the mean value of natural productivity, which is determined by fish and the biological standards (Andrûŝenko et al. 2014).

Growth and development of fish depend not only on water temperature but also on the nature and course of various diseases. The resistance of fish and other aquatic organisms to threshold temperatures depends on their adaptation to particular temperatures. Different fish species and their life stages (eggs, larvae, fries, and juveniles) require certain temperatures for development. Abrupt temperature fluctuations can cause severe stress, resulting in a decrease in fish resistance to diseases. Temperature not only influences fish condition, but also the development of parasites and the occurrence of various diseases. Some infectious diseases in fish, including the viral ones, occur in relatively cold water (around 10–12°C), while bacterial diseases are more acute at higher water temperatures (18–25°C and higher) (Matvienko et al. 2015). Besides, depending on water temperature, pathogens accumulate some concomitant parasitic diseases (ichthyophthyriosis, dactylogyrosis) (Khan et al. 2003, Davydov et al. 2012). The increase in the water temperature contributes to the acceleration of the parasites' development cycles and consequently increases the number of generations (Morgan

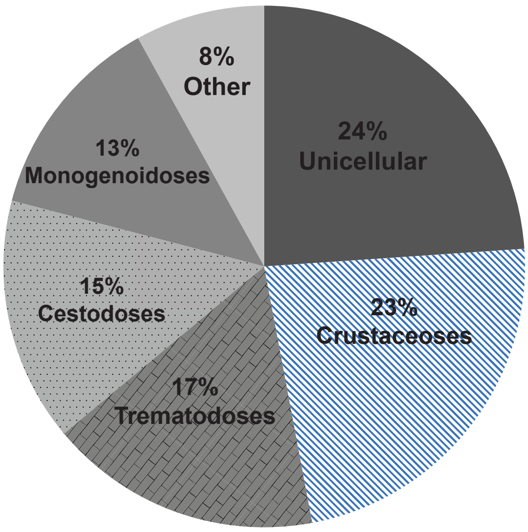

Fig. 2. Parasite occurrence in fish in inland waters of Ukraine during period 2011–2017

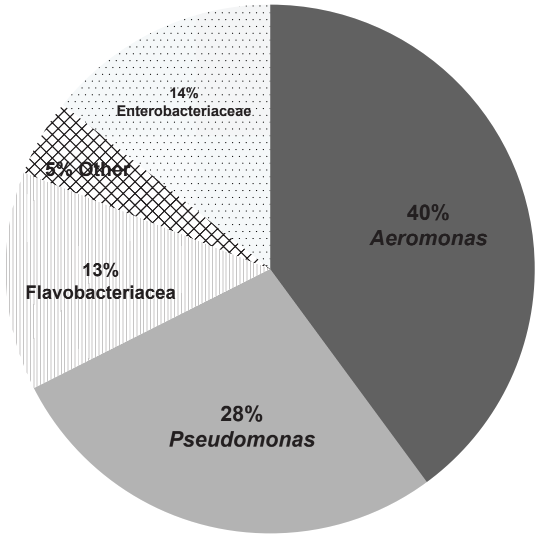

Fig. 3. Bacterial diseases of fish from pond aquaculture in Ukraine

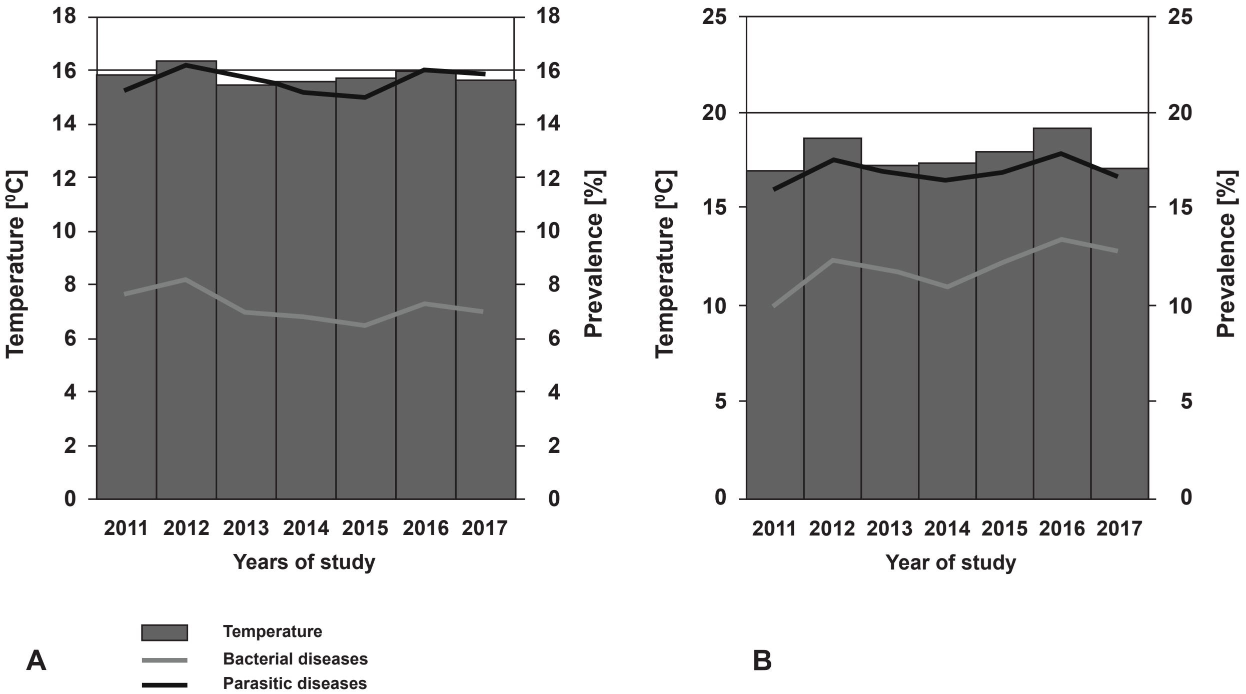

Fig. 4. Dependence of bacterial and parasitic diseases of fish in Ukraine on the air temperature in Aquaculture Zone A (Polesie); (**A**) Kyiv Oblast; (**B**) Lviv Oblast

and Wall 2009). Also, the physiological state of the fish is deteriorating, which also makes the fish prone to infection. Simultaneously, fish parasites are the most sensitive indicators of the state of the aquatic ecosystems. Their abundance and possible structural anomalies objectively reflect the trophic level of the particular water body and the degree of its anthropogenic pollution (Valtonen et al. 2003). High infection of fish with ciliates and microsporidians indicates higher biogenic contamination of waters. A significant level of fish infection with myxozoans is characterized by the high density of the populations of oligochaetes in the water reservoir. The absence of parasitic crustaceans that are usually resistant to external toxicants indicates that industrial water contamination is limiting their number (Morozińska-Gogol et al. 1998, Morales-Serna et al. 2019).

While analyzing the information presented in the graphs (Fig. 4) we can ascertain the relation between the rate of disease incidence and the temperature regime. Thus, in the years with hot summers there were outbreaks of infectious diseases mainly of bacterial nature (2012, 2015, 2016). This is expected because the rate of bacterial reproduction depends primarily on temperature, as the bacteria divide faster if they encounter favorable conditions. Increased water temperature causes a rapid spread of diseases, and the absence of abrupt day and night

Table 5

Parasites registered in commercial fish in different reservoirs in Ukraine

Fish species	Parasite species	PR[%]	IR	MI
	Kamyanske Reservoir			
Abramis brama	*Ligula intestinalis*	21.9	1–2	1.8 ± 0.4
	Diplostomum spp.	90.6	11–36	21.6 ± 8.8
	Posthodiplostomum cuticola	20.0	2–7	4.1 ± 2.02
	Pseudamphistomum truncatum	1.6	7–13	9.2 ± 2.2
Rutilus rutilus	Not found			
Sander lucioperca	*Eustrongylides excisus*	20.0	3–5	4.4 ± 0.9
Esox lucius	Not found			
Perca fluviatilis	*Eustrongylides excisus*	30.0	7–12	8.6 ± 1.6
	Kaniv Reservoir			
Abramis brama	*Diplostomum* spp.	87.0	2–4	2.8 ± 0.7
Leuciscus aspius	Not found			
Blicca bjoerkna	Not found			
Rutilus rutilus	*Diplostomum* spp.	22.0	1–7	4.6 ± 2.0
	Posthodiplostomum cuticola	25.0	2–15	6.4 ± 4.5
Sander lucioperca	*Dermocystidium* sp.	7.0	1–3	2.0 ± 1.0
	Eustrongylides excisus	25.0	3–5	4.0 ± 0.9
Scardinius erythrophthalmus	Not found			
Tinca tinca	Not found			
Silurus glanis	*Eustrongylides excisus*	15.0	3–7	5.0 ± 1.6
Esox lucius	Not found			
Perca fluviatilis	*Ergasilus* sp.	10.0	2–5	3.5 ± 1.3
	Diplostomum spp.	15.0	1–3	1.8 ± 0.9
	Sanguinicola sp.	1.3.0	1–2	1.4 ± 0.5
	Eustrongylides excisus	43.0	10–12	10.7 ± 0.9
	Kyiv Reservoir			
Abramis brama	*Ichthyophthirius multifiliis*	85.7	1–30	14.4 ± 8.3
	Diplostomum spp.	76.2	7–12	8.2 ± 1.6
	Posthodiplostomum cuticola	40.0	2–4	3.0 ± 0.9
	Philometroides sp.	10.0	1–3	1.9 ± 0.9
Blicca bjorkna	Not found			
Leuciscus aspius	Not found			
Leuciscus idus	*Diplostomum* spp.	55.0	1–31	8.2 ± 8.6
	Posthodiplostomum cuticola	30.0	2–12	6.7 ± 3.7
	Triaenophorus nodulosus	5.0	1–3	1.8 ± 0.9
Rutilus rutilus	*Caryophyllaeus fimbriceps*	40.0	3–7	4.3 ± 1.5
Sander lucioperca	*Dermocystidium* sp.	15.0	3–10	6.9 ± 2.4
	Ichthyophthirius multifiliis	10.0	10–40	24.8 ± 8.9
	Eustrongylides excisus	45.0	7–10	8.2 ± 1.2
Scardinius erythrophthalmus	Not found			
Esox lucius	*Triaenophorus nodulosus*	60.0	3–5	3.7 ± 0.8
Perca fluviatilis	*Eustrongylides excisus*	85.0	10–12	10.8 ± 0.9
Neogobius fluviatilis	*Eustrongylides excisus*	10.0	1–5	4.3 ± 1.2
	Yavoriv Reservoir			
Carassius gibelio	*Caryophyllaeus fimbriceps*	20.0	6–8	7.1 ± 0.9
Cyprinus carpio	*Khawia sinensis*	15.0	2–10	5.5 ± 2.7
Hypophthalmichthys spp.	*Sinergasilus polycolpus*	23.0	3–8	5.5 ± 1.6
Rutilus rutilus	Not found			
Tinca tinca	Not found			
Esox lucius	Not found			
Perca fluviatilis	Not found			

PR = prevalence (%), IR = intensity range, MI = mean intensity (± standard deviation).

Table 6

Bacterial pathogens registered in aquaculture fish in different regions of Ukraine

Fish species	AE	PS	FL	EN	Other
Chernihiv Oblast					
Acipenser ruthenus	+				
Cyprinus carpio	+	+		+	
Chernivtsi Oblast					
Cyprinus carpio	+	+	+		
Salvelinus fontinalis	+			+	
Oncorhynchus mykiss	+			+	
Dnipropetrovsk Oblast					
Ctenopharyngodon idella	+				
Cyprinus carpio	+		+	+	
Hypophthalmichthys molitrix	+	+			
Donetsk Oblast					
Carassius gibelio			+	+	
Cyprinus carpio	+	+			+
H. molitrix × *H. nobilis*		+			
Kharkiv Oblast					
Cyprinus carpio	+			+	
Hypophthalmichthys molitrix		+			
Kherson Oblast					
Ctenopharyngodon idella		+			
Cyprinus carpio	+		+		+
Hypophthalmichthys molitrix		+			
Hypophthalmichthys nobilis	+	+			
Kyiv Oblast					
Carassius gibelio	+				
Ctenopharyngodon idella		+			
Cyprinus carpio	+	+	+		+
Hypophthalmichthys nobilis	+	+			
Rutilus rutilus	+			+	
Tinca tinca	+				
Esox lucius					
Lviv Oblast					
Carassius gibelio					
Ctenopharyngodon idella					
Cyprinus carpio	+	+	+		
H. molitrix × *H. nobilis*	+	+			
Tinca tinca			Not found		
Oncorhynchus mykiss	+			+	+
Odessa Oblast					
Acipenser ruthenus	+	+		+	
Acipenser gueldenstaedtii	+				+
Huso huso × *Acipenser ruthenus*	+		+		
Ctenopharyngodon idella					
Cyprinus carpio	+	+	+		
Hypophthalmichthys molitrix		+			
Hypophthalmichthys nobilis		+			
Rivne Oblast					
Carassius gibelio	+			+	
Cyprinus carpio	+	+	+		
H. molitrix × *H. nobilis*		+			
Oncorhynchus mykiss	+			+	
Zakarpattia Oblast					
Cyprinus carpio	+		+		
Hypophthalmichthys molitrix		+			
Hypophthalmichthys nobilis	+				
Oncorhynchus mykiss	+			+	
Zhytomyr Oblast					
Carassius gibelio					
Ctenopharyngodon idella	+				
Cyprinus carpio	+	+	+		
H. molitrix × *H. nobilis*	+	+			

AE = *Aeromonas*, PS = *Pseudomonas*, FL = *Flavobacterium*, EN = Enterobacteriacea

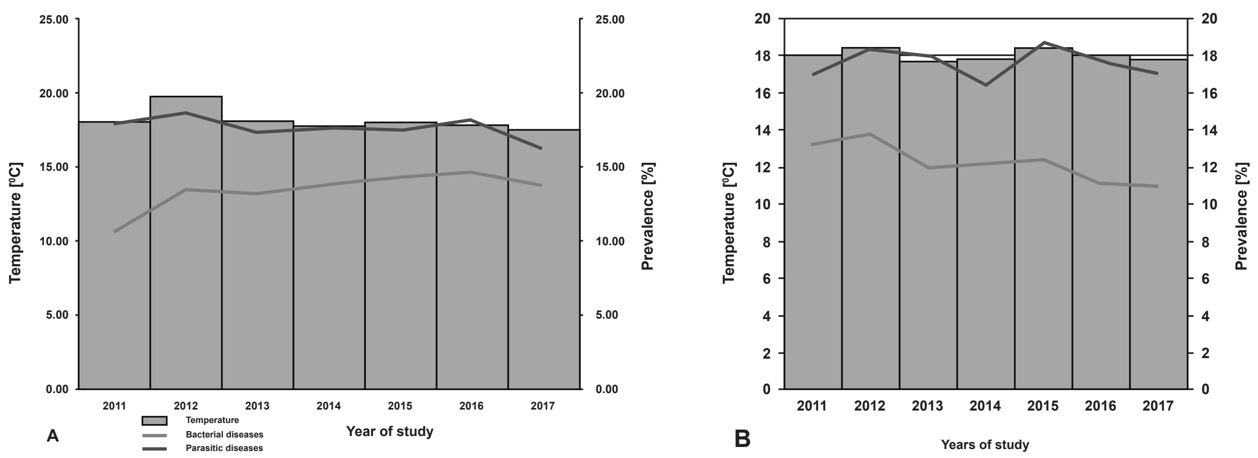

Fig. 5. Dependence of bacterial and parasitic diseases of fish in Ukraine on the air temperature in Aquaculture Zone B (Forest Steppes and Carpathians); (**A**) Kharkiv Oblast; (**B**) Zakarpattia Oblast

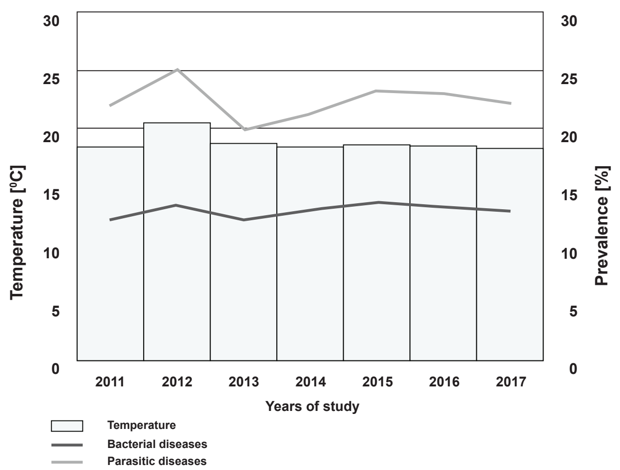

Fig. 6. Dependence of bacterial and parasitic diseases of fish in Ukraine on the air temperature in Aquaculture Zone C (Northern Steppe) in the case of Dnipropetrovsk Oblast

fluctuations is an additional favorable factor. The highest indicators of the quantitative composition of the microflora were observed in June and July when the pathogenic (vibrioflora) and opportunistic pathogenic microflora (aeromonads, pseudomonads, and enterobacteria) were active. The opportunistic pathogenic bacteria of the genera *Pseudomonas*, *Aeromonas*, and *Flavobacterium* were dominant. At the same time, the representatives of the family Enterobacteriaceae were identified in lower quantity and bacteria of genera *Staphylococcus*, *Proteus*, and *Streptococcus* were sporadically present.

In general, the maximum temperatures are not critical for the bacterial accumulation and growth rate, but the daily fluctuations within 3–5°C are important and should be considered as environmental optimum (Pękala-Safińska 2018). With daily fluctuations of the ambient water temperature over 5ºC, the rates of culture development and bacterial mass accumulation are considerably lower. During the warm period, instability of the temperature does not act as a limiting factor for the development of pathogenic bacteria. On the contrary, under certain conditions, their population density may increase markedly. This can explain the different incidence rates of infectious diseases in fish in different regions. Thus, in the fisheries of Zone A (Kyiv and Lviv oblasts), the incidence of diseases, even in rather hot years, was much lower than in Zones C and D, where abrupt daily fluctuations in air temperature were absent. When the temperature falls significantly in winter, most of the bacteria remain alive and the following year they cause disease outbreaks because of the significant number of environmental blowouts that remained (Austin 2016, Kousar et al. 2019).

One of the main concerns of sustainable development is to ensure adequate water quality. The hydrobiont status affects the bacteriological contamination of the surface water. Taking the high level of anthropogenic impact into account, it can be predicted that the negative impact of global climate change will further impact on the quality of Ukraine's major waterways.

The infectious agents are a real threat to the life and health of the fish, and they cause significant economic losses at specialized farms (Davydov et al. 2012, Matvienko et al. 2015). Among the parasitic agents, we registered only one species, the opistorchid *Pseudamphistomum truncatum*, which poses minimal risk to human health (Simpson et al. 2005).

One of the negative consequences of the intensification of agricultural production, including aquaculture, is the pollution of the environment not only by various chemicals but also by pathogenic and opportunistic pathogenic microorganisms. By getting into the environment (soils, waters), some of them can maintain their viability for a long time, while individual species can even form sustainable natural foci that pose a constant threat to fish.

There is a certain relation between the air temperature and the intensity of parasitic diseases. Also, there is an increase in the rate of the parasitic infection of fish during the hot growing season (2012, 2016). Some of the parasites in fish, i.e., ciliates *Ichthyophthirius multifiliis* and monogenean *Dactylogyrus vastator*, forming 43% of the total spectrum of parasitic infection, have a simple life cycle, which strongly depends on the temperature.

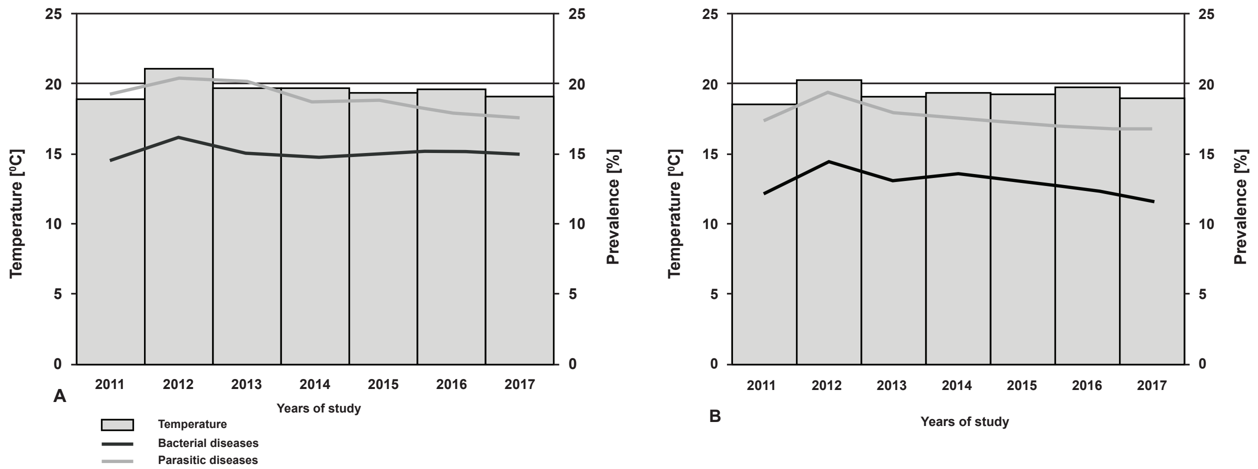

Fig. 7. Dependence of bacterial and parasitic diseases of fish in Ukraine on the air temperature in Aquaculture Zone C (Southern Steppe); (**A**) Kherson Oblast; (**B**) Odessa Oblast

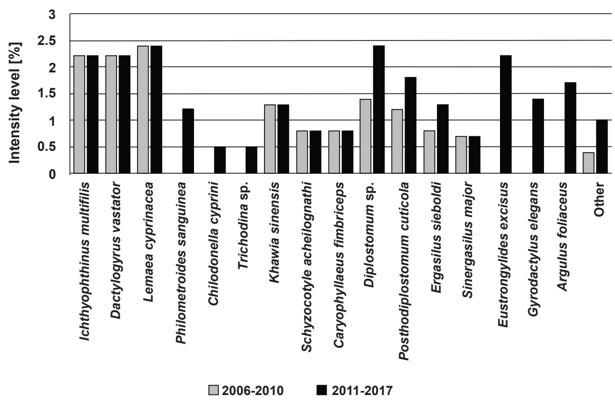

Fig. 8. The intensity of infection of pond fish in Ukraine with different parasite species (percent range) in different time periods

The temperature most favorable for their reproduction is 21–26°C. At higher temperatures, the development of the parasites accelerates, but at lower temperatures, it becomes slow (Olìjnik unpublished[*]). This explains the outbreak of fish damage in Dnipropetrovsk Oblast in 2012. The temperature changes explain the spread of the parasitic disease, lernaeosis, on the territory of Ukraine. It was caused by parasitic crustaceans of the genus *Lernaea*. The optimum water temperature for the development of this parasite is 23–30°C. Until now, this parasite was characteristic for 4–6 aquaculture farms, but nowadays, this copepod is widely registered in different fish farms in Lviv Oblast. This can be explained by the change in the temperature and the adaptive mechanism of the parasite.

In the natural ecosystems formed under the conditions of intensive anthropogenic load, an unpredictable change of components is observed. The most expressed transformation occurs at the sites of accumulation with the heaviest anthropogenic impact. As a result, there is a violation of the balanced structure of their assemblages, which affects all members of the aquatic communities (Buzevìč 2012). Parasites being an integral part of the assemblages and able to act as an indicator of the ecosystem's status are not exceptions (Abbas et al. 2014). The observed relative well-being of the reservoir from a parasitological point of view is unstable, and with an increase in the supply of the biogenic load caused by anthropogenic factors, the changes in water temperature may cause mass outbreaks of fish diseases (ligulosis, diplostomosis, eustrongylosis). Due to the eutrophication in reservoirs of the Dnieper Cascade, another problem arises, the expansion of species spectrum of invasive diseases (Koop et al. 2011, Esipova 2013). The data of the parasitological study of the main industrial carnivorous fish of the Dnieper reservoirs (Kyiv, Kaniv, Kamyanske) proves the detection of the genus *Eustrongylides* larvae in pike-perch and perch. The adults of this parasite live in the stomachs of cormorants and pelicans, but the intermediate hosts are oligochaetes and the paratenic hosts are different species of fish (Moravec 2013). The most pathogenic species is Eustrongylides *excisus*, recorded in the body cavity of sturgeon, carp, pike, and perch. The third stage larvae can encapsulate in the body cavity or migrate into the muscles or liver. In this case, there is a capsule around the parasite formed by the tissues of the host (Moravec 2013). When infected with this parasite, the fish becomes unapt for food and may also become unfit for reproduction (Measures 1987, Hoffman 1999).

The infection of fish with helminth species is characteristic of the general trends in the parasitefauna changes in the eutrophic reservoirs (Jurišinec′ et al. 2012). Monitoring of the aquatic ecosystems, including the fish and parasite faunas, is an important direction in the development of the applied and theoretical aspects of veterinary science and biology as well as the development of conservation measures. The protection of human and animal health as well as providing the population with biologically and epidemiologically safe products is a paramount task.

[*] See footnote on page 334.

CONCLUSIONS

Analysis of the results of monitoring studies in fish diseases in the period of 2011–2017 in different geographical areas of Ukraine showed the existence of a relation between the disease level and the air temperature regime. This pattern can be traced both in bacterial and parasitic diseases.

It is noted that in the years with relatively warm vegetation period, the pathogen infection extent increased significantly to 25% and above. A significant expansion of the range of parasitic infections over the last decade was observed in *Apiosoma piscicola, Ichthyophthirius multifiliis, Trichodina* spp., *Dactylogyrus* sp., *Gyrodactylus* sp., *Caryophyllaeus fimbriceps*, *Khawia sinensis*, *Ligula intestinalis*, *Schyzocotyle acheilognathi*, *Diplostomum* spp., *Philometroides* sp., *Piscicola geometra*, *Lernaea cyprinacea*, *Sinergasilus polycolpus*, *Ergasilus* sp., *Argulus* sp., and others.

The study identified the disturbances of ecological balance in the ecosystems and, as a result, there is an increase in the number of pathogens detrimental to fish and human health. Accumulation of the opportunistic pathogenic bacteria leads to outbreaks of bacterial epizootics and mass mortality of fish the surviving fish is often damaged and has no nutritional value. The diseases are caused by associated bacterial infections.

Increased water temperature causes the rapid spread of bacterial diseases in the fish, while the absence of sharp fluctuations day and night is an additional favorable factor.

To prevent\adverse impacts of increased temperature due to climate change on disease outbreaks in the freshwater aquaculture in Ukraine, it is necessary to constantly monitor, develop, and implement preventive measures with due regard for the fisheries and the specific nature of the farms.

ACKNOWLEDGMENTS

This study was conducted under the Food and Agriculture Organization of the United Nations (FAO) project TCP/UKR/3603/C2 “Support to Improve Technical and Institutional Capacities for Climate Change Adaptation and Mitigation in Agricultural Sectors”.

REFERENCES

Abbas F., Ashraf M., Hafeez-ur-Rehman M., Iqbal K.J., Abbas S., Javid A. 2014. *Lernaea* susceptibility, infestation and its treatment in indigenous major and exotic Chinese carps under polyculture system. Pakistan Journal of Zoology **46** (5): 1215–1222.

Andrûŝenko [Andriushchenko] A.Ì., Vovk N.Ì., Bazajeva [Bazaieva] A.V. 2014. Metodičnij posìbnik: Tehnologìï virobnictva ribi v stavovìj akvakulturì ta shemi osnovnih lanok tehnologìčnih procesìv. [Methodological guide: Technologies of fish production in pond aquaculture and schemes of main chains of technological process.] Nacìonal’nij unìversitet bioresursìv ì prirodokoristuvannâ Ukraïni. [National University of Life and Environmental Sciences of Ukraine.] Kiïv, Ukraine. [In Ukrainian.]

Austin B. 2016. The value of bacterial cultures to modern fish diseases microbiology. Bulletin of European Association of Fish Pathologists **36** (1): 2–10.

Bauer O.N. 1987. Opredelitel′ parazitov presnovodnyh ryb fauny SSSR. Tom 3. Parazitičeskie Mnogokletočnye (Vtoraâ čast′). [Key to the parasites of the freshwater fish fauna of the USSR. Volume 3. Parasitic Metazoa (Second part).] Izdatel′stvo Nauka, Leningrad, USSR. [In Russian.]

Bauer O.N., Musselius V.A., Strelkov Û.A. 1981. Bolezni prudovyh ryb. [Diseases of pond fishes.] Legkaâ i piŝevaâ promyšlennost′, Moskva, USSR. [In Russian.]

Buchmann K. 2007. An introduction to practical methods in fish parasitology. Classical and molecular techniques. Biofolia Press, Frederiksberg, Denmark.

Bush A.O., Lafferty K.D., Lotz J.M., Shostak A.W. 1997. Parasitology meets ecology on its own terms: Margolis et al. revisited. Journal of Parasitology **83** (4): 575–583. DOI: 10.2307/3284227

Buzevìč Ì. [Buzevich I.] 2012. Pokazniki bìorìznomanìttâ ìhtiofauni Dnìprovskih vodoshovišč jak činniki vplivu na veličinu promislovih uloviv ribi. [Indices of biodiversity of ichthyofauna of the Dnieper reservoirs as factors affecting the amount of commercial fish catches.] Ribogospodarska Nauka Ukrainy **1**: 4–8. [In Ukrainian with English summary.]

Cochrane K., De Young C., Soto D., Bahri T. 2009. Climate change implications for fisheries and aquaculture—Overview of current scientific knowledge. FAO, Rome.

Davydov O.N., Kurovskaya L.Y., Temnikhanov Y.D., Neborachek S.I. 2012. Parasites of some invasive fishes of the fresh water. Hydrobiological Journal **48** (2): 72–84. DOI: 10.1615/hydrobj.v48.i2.80

Diduh Â.P. [Didukh Ya.P.] 2014. Novij pìdhìd do ocìnki stijkostì ta rizikìvvtrati ekosistem. [A novel approach to the assessment of the stability and the risks of losses in ecosystems.] Dopovìdì NAN Ukraïni **2014** (8): 149–155. [In Ukrainian with English summary.] DOI: 10.15407/dopovidi2014.08.149

Eggers D.M., Bartoo N.W., Rickard N.A., Nelson R.E., Wissmar R.C., Burgner R.L., Devol A.H. 1978. The Lake Washington ecosystem: The perspective from the fish community production and forage base. Journal of the Fisheries Research Board of Canada **35** (12): 1553–1571. DOI: 10.1139/f78-246

Esipova [Yesipova] N.B. 2013. Rasprostranenie parazitičeskoj nematody *Eustrongylides excisus* u ryb Zaporožskogo (Dneprovskogo) vodohranilišča. [The spread of parasitic nematodes *Eustrongylides excisus* in fish of Zaporozhye (Dnipro) Reservoir.] Pp. 86–88. *In*: Grubenko V.V. (ed.) Sučasnì problemi teoretičnoï ta praktičnoï ìhtìologìï. [Modern issues of theoretical and applied ichthyology.] Pp. 86–88. *In*: Abstracts of 6th International Conference (October 9–11, 2013, Ternopil, Ukraine). Vektor, Ternopil. [In Russian with English summary.]

Evtušenko A.V. [Yevtushenko A.V.], Evtušenko Ì.D. [Yevtushenko I.D.], Volovik T.P., Zbožinska [Zboghinska] O.V. 2015. Osoblivostì citrkulâcìï zbudnikìv osnovnih parazitarnih zahvorûvan′ rib u vodojmah z rìznimi gìdrologìčnimi režimami. [Features of circulation of causative agents of basic parasitogenic illnesses of Pisces in reservoirs with different hydrological modes.] Veterinarna medicina (Veterinary Medicine) **100**: 167–169. [In Ukrainian with English summary.]

Gaevs′ka [Gayevska] A.V. 2004. Parazitologìâ ta patologìâ rib. Enciklopedičnij slovnik-dovìvdik [Parasitology and pathology of fish. Encyclopedic dictionary]. Naukova Dumka, Kiïv, Ukraine. [In Ukrainian.]

Harrod C., Ramírez A., Valbo-Jørgensen J., Funge-Smith S. 2019. [Chapter 19] Current anthropogenic stress and projected effect of climate change on global inland fisheries. Pp. 86–88. *In*: Barange M., Bahri T., Beveridge M.C.M., Cochrane K.L., Funge-Smith S., Florence P. (eds.) Impacts of climate change on fisheries and aquaculture: Synthesis of current knowledge, adaptation and mitigation options. FAO Fisheries and Aquaculture Technical Paper 627. FAO, Rome.

Hoffman G.L. 1999. Parasites of North American freshwater fishes. 2nd edn. Comstock Publishing Associates, Ithaca, NY, USA.

Jurišinec′ V.I., Zaìčenko N.V., Ribka T.S. 2012. Ocìnka ekologìčnogo stanu vodnih ob′êktiv ìz zastosuvannâm parazitologìčnih pokaznikìv. Naukovì Zapiski Ternopils′kogo nacional′nogo pedagogìčnogo universitetu, Serìâ Bìologìâ **51** (2): 315–318. [In Ukrainian.]

Karvonen A., Rintamäki P., Jokela J., Valtonen E.T. 2010. Increasing water temperature and disease risks in aquatic systems: Climate change increases the risk of some, but not all, diseases. International Journal for Parasitology **40** (13): 1483–1488. DOI: 10.1016/j.ijpara.2010.04.015

Khan T.A., Wilson M.E., Khan M.T. 2003. Evidence for invasive carp mediated trophic cascade in shallow lakes of western Victoria, Australia. Hydrobiologia **506** (1–3): 465–472. DOI: 10.1023/B:HYDR.0000008558.48008.63

Koop J.A.H., Huber S.K., Laverty S.M., Clayton D.H. 2011. Experimental demonstration of the fitness consequences of an introduced parasite of Darwin's finches. PlosOne **6** (5): e19706. DOI: 10.1371/journal.pone.0019706

Kousar R., Shafi N., Andleeb S., Mazhar Ali N., Akhtar T., Khalid S. 2019. Assessment and incidence of fish associated bacterial pathogens at hatcheries of Azad Kashmir, Pakistan. Brazilian Journal of Biology **21** (3): 1–8. DOI: 10.1590/1519-6984.217435

Krieg N.R., Holt J.G. (eds.) 1984. Bergey's manual of systematic bacteriology. Williams and Wilkins, Baltimore, USA.

Kriticos D.J., Sutherst R.W., Brown J.R., Adkins S.W., Maywald G.F. 2003. Climate change and biotic invasions: A case history of a tropical woody vine. Biological Invasions **5** (3): 147–165. DOI: 10.1023/A:1026193424587

Lom J., Dykova I. 1992. Protozoan parasites of fish. Elsevier, Amsterdam, the Netherlands.

Mansfield B. 2010. [Chapter 4] "Modern" industrial fisheries and the crisis of overfishing. Pp. 84–99. *In*: Peet R., Robbins P., Watts M. (eds.) Global political ecology. Routledge, London, UK.

Matvienko N.M., Vaschenko A.V., Tsiganok I.O., Buchatsky L.P. 2015. Results of surveillance studies of infectious fish diseases in freshwater aquaculture of Ukraine. Agricultural Science and Practice **2** (2): 32–38. DOI: 10.15407/agrisp2.02.032

Measures L.N. 1987. Epizootiology, pathology, and description of *Eustrongylides tubifex* (Nematoda: Dioctophymatoidea) in fish. Canadian Journal of Zoology **66** (10): 2212–2222. DOI: 10.1139/z88-329

Morales-Serna F.N., Rodríguez-Santiago M.A., Gelabert R., Flores-Morales L.M. 2019. Parasites of fish *Poecilia velifera* and their potential as bioindicators of wetland restoration progress. Helgoland Marine Research **73**: e1. DOI: 10.1186/s10152-019-0522-1

Moravec F. 2013. Parasitic nematodes of freshwater fishes of Europe (2nd ed.). Academia, Praha, Czech Republic.

Morgan E.R., Wall R. 2009. Climate change and parasitic disease: Farmer mitigation? Trends in Parasitology **25** (7): 308–313. DOI: 10.1016/j.pt.2009.03.012

Morozińska-Gogol J., Rokicki J., Frelek K., Szefer P. 1998. Trace metals in *Gasterosteus aculeatus* L. and its parasites from the Gulf of Gdańsk. Oceanological Studies **27** (3): 71–75.

Osipčuk S.O. 2008. Pripodno-sil′skogospodars′ke rajonuvannâ Ukraïni. [Natural and agricultural zoning of Ukraine.] Urozhay, Kiïv, Ukraine. [In Ukrainian.]

Pękala-Safińska A. 2018. Contemporary threats of bacterial infections in freshwater fish. Journal of Veterinary Research **62** (3): 261–267. DOI: 10.2478/jvetres-2018-0037

Pritchard M.H., Kruse G.O. 1982. The collection and preservation of animal parasites. Technical Bulletin 1. The Harold W Manter Laboratory, University of Nebraska Press, Lincoln, NE, USA.

Rózsa L., Reiczigel J., Majoros G. 2000. Quantifying parasites in samples of hosts. Journal of Parasitology **86** (2): 228–232. DOI: 10.1645/0022-3395(2000)086[0228:QPISOH]2.0.CO;2

Simpson V.R., Gibbons L.M., Khalil L.F., Williams J.L.R. 2005. Cholecystitis in otters (*Lutra lutra*) and mink (*Mustela vison*) caused by the fluke *Pseudamphistomum truncatum*. Veterinary Record **157** (2): 49–52. DOI: 10.1136/vr.157.2.49

Valtonen E.T., Holmes J.C., Aronen J., Rautalahti I. 2003. Parasite communities as indicators of recovery from pollution: Parasites of roach (*Rutilus rutilus*) and perch (*Perca fluviatilis*) in central Finland. Parasitology **126**: S43–S52. DOI: 10.1017/S0031182003003494

Yazdi S.K., Shakouri B. 2010. The effects of climate change on aquaculture. International Journal of Environmental Science and Development **1** (5): 378–382. DOI: 10.7763/IJESD.2010.V1.73

Received: 25 May 2020
Accepted: 18 August 2020
Published electronically: 4 September 2020