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SPECIES DIVERSITY OF CARP, *CYPRINUS CARPIO* (CYPRINIFORMES, CYPRINIDAE), PARASITES IN SOME CULTIVATION REGIONS

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Species Diversity of Carp, *Cyprinus carpio* (Cypriniformes, Cyprinidae), Parasites in Some Cultivation Regions. Davydov O. N., Lysenko V. N., Kurovskaya L. Ya. — Zoogeographical comparison for species diversity of carp parasites in different cultivation regions including aquatic ecosystems of Ukraine, Uzbekistan, Russia, and Vietnam was carried out. Totally, 160 parasitic species were recorded in carp within these regions. Parasitic species with direct and complex life cycles important in epizootic, veterinary, and health areas were registered.

Key words: carp, species diversity of parasites, aquatic ecosystems.

Особенности видового разнообразия паразитов карпа, *Cyprinus carpio* (Cypriniformes, Cyprinidae), в некоторых регионах культивирования. Давыдов О. Н., Лысенко В. Н., Куровская Л. Я. — Проведено зоогеографическое сравнение особенностей видового разнообразия паразитов карпа из разных регионов разведения, включая водные экосистемы Украины, Узбекистана, России, Вьетнама. Всего у карпа в пределах этих регионов зарегистрировано 160 видов паразитов. Отмечены специфические и имеющие эпизоотологическое и медико-ветеринарное значения виды паразитов с прямым и сложным циклом развития.

Ключевые слова: карп, видовое разнообразие паразитов, водные экосистемы.

Introduction

Carp, *Cyprinus carpio* Linnæus, 1758, inhabits fresh and brackish waters of the basins of the Black Sea, the Sea of Azov, the Caspian Sea, and the Aral Sea, and the basins of the Pacific Ocean (from the Amur River in the north to Burma's rivers in the south). Within its range, carp has four subspecies: European, Amur-Chinese, Aral and Vietnamese living in the waters of Indo-China (Bogutskaya, Naseka, 2004). Each of the subspecies is the source of domestication and the formation of certain breeds of carp in the region.

Carp is the object of fish-farming and was acclimatized in temperate latitudes almost all over the world. It is grown in ponds, cage-farms in warm waters from power stations, nuclear power plants, etc. First mentions of the carp extend far into the past (about 1000 BC). Carp's historical homeland is China from where he was introduced to Japan, and later to Europe, America, Africa, and Asia. High numbers it reaches in the central Europe and the Far East where it is typical background species. Into the natural reservoirs of the Dnieper basin it got as a result of seeding and escaping from fish farms. In Ukraine, Dnieper reservoirs were seeded out with juvenile carp, Kremenchug reservoir — with two-year old fishes. In the lower reaches of rivers flowing into the Black Sea, carp is common in brackish waters. With a natural diet it is euryphage consuming almost all the food available in the pond.

Despite the fact that the study of fish parasites, especially in carp, has been carried out for more than 200 years, zoogeography of parasites is poorly known. There are a few reasons: 1) the geography of the parasites of freshwater and marine animals is behind the level of the zoogeography of terrestrial animals; 2) parasitological material is taken without temporal relationship and connection to reservoirs of various types; 3) instability of taxonomy of parasites of aquatic organisms, association of species under the same name, and, to the contrary, separation of species with narrow ranges of distribution. All these issues misrepresent the conclusions of zoogeographical analysis of fish parasites.

Till now, there were no literary comparative data on the qualitative and quantitative composition of carp parasites in zoogeographical aspects. The promise of such research to address issues of ecology, zoo-

geography and origin of the parasites and their hosts was shown by many researchers (Dogiel, 1962; Pugachev, 1984; Roitman, Beer, 2008, etc.). The urgency of the study is also determined by significant differences in habitats (different types of aquaculture, rivers, etc.) of fishes themselves and their parasites, respectively, as well as anthropogenic activity altering the host-parasite relationships, fauna composition and structure of parasitic systems.

This work is aimed at comparative qualitative and quantitative analysis of the carp parasites fauna from 5 different regions: European — Ukraine (ponds, rivers and reservoirs and brackish coastal waters of the Black Sea and the Sea of Azov), Amur-Chinese — Russia (ponds, river basins), Aral — Uzbekistan (ponds, rivers, the Aral Sea basin), and Vietnamese — Vietnam (ponds, rivers and coastal seas).

Material and methods

Summarized are the results of our long-term studies and works of other authors on the species composition of carp parasites in Ukraine, as well as published data from the aforementioned regions. Since 1950 to the present, parasitological studies of fish in Ukraine have covered the following water bodies: rivers Dnieper, Dniester, the Siversky Donets, Danube, Prut, and the Southern Bug; Dnieper cascade of reservoirs; ponds in western Ukraine and Crimea; the lakes Nobel and Kugurlay; the Azov-Black Sea basin; pond fisheries including Nyvka and Nemeshaevo fish farms (Kyiv oblast.).

Parasite species were identified according to “The Key of parasites of freshwater fishes of the USSR” (in 3 volumes, 1984, 1985, 1987). Systematic correction of names of all taxa of fish parasites was estimated according to Brands (1989–2007) and data of foreign authors on some groups of parasites: Myxozoa, Ciliophora, Dinozoa (Lom, Dykova, 1992); Platyhelminthes (Khalil et al., 1994, Gibson et al., 2002); Nematoda (Moravec, 1998); Acanthocephala (Amin, 1987); Annelida and Mollusca (McDonald, Margolis, 1995); Arthropoda (Kabata, 1988).

Results and discussion

The species diversity of carp parasites from 5 explored regions is shown in table 1. In separation to Palaearctic and Sino-Indian fish parasites, only species which validity was beyond doubt were considered, doubtful ones were not included.

In the mentioned regions, 160 parasite species were noted in carp, including protozoa — 60 species, monogeneans — 23, cestodes — 14, trematodes — 25 (of them metacercariae — 16), nematodes — 11, leeches — 2, acanthocephalans — 7, molluscs — 2, parasitic copepods — 16. All of them are exclusively freshwater species characteristic for the carp parasites. Diversity of carp parasites is based on the fact that it is eurybiont, euryhaline, eurythermic animal with wide food range. Most parasite species (61.9%) actively infect carp, 38.1% of them are transferred with food. Parasites with complex life cycle compose 36.2%, those with simple cycle — 63.8%. Mature fishes are parasitized by 54 helminth species (65.9%), larval stages — by 28 species (34.1%). Most species are parasites of body surface, fins and gills (40.6%), followed by the number of endoparasite species localized in the digestive tract (24.4%).

Differences in species composition of carp parasites from the freshwater and coastal waters of the Black Sea and the Sea of Azov in Ukraine, 78 and 37 species, respectively, Uzbekistan — 43, Russia — 53, and Vietnam — 54 were noted.

Due to the long-term studies, parasites of carp from water bodies of Ukraine are known to date fairly well (Markevitch, 1951; Iskov, 1967, 1989; Davydov et al, 1982, 2000, Davydov, Kurovskaya, 1991; Rozum, Onyshchenko, 2008). In the 1950th, 33 species of carp parasites were indicated in Ukraine (Malevitskaya, 1952; Ivasyk, 1953). Totally, in this period, 36 species of parasites have been found in carp from water bodies of the former Soviet Union (Bauer, 1959).

Today, the quantitative composition of the parasitic fauna of carp from freshwater bodies of Ukraine (78 species) is significantly different from those in carp from other regions represented by not so rich fauna of parasites. This may be either due to more complete examination of the water bodies of Ukraine, or due to the larger number of intermediate hosts.

The greatest variety of carp parasites in Ukraine was found in protozoans — 33 species; monogeneans — 12; cestodes and crustaceans — 10 and 9 species, respec-

Table 1. Species composition of carp parasites from different regions

Таблица 1. Видовой состав паразитов карпа из разных регионов

Parasite species	Water bodies				
	1	2	3	4	5
Type Euglenozoa					
<i>Trypanosoma carassii</i> Mitrophanov, 1883	+	+		+	
<i>Cryptobia branchialis</i> Nie (in: Chen, 1956)					+
<i>C. cyprini</i> (Plehn, 1903)*	+	+	+		
<i>Ichthyobodo necatrix</i> Henneguy, 1884	+		+		+
Type Apicomplexa					
<i>Eimeria carpelli</i> Léger et Stankovitch, 1921*	+		+		
<i>E. subepithelialis</i> Moroff et Fiebiger, 1905*	+				
<i>Coussia carpelli</i> Léger et Stankovitch, 1921					+
Type Myxozoa					
<i>Myxidium pfeifferi</i> Auerbach, 1908	+	+	+	+	
<i>M. rhodei</i> Léger, 1905	+			+	
<i>Sphaerospora angulata</i> Fujita, 1912*				+	
<i>S. branchialis</i> Razmashkin et Skripchenko, 1967	+				
<i>S. carassii</i> Kudo, 1919	+				
<i>S. cyprini</i> (Fujita, 1912)*				+	
<i>Hoferellus cyprini</i> (Doflein, 1898)	+		+		
<i>Chloromyxum cyprini</i> Fujita, 1927*				+	
<i>Ch. koi</i> Fujita, 1913*	+		+	+	
<i>Myxosoma cerebrealis</i> Hofer, 1903				+	
<i>Myxobolus achmerovi</i> Schulman, 1966					+
<i>M. amurensis</i> Achmerov, 1960*	+			+	
<i>M. anisocapsularis</i> Schulman, 1962					+
<i>M. artus</i> Achmerov, 1960*	+			+	+
<i>M. braamae</i> Reuss, 1906	+			+	
<i>M. cordis</i> Keysselitz,			+		
<i>M. cyprini</i> Doflein, 1898	+	+	+	+	
<i>M. cyprinicola</i> Reuss, 1906	+		+		
<i>M. dispar</i> Thélohan, 1895	+		+	+	+
<i>M. dogieli</i> I. et B. Bychowsky, 1940	+			+	
<i>M. ellipsoides</i> Thélohan, 1892	+			+	
<i>M. koi</i> Kudo, 1919*	+			+	+
<i>M. kubanicus</i> I. et B. Bychowsky, 1940		+			
<i>M. oviformis</i> Thélohan, 1882				+	
<i>M. sandrae</i> Reuss, 1906	+				
<i>M. squamae</i> Keysselitz, 1908				+	
<i>M. toyamai</i> Kudo, 1915				+	+
<i>Myxobolus</i> sp.			+		+
<i>Thelohanellus nicolskii</i> Achmerov, 1955					+
<i>T. catlae</i> Chakrawarty et Basu, 1958					+
<i>T. dogieli</i> Achmerov, 1955*				+	+
<i>T. fuhrmanni</i> (Auerbach, 1909)				+	+
<i>T. pyriformis</i> (Thélohan, 1892)	+				
Type Ciliophora					
<i>Chilodonella piscicola</i> (Zacharias, 1984) Jankowski, 1980	+		+		+
<i>Chilodonella</i> sp.					+
<i>Hemiophrys branchiarum</i> (Wenrich, 1924) Kahl, 1931	+				
<i>Pseudoamphileptus macrostoma</i> (Chen, 1955) Foissner, 1983					+
<i>Ichthyophthirius multifiliis</i> Fouquet, 1876	+		+		+
<i>Epistylis lwoffii</i> Fauré-Fremiet, 1943	+				
<i>Epistylis</i> sp.					+
<i>Apiosoma minutum</i> (Chen, 1961)					+
<i>A. piscicolum cylindriciformis</i> (Chen, 1955)					+
<i>Apiosoma</i> sp.	+		+		
<i>Trichodina acuta</i> Lom, 1961	+				+
<i>T. domerguei domerguei</i> Wallengren, 1897	+				
<i>T. nigra</i> Lom, 1961	+				+
<i>T. nobilis</i> Chen, 1963				+	+
<i>T. pediculus</i> Ehrenberg, 1838	+				+
<i>T. reticulata</i> Hirschmann et Partsch, 1955	+			+	
<i>Trichodina</i> sp.			+		+
<i>Trichodinella epizootica</i> (Raabe, 1950)	+		+		

Table 1 (continued).
Продолжение таблицы 1.

Parasite species	Water bodies				
	1	2	3	4	5
<i>Tripartiella cyprini</i> (Dogiel, 1940)			+		
<i>Tripartiella</i> sp.			+		
Type Platyhelminthes					
<i>Dactylogyrus achmerowi</i> Gussev, 1955				+	+
<i>D. anchoratus</i> (Dujardin, 1845)*	+	+	+		+
<i>D. auriculatus</i> (Nordmann, 1832)	+				
<i>D. curvicirrus</i> Achmerow, 1952				+	
<i>D. extensus</i> Mueller et Van Cleave, 1932*	+	+	+	+	+
<i>D. falciformis</i> Achmerow, 1952*				+	+
<i>D. inexpectatus</i> Izjumova in Gussev, 1955				+	
<i>D. minutus</i> Kulwicz, 1927*	+		+	+	+
<i>D. vastator</i> Nybelin, 1924*	+	+	+	+	
<i>D. yinwenyingae</i> Gussev, 1962			+		
<i>Dactylogyrus</i> sp.					+
<i>Pseudaccolpenteron pavlovskii</i> Bychowsky et Gussev, 1955*			+		
<i>Gyrodactylus cyprini</i> Diarova, 1964*	+		+		
<i>G. elegans</i> Nordmann, 1832*	+		+		
<i>G. gracilis</i> Kathariner, 1894	+				
<i>G. katharineri</i> Malmberg, 1964	+				
<i>G. medius</i> Kathariner, 1893*	+	+	+		+
<i>G. nagibinae</i> Gussev, 1962*			+		
<i>G. sprostonae</i> Ling, 1962*	+		+	+	
<i>Gyrodactylus</i> sp.			+		+
<i>Diplozoon paradoxum</i> Nordmann, 1832	+				
<i>Diplozoon</i> sp.			+	+	
<i>Paradiplozoon doi</i> (Ky, 1971)					+
<i>Caryophyllaeus fimbriceps</i> Annenkova–Chlopina, 1919	+	+	+		
<i>C. laticeps</i> (Pallas, 1781)	+	+			
<i>Biacetabulum appendiculatum</i> (Szidat, 1937)	+				
<i>Khawia japonensis</i> Yamaguti, 1934				+	
<i>Kh. rossittensis</i> (Szidat, 1937)	+				
<i>Kh. sinensis</i> Hsü, 1935	+			+	+
<i>Bothriocephalus gowkongensis</i> Yeh, 1955	+		+		
<i>Diphyllobothrium</i> sp. 1					+
<i>Ligula intestinalis</i> L (Linnaeus, 1758)	+				
<i>Digramma interrupta</i> L (Rudolphi, 1810)		+			
<i>Proteocephalus</i> sp.	+				
<i>Neogryporhynchus cheilancristrotus</i> L (Wedl, 1955)	+				
<i>Paradilepis scolecina</i> L (Rudolphi, 1819)		+	+		
<i>Valipora campylancristrota</i> L (Wedl, 1855)	+	+	+		
<i>Aspidogaster conchicola</i> Baer, 1927		+		+	
<i>Asymphyllodora kubanica</i> Issaitschikoff, 1923		+			
<i>Stephanostomum</i> sp. mtc					+
<i>Allocreadium isoporum</i> (Looss, 1894)		+			+
<i>Clonorchis sinensis</i> Cobbold, 1875				+	
<i>Pseudamphistomum truncatum</i> mtc (Rudolphi, 1819)		+			
<i>Metorchis xanthosomus</i> mtc (Creplin, 1846)		+			
<i>Phagicola</i> sp. mtc				+	
<i>Metagonimus yokogawai</i> mtc Katsurada, 1912		+		+	
<i>Apophallus muehlingi</i> mtc Jägerskiöld, 1898		+			
<i>Centrocestus formosanus</i> mtc Nishigori, 1924					+
<i>Centrocestus</i> sp. mtc					+
<i>Azygia lucii</i> (Müller, 1776) Lühe, 1909		+			
<i>Bucephalus polymorphus</i> mtc Baer, 1827	+	+			
<i>Sanguinicola inermis</i> Plehn, 1905	+		+	+	
<i>Aponurus tschugunovi</i> Issaitschikoff, 1927		+			
<i>Diplostomum spathaceum</i> mtc (Rudolphi, 1819)	+	+	+		
<i>Tylodelphus clavata</i> mtc (Nordmann, 1832)	+	+			
<i>Hysteromorpha triloba</i> mtc (Rudolphi, 1819)		+			
<i>Hysteromorpha</i> sp.				+	
<i>Conodiplostomum perlatum</i> mtc (Ciurea, 1911)		+			
<i>Posthodiplostomum cuticola</i> mtc (Nordmann, 1832)	+	+			
<i>Ichthyocotylurus pileatus</i> mtc (Rudolphi, 1802)	+	+			

Table 1 (continued).
Продолжение таблицы 1.

Parasite species	Water bodies				
	1	2	3	4	5
<i>Tetracotyle</i> sp. mtc				+	
<i>Paracoenogonimus ovatus</i> mtc Katsurada, 1914		+		+	
Type Nematoda					
<i>Capillaria tomentosa</i> Dujardin, 1843			+		
<i>Eustrongylides mergorum</i> l (Rudolphi, 1809)		+			
<i>Camallanus truncatus</i> (Rudolphi, 1814)					+
<i>Philometra abdominalis</i> Nybelin, 1928	+				
<i>Philometra</i> sp.					+
<i>Philometroides lusiana</i> (Vismanis, 1966)	+				
<i>Cucullanus cyprini</i> Yamaguti, 1941				+	+
<i>Rhaphidascaris acus</i> (Bloch, 1779)		+			
<i>Rhaphidascaris</i> sp.				+	
<i>Contracaecum microcephalum</i> l (Rudolphi, 1819)		+	+		
<i>Contracaecum</i> sp. l				+	
Type Annelida					
<i>Hemiclepsis marginata</i> (Müller, 1774)	+				
<i>Piscicola geometra</i> (Linnaeus, 1761)	+		+		
Type Acanthocephala					
<i>Neoechinorhynchus</i> sp.				+	
<i>Dendronucleata dogieli</i> Sokolowskaja, 1962					+
<i>Paracanthocephalus curtus</i> Achmerov et Dombrowskaja-Achmerova, 1941				+	
<i>P. tenuirostris</i> Achmerov et Dombrowskaja-Achmerova, 1941				+	
<i>Acanthocephalus anguillae</i> Müller, 1780)	+				
<i>A. lucii</i> (Müller, 1776)	+				
<i>Brentisentis cyprini</i> Yin et Wu, 1984					+
Type Mollusca					
<i>Unio crassus</i> Philipsson, 1788	+				
<i>U. pictorum</i> Linnaeus, 1758	+				+
Type Artropoda					
<i>Ergasilus briani</i> Markewitsch, 1932	+			+	
<i>E. nanus</i> Beneden, 1871		+			
<i>E. sieboldi</i> Nordmann, 1832	+	+			
<i>Sinergasilus undulatus</i> (Markewitsch, 1940)				+	
<i>Paraergasilus brevidigitus</i> Yin, 1954				+	+
<i>P. medius</i> Yin, 1956					+
<i>P. rylovi</i> Markewitsch, 1937	+				
<i>Paraergasilus</i> sp.					+
<i>Lernaea cyprinacea</i> Linnaeus, 1758	+		+	+	+
<i>L. elegans</i> Leigh–Sharpe, 1925	+				
<i>Lernaea</i> sp.					+
<i>Caligus lacustris</i> Steenstrup et Lütken, 1861	+	+			
<i>Argulus coregoni</i> Thorell, 1864	+			+	
<i>A. foliaceus</i> (Linnaeus, 1758)	+		+		+
<i>A. japonicus</i> Thiele, 1900	+		+		
<i>Argulus</i> sp.					+
Totally: 160 species	78	37	43	53	54

* Specific species.

Note. Here and below: 1 — ponds, rivers and reservoirs in Ukraine; 2 — brackish coastal areas of the Black Sea and Sea of Azov in Ukraine; 3 — ponds, river basins of the Aral Sea in Uzbekistan; 4 — basins of Russian rivers; 5 — ponds, rivers and coastal waters of Vietnam.

tively. Noted groups belong to 10 types and 14 classes. Less species were recorded among trematodes — 5; nematodes, leeches, parasites, and molluscs — 2 species of each. Along with a large number of parasites specific for Palaearctic (9 species), there are some of Sino-Indian species (6) pointing out the contact of European carp with the Sino-Indian fauna for a long geological time.

Among carp parasites from brackish coastal waters of the Black Sea and the Sea of Azov in Ukraine 37 species (protozoans — 5, monogeneans — 4; cestodes — 5; trematodes — 17; nematodes — 3; crustaceans — 3) were found. There were no parasites from the following groups: acanthocephalans, leeches, molluscs (Gaevskaya et al, 1975; Solonchenko, 1982; Karataev, 1984). Most parasite species in these populations of carp are of freshwater origin. However, they greatly differ in the degree of adaptation to water mineralization (salinity). Should be noted the significant difference in the composition of ectoparasites and endoparasites, 12 and 25 species, respectively. Carp ectoparasites living on the body surface or gill filaments are under the direct influence of high salinity, but endoparasites, even being typical freshwater, can infect the fish in fresh water and then be brought into the brackish water. Of 25 trematode species known in carp of this region, 17 species were identified and 12 of them were larvae.

In carp from ponds and basins of the Aral Sea (Uzbekistan), 47 parasite species were recorded, of them 19 protozoan species; 14 — monogeneans; 4 — cestodes; 2 — trematodes and 2 — nematodes; 1 — leeches and 3 — crustaceans. Parasites with direct life cycle were represented by 36 species (80%), with complex life cycle — 9 (20%) (Osmanov, 1971; Allamuratov, 1986).

The fauna of carp parasites of Russian river basins includes 53 species of 7 types and 10 classes. The significant species diversity of protozoans was revealed — 23 species constituting 43.4% of all carp parasites in this region. The most common species are from the genus *Myxobolus* (11 species). In flatworms (Plathelminthes), monogeneans (9) and trematodes (8) predominate. The rarest, both in species number and occurrence, are the parasites of the following groups: cestodes, nematodes, acanthocephalans: 2, 3, and 3 species, respectively (Strelkov, Shulman, 1971).

The data on fish parasites of Vietnam were known from the late nineteenth century when Albert Billet (medical parasitologist of the French army) first described several species of trematodes in catfish (Billet, 1898). By 2003, the composition of parasites of freshwater fishes (140 species) counted 451 species: Protozoa — 48, Myxozoa — 33, Digenea — 151, Monogenea — 112, Cestoda — 16, Nematoda — 53, Acanthocephala — 21, Hirudinea — 2, Branchiura — 3, Copepoda — 12 in different water bodies of Vietnam (Chon, 1999; Arthur, Te, 2005).

In carp from ponds in Vietnam, 54 parasite species belonging to 9 types, 14 classes were found. The most numerous are protozoans — 26 species; monogeneans — 9; and crustaceans — 7. Fewer are cestodes — 2; trematodes — 4; nematodes — 3, and acanthocephalans — 2. In protozoans, fauna of ciliated infusoria is the richest — 12 species.

Among carp parasites from 5 regions considered, significant predominance of species with direct life cycle is seen, i. e. parasites with life cycle without host changes (table 2). The exceptions are the carp parasites from brackish coastal areas of the Black Sea and the Sea of Azov in Ukraine. The predominating parasites are 59 species of protozoans (without 1 species of blood parasite *Trypanosoma carassii* developing with the change of two hosts) and monogeneans (24 species). These groups of parasites are the most abundant and widely distributed in the Palaearctic region. They are followed by parasitic crustaceans (17 species), leeches and larvae of elasmobranchian mollusks — glochidia (2 species each). Thus, 104 species of parasites with direct life cycle are against 57 species developing with the change of hosts. Such low number of parasites with complex life cycle are defined by low resistance of their exogenous stages to high and low temperatures and a small number of their intermediate hosts (chironomid larvae, copepods and oligochaetes) in environment. However, the difference in the number of intermediate hosts only is not enough for explanation of such sharp difference in species composition between parasites with direct life cycle and complex life cycle. From other cultured fish and native fish species (herbivorous, bream, silver bream, etc.)

Table 2. The number of parasite species developing without changing of hosts (A), and with changing of hosts (B) in each taxonomic group in carp from the regions considered

Таблица 2. Количество видов паразитов, развивающихся без смены (А) и со сменой (Б) хозяев, в каждой их систематической группе у карпа из рассматриваемых регионов

Groups of parasites	1		2		3		4		5	
	A	B	A	B	A	B	A	B	A	B
Protozoa	32	1	4	1	18	—	22	1	26	—
Monogenea	12	—	4	—	13	—	9	—	9	—
Cestoda	—	10	—	5	—	4	—	2	—	2
Trematoda	—	6	—	17	—	2	—	8	—	4
Nematoda	—	2	—	3	—	2	—	3	—	3
Molluscs	2	—	—	—	—	—	—	—	1	—
Acanthocephala	—	2	—	—	—	—	—	3	—	2
Hirudinea	2	—	—	—	1	—	—	—	—	—
Crustaceans	9	—	3	—	3	—	5	—	7	—
	57	21	11	26	35	8	36	17	43	11

numerous widely specific parasites with direct development move easily to cultivated carp, and this leads to disparities between them and the species developing with the change of hosts where more specific parasites predominate. The large number of species and diversity of trematodes in carp from brackish waters of the Black Sea and Sea of Azov may be explained by the large number of species of definitive hosts — fish eating water birds and carnivorous mammals.

Today, the degree of knowledge on carp parasites in these regions is unequal due to extraordinary variety of fish habitats in different water bodies and, finally, insufficient development of some taxonomic issues for certain groups of parasites (tabl. 3, 4).

Systematically, carp protozoans belong to 4 types, 6 classes, 9 orders, 12 families and 21 genera. In protozoan fauna there is considerable ecological diversity (7 genera) among Myxosporidia (Myxosporea) including specific species (8) consisting 24.2% of the total number (33 species). All Myxosporidia are equally represented by Palaearctic and Sino-Indian species. Among other parasitic protozoans, ciliates should be distinguished (17 species) from nine genera. Many of them have long been known as epizootic agents in fish farms (*I. multifiliis*, *Ch. cyprini*, etc.).

Type Plathelminthes includes 3 classes, 11 orders, 23 families and 39 genera. Class Monogenea is emblematic for carp (23 species, 5 genera). Of monogeneans identified, 11 species are specific representing about 50%. Most specific carp monogeneans are observed in Ukrainian and Uzbekistan ponds. Comparing the fauna of carp monogeneans from different regions, it should be noted a large number of identical species from genus *Dactylogyrus* (7–9 species), and in carp from ponds in Ukraine species from the genus *Gyrodactylus* (7 species) predominate.

In the water bodies analyzed, we identified 14 cestode species in carp. Variety of tapeworm species (11 genera) in these regions is due to the favorable abiotic environment and the presence of intermediate and final hosts. With the exception of *Diphyllobothrium* sp., all species are termophilic, stenothermic with wide specificity. In Ukraine, carp cestode fauna was formed at the expense of other native carps infected with parasites. Recently, *L. intestinalis*, *N. cheilancristrotus*, *V. unilateralis* became widespread due to the concentration of wading birds (definitive hosts of these helminthes) living in shallow waters of Dnieper reservoirs and the “open” fish farms.

The fauna of trematodes (Trematoda) in carp counts 25 species including 21 species of metacercariae, others are maritas. Ecological diversity of trematodes (23 genera) is determined by the great number of intermediate hosts particularly in fresh and brackish waters. Rather poor trematode fauna seen in the water bodies of Vietnam, Uzbekistan, and Russia appears to be due to its insufficient study as compared to

Table 3. Taxonomic characteristic of carp parasites
Таблица 3. Систематическая характеристика паразитов карпа

Type	Class	Order	Family	Main genera				
Euglenozoa	Kinetoplastea	Trypanosomatida	Trypanosomatidae	<i>Trypanosoma</i>				
		Bodonida	Bodonidae	<i>Cryptobia</i> <i>Ichthyobodo</i>				
Apicomplexa	Coccidiasina	Eucoccidiorida	Eumeriidae	<i>Eimeria</i> <i>Goussia</i>				
Myxozoa	Myxosporaea	Bivalvulida	Myxidiidae	<i>Myxidium</i>				
			Sphaerosporidae	<i>Sphaerospora</i> <i>Hoferellus</i>				
			Chloromyxidae	<i>Chloromyxum</i>				
			Myxobolidae	<i>Myxosoma</i> <i>Myxobolus</i> <i>Thelohanellus</i>				
Ciliophora	Phyllopharyngea	Chlamidodontida	Chilodonellidae	<i>Chilodonella</i>				
		Litostomatea	Pleurostomatida	Amphileptidae	<i>Hemiophrys</i> <i>Pseudoamphileptus</i>			
	Olygohymenophorea	Hymenostomatida	Ichthyophthiridae	Ichthyophthiridae	<i>Ichthyophthirius</i>			
			Sessilida	Epistylididae	<i>Epistylis</i> <i>Apiosoma</i>			
		Mobilida	Trichodinidae	Trichodinidae	<i>Trichodina</i> <i>Trichodinella</i> <i>Tripartiella</i>			
Platyhelminthes	Monogenea	Dactylogyridea	Dactylogyridae	<i>Dactylogyrus</i> <i>Pseudacolpenteron</i>				
		Gyrodactylidea	Gyrodactylidae	<i>Gyrodactylus</i>				
		Mazocreaidea	Diplozoidae	<i>Diplozoon</i> <i>Paradiplozoon</i>				
	Cestoda	Caryophyllidea	Caryophyllaeidae	Caryophyllaeidae	<i>Caryophyllaeus</i> <i>Biacetabulum</i> <i>Khawia</i>			
					Pseudophyllidea	Bothriocephalidae	Diphyllobothriidae	<i>Bothriocephalus</i> <i>Diphyllobothrium</i> <i>Ligula</i> <i>Digramma</i>
								Proteocephalidae
		Cyclophyllidea	Dilepididae	Dilepididae	Dilepididae	<i>Neogryporhynchus</i> <i>Paradilepis</i>		
						Gryporhynchidae	<i>Gryporhynchus</i>	
		Trematoda	Aspidogastriida	Plagiorchiida	Aspidogastriidae	<i>Aspidogaster</i>		
					Monorchidae	<i>Asymphylogadora</i>		
	Acanthocolpidae				<i>Stephanostomum</i>			
	Allocreadiidae				<i>Allocreadium</i>			
	Opistorchiidae				<i>Clonorchis</i> <i>Pseudamphistomum</i> <i>Metorchis</i>			
Heterophyidae	Heterophyidae				Heterophyidae	<i>Phagicola</i> <i>Metagonimus</i> <i>Apophallus</i> <i>Centrocestus</i>		
						Azygiidae	<i>Azygia</i>	
						Bucephalidae	<i>Bucephalus</i>	
Strigeidida	Strigeidida	Strigeidida	Strigeidida	<i>Sanguinicola</i> <i>Aponurus</i> <i>Diplostomum</i> <i>Tylodelphys</i> <i>Hysteromorpha</i> <i>Conodiplostomum</i> <i>Posthodiplostomum</i> <i>Ichthyocotylurus</i> <i>Tetracotyle</i>				

Table 3 (continued).
Окончание таблицы 3.

Type	Class	Order	Family	Main genera
Nematoda	Adenophorea	Enoplida	Cyathocotylidae	<i>Paracoenogonimus</i>
			Capillariidae	<i>Capillaria</i>
	Secernentea	Spirurida	Dioctophymatidae	<i>Eustrongylides</i>
			Camallanidae	<i>Camallanus</i>
Philometroides		Ascaridida	Philometridae	<i>Philometra</i>
			Cucullanidae	<i>Cucullanus</i>
			Anisakidae	<i>Rhaphidascaris</i>
Annelida	Hirudinea	Rhynchobdellida	Glossiphoniidae	<i>Hemiclepsis</i>
			Piscicolidae	<i>Piscicola</i>
Acanthocephala	Eoacanthocephala	Neoechinorhynchida	Neoechinorhynchidae	<i>Neoechinorhynchus</i>
		Neoacanthocephala	Dendronucleatidae	<i>Dendronucleata</i>
	Palaeacanthocephala	Paracanthocephalida	Paracanthocephalidae	<i>Paracanthocephalus</i>
		Echinorhynchida	Echinorhynchidae	<i>Acanthocephalus</i>
Mollusca	Bivalvia	Unionoidea	Unionidae	<i>Unio</i>
Artropoda	Maxillopoda	Cyclopoida	Ergasilidae	<i>Ergasilus</i>
				<i>Sinergasilus</i>
				<i>Paraergasilus</i>
		Siphonostomatoida	Lernaeidae	<i>Lernaea</i>
				Caligidae
Arguloida	Argulidae	<i>Argulus</i>		

Table 4. Number of parasites from different classes within natural range of carp

Таблица 4. Количество видов паразитов разных классов в пределах ареала карпа

Parasites	Water bodies				
	1	2	3	4	5
Type Euglenozoa					
Kinetoplastea	3	2	2	1	2
Type Apicomplexa					
Coccidiasina	2	0	1	0	1
Type Myxozoa					
Myxosporea	17	3	8	20	11
Type Ciliophora					
Phyllopharyngea	1	0	1	0	2
Litostomatea	1	0	0	0	1
Olygohymenophorea	9	0	6	2	9
Type Platyhelminthes					
Monogenea	12	4	13	9	9
Cestoda	10	5	4	2	2
Trematoda	6	17	2	8	4
Type Nematoda					
Adenophorea	0	1	1	0	0
Secernentea	2	2	1	3	3
Type Annelida					
Hirudinea	2	0	1	0	0
Type Acanthocephala					
Eoacanthocephala	0	0	0	1	1
Palaeacanthocephala	2	0	0	2	1
Type Mollusca					
Bivalvia	2	0	0	0	1
Type Artropoda					
Maxillopoda	9	3	3	5	7

Ukraine. All trematodes have wide specificity and confined to the thermophilic eurythermic and stenothermic fish species. Among trematode metacercariae, there are the species harmful for humans and commercially valuable animals: *M. yokogawai*, *M. xantasmus*, *P. ovatus*, and *C. sinensis* were found.

Type Nematoda is represented by 2 classes, 3 orders, 6 families and 8 genera. Totally, in carp living in ponds of various regions 11 species were recorded including two species as larval forms. There is a certain peculiarity of the species composition of nematodes (8 genera) as compared to other cyprinid fishes (herbivorous, etc.). For two species (*R. acus* and *C. microcephalum*), definitive hosts are predatory fishes. Nematodes are thermophilic eurythermic Palaearctic and Sino-Indian species. All of them have wide specificity. Since most nematodes develop with alternation of 2 or even 3 hosts (warm-blooded animals), they have fewer opportunities to adapt under different conditions, that ultimately reflects great mosaicity of their distribution in the water bodies analyzed.

Type Acanthocephala includes 2 classes, 4 orders, 4 families, and 5 genera. In the water bodies analyzed, in carp we have found 7 acanthocephalan species. They develop using crustaceans (amphipods, isopods). Parasites do not show any specificity for definitive hosts — fishes, they are eurythermic and characteristic for Palaearctic and Sino-Indian province.

Class Crustacea (Type Arthropoda) presented by 3 orders, 4 families, and 6 genera. There are 16 species. All species have wide specificity and taxonomically close to other crustaceans from cyprinid fishes. One part of these parasites are adapted to cold-water fish species (the genera *Paraergasilus* and *Lernaea*), the other — to the thermophilic ones (the genera *Argulus* and *Ergasilus*).

Class Hirudinea (type Annelida) and type Mollusca are represented by two species of parasites each. All of them are eurythermic and distributed in the above-mentioned aquatic ecosystems.

Conclusions

Thus, each of 5 reviewed regions has its own unique species composition of parasites. The majority of parasites recorded in carp are widespread in the explored regions.

Most parasites with direct life cycle and complex life cycle do not exhibit narrow specificity to the carp, which is not specific to abiotic and biotic environmental conditions. The representatives of the genera *Myxobolus*, *Dactylogyrus*, *Diplostomum*, *Ergasilus* and *Argulus* are of epizootic importance. Particularly pathogenic for carps bred in new ponds are tapeworms *B. gowkongensis*, *Kh. sinensis*, *L. intestinalis*, *D. interrupta*. The listed trematode metacercariae have medical and veterinary importance, and probability of infection is determined by the presence of intermediate hosts, molluscs from genera *Bithynia*, *Melania*, etc.

Distribution areas of parasites reflect the integrated distribution of hosts (intermediate and final) participating in their life cycles. Moreover, some species and taxonomic groups of parasites demonstrate different level of adaptability with respect to the host as a habitat (Pugachev, 1984). Modern specific monogenean species, on the one hand, are associated with the natural evolution of aboriginal populations of carp, and, on the other hand, are determined by anthropogenic influence (carp introduction). It resulted in “new” species of specific carp monogeneans introduced into new reservoirs.

In general, it should be emphasized that zoogeographical analysis of carp parasites should be made on separate groups of parasites and, moreover, the species diversity of parasites with simple life cycle and complex life cycle should be considered separately because of the peculiarities of their formation.

The nature of structure of carp parasitic system and its connection to the biotope is due to the degree of parasites specificity of intermediate and final hosts in different

parts of these fish habitat. Such functioning of the parasitic trematode population (in molluscs) in carp is likely in brackish coastal waters of the Black Sea and the Sea of Azov. The same can be said about the existence of parasitic cestode populations (in copepods, oligochaetes, predatory fish, fish-eating birds, etc.) in freshwater carp in Ukraine. The complete absence of acanthocephalans, in particular from the genera *Acanthocephalus* and *Neochinorhynchus* characteristic for the southern regions and widely specific in carp in Uzbekistan ponds may be due to the low frequency of occurrence of these parasites in intermediate hosts (amphipods, isopods).

It becomes clear that the functioning and stability of the existent parasitic system in carp within the distribution range are provided by the presence of intermediate hosts and their contact with the exogenous stages of the pathogen in different water biocenoses, and the influence of physical and climatic factors.

The number of carp helminthes with benthic invertebrates as intermediate hosts are more than 2 times larger than the number of parasites with life cycles involving planktonic crustaceans. This is the evidence of its ancient topical and trophic relationships with molluscs, oligochaetes, amphipods, freshwater shrimps and planktonic crustaceans. Entering the life cycles of trematodes from the family Diplostomatidae (metacercariae), cestodes from the family Diphyllbothriidae and many other helminthes as additional or reservoir host, carp shows broad adaptive possibilities (mechanisms) of its distribution in extremely diverse conditions in the southern Palaearctic regions. At every stage of the formation of the parasite fauna (formation of host-parasite relationships), carp as a host accumulated the maximum number of different (ecological) parasites. Therefore, it is not surprising that such a rich and heterogeneous species composition of carp parasites is unique among the other hosts (aquatic or terrestrial) in the number of parasitic species.

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