Vestnik zoologii, **45**(6): 491–502, 2011

UDC 576.89:597.551.2

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

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Received 10 March 2011
Accepted 4 July 2011

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

Table 1 (continued).
Продолжение таблицы 1.

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

Table 1 (continued).
Продолжение таблицы 1.

Parasite species	Water bodies				
	1	2	3	4	5
Tetracotyle sp. mtc				+	
Paracoenogonimus ovatus mtc Katsurada, 1914		+		+	
Type Nematoda					
Capillaria tomentosa Dujardin, 1843			+		
Eustrongylides mergorum l (Rudolphi, 1809)		+			
Camallanus truncatus (Rudolphi, 1814)					+
Philometra abdominalis Nybelin, 1928	+				
Philometra sp.					+
Philometroides lusiana (Vismanis, 1966)	+				
Cucullanus cyprini Yamaguti, 1941				+	+
Rhaphidascaris acus (Bloch, 1779)		+			
Rhaphidascaris sp.				+	
Contracaecum microcephalum l (Rudolphi, 1819)		+	+		
Contracaecum sp. l				+	
Type Annelida					
Hemiclepsis marginata (Müller, 1774)	+				
Piscicola geometra (Linnaeus, 1761)	+		+		
Type Acanthocephala					
Neoechinorhynchus sp.				+	
Dendronucleata dogieli Sokolowskaja, 1962					+
Paracanthocephalus curtus Achmerov et Dombrowskaja-Achmerova, 1941				+	
P. tenuirostris Achmerov et Dombrowskaja-Achmerova, 1941				+	
Acanthocephalus anguillae Müller, 1780)	+				
A. lucii (Müller, 1776)	+				
Brentisentis cyprini Yin et Wu, 1984					+
Type Mollusca					
Unio crassus Philipsson, 1788	+				
U. pictorum Linnaeus, 1758	+				+
Type Artropoda					
Ergasilus briani Markewitsch, 1932	+			+	
E. nanus Beneden, 1871		+			
E. sieboldi Nordmann, 1832	+	+			
Sinergasilus undulatus (Markewitsch, 1940)				+	
Paraergasilus brevidigitus Yin, 1954				+	+
P. medius Yin, 1956					+
P. rylovi Markewitsch, 1937	+				
Paraergasilus sp.					+
Lernaea cyprinacea Linnaeus, 1758	+		+	+	+
L. elegans Leigh–Sharpe, 1925	+				
Lernaea sp.					+
Caligus lacustris Steenstrup et Lütken, 1861	+	+			
Argulus coregoni Thorell, 1864	+			+	
A. foliaceus (Linnaeus, 1758)	+		+		+
A. japonicus Thiele, 1900	+		+		
Argulus 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 (Plathelmintes), 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 Plathelmintes 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, stenotermic 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	*Trypanosoma*
		Bodonida	Bodonidae	*Cryptobia*
				Ichthyobodo
Apicomplexa	Coccidiasina	Eucoccidiorida	Eumeriidae	*Eimeria*
				Goussia
Myxozoa	Myxosporea	Bivalvulida	Myxidiidae	*Myxidium*
			Sphaerosporidae	*Sphaerospora*
				Hoferellus
			Chloromyxidae	*Chloromyxum*
			Myxobolidae	*Myxosoma*
				Myxobolus
				Thelohanellus
Ciliophora	Phyllopharyngea	Chlamidodontida	Chilodonellidae	*Chilodonella*
	Litostomatea	Pleurostomatida	Amphileptidae	*Hemiophrys*
				Pseudoamphileptus
	Olygohymenophorea	Hymenostomatida	Ichthyophthiridae	*Ichthyophthirius*
		Sessilida	Epistylididae	*Epistylis*
				Apiosoma
		Mobilida	Trichodinidae	*Trichodina*
				Trichodinella
				Tripartiella
Platyhelminthes	Monogenea	Dactylogyridea	Dactylogyridae	*Dactylogyrus*
				Pseudacolpenteron
		Gyrodactylidea	Gyrodactylidae	*Gyrodactylus*
		Mazocreaidea	Diplozoidae	*Diplozoon*
				Paradiplozoon
	Cestoda	Caryophyllidea	Caryophyllaeidae	*Caryophyllaeus*
				Biacetabulum
			Lytocestidae	*Khawia*
		Pseudophyllidea	Bothriocephalidae	*Bothriocephalus*
			Diphyllobothriidae	*Diphyllobothrium*
				Ligula
				Digramma
		Proteocephalidea	Proteocephalidae	*Proteocephalus*
		Cyclophyllidea	Dilepididae	*Neogryporhynchus*
				Paradilepis
			Gryporhynchidae	*Gryporhynchus*
	Trematoda	Aspidogastrida	Aspidogastridae	*Aspidogaster*
		Plagiorchiida	Monorchiidae	*Asymphylodora*
			Acanthocolpidae	*Stephanostomum*
			Allocreadiidae	*Allocreadium*
			Opistorchiidae	*Clonorchis*
				Pseudamphistomum
				Metorchis
			Heterophyidae	*Phagicola*
				Metagonimus
				Apophallus
				Centrocestus
		Azygiida	Azygiidae	*Azygia*
		Strigeidida	Bucephalidae	*Bucephalus*
			Sanguinicolidae	*Sanguinicola*
			Lecithasteridae	*Aponurus*
			Diplostomatidae	*Diplostomum*
				Tylodelphys
				Hysteromorpha
				Conodiplostomum
				Posthodiplostomum
			Strigeidae	*Ichthyocotylurus*
				Tetracotyle

Table 3 (continued).
Окончание таблицы 3.

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

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. xantasomus, 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 Diphyllobothriidae 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.

Allamuratov B. A. Parasitic protozoans and protozoan diseases of fish in some fish farms of Uzbekistan and southern Kazakhstan. — Nukus : Karakalpakstan, 1986. — 98 p. — Russian : *Алламуратов Б. А.* Паразитические простейшие и протозойные болезни рыб некоторых прудовых хозяйств Узбекистана и на юге Казахстана.

Amin O. M. Key to the families and subfamilies of Acanthocephala, with the erection of a new class (Polyacanthocephala) and a new order (Polyacanthorhynchida) // J. Parasitol. — 1987. — **73**. — P. 1216–1219.

Arthur I. R., Te B. Q. Checklist of the parasites of fishes of Viet Nam // FAO Fisheries Technical Paper. — Rome, 2005. — N 369/2. — 133 p.

Bauer O. N. Ecology of freshwater fish parasites // News VNIIORH. — 1959. — **49**. — 206 p. — Russian : *Бауэр О. Н.* Экология паразитов пресноводных рыб.

Billet A. Notes sur la faune da Haut-Tonkin II Sur quell gues distomes // Bull. Soc. Fr. Belg. — 1898. — N 28. — P. 283–303.

Bogutskaya N. G., Naseka A. N. Catalog of Agnatha and fishes of fresh and brackish waters of Russia with nomenclature and taxonomic comments. — Moscow : Ass. Nauchn. Publications CMC, 2004. — 389 p. — Russian: *Богуцкая Н. Г., Насека А. Н.* Каталог бесчелюстных и рыб пресных и солоноватых вод России с номенклатурной и таксономическими комментариями.

Brands S. L. Systema Naturae 2000. Universal Taxonomic Services. — Amsterdam, 1989–2005. — [Online: http: // sn2000. taxonomy. nl/].

Chon T. T. Parasitic diseases on fish cultivated in Vietnamese Agricult. Forest. — 1999. — N 11. — P. 97–100.

Davydov O. M., Kurovskaya L. Ya. Ectoparasites of carp in warm-water fisheries. — Kyiv, 1991. — 253. — Manuscript Dep. in UkrNIINTI, N 1630-Uk91. — Russian : *Давыдов О. Н., Куровская Л. Я.* Эктопаразиты карпа в тепловодном рыбоводстве.

Davydov O. M., Isaeva N. M., Kurovskaya L. Ya. Ichthyopathological encyclopedia. — Kyiv : Phytosociology, 2000. — 164. — Russian : *Давыдов О. Н., Исаева Н. М., Куровская Л. Я.* Ихтиопатологическая энциклопедия.

Davydov O. M., Seregina L. V., Strazhnik L. V., Kurovskaya L. Ya. Features of parasitic fish fauna of water cooling reservoir of the Kyiv HPP-5 // Vestn. zoology. — 1982. — N. 4. — P. 16–20. — Russian : *Давыдов О. Н., Серегина Л. В., Стражник Л. В., Куровская Л. Я.* Особенности паразитофауны рыб водоема-охладителя Киевской ТЭЦ-5.

Dogiel V. A. General parasitology. — Leningrad : Izd-vo Leningrad State University, 1962. — 464 p. — Russian : *Догель В. А.* Общая паразитология.

Gaevskaya A. V., Gusev A. V., Donets Z. S. et al. Key for parasites of vertebrates of the Black Sea and Sea of Azov. — Kyiv : Nauk. dumka, 1975. — 551. — Russian : *Гаевская А. В., Гусев А. В., Донец З. С. и др.* Определитель паразитов позвоночных Черного и Азовского морей.

Iskov M. P. On the species composition of parasites of carp in fish farms in Ukraine // Fishing farmery. — 1967. — **5.** — P. 112–121. — Russian : *Исков М. П.* О видовом составе паразитов карпа в прудовых хозяйствах Украины.

Iskov M. P. Fauna of Ukraine. Myxosporidia (Mixosporea). — Kyiv : Nauk. dumka, 1989. — Vol. 37, fasc. 4. — 210 p. — Russian : *Исков М. П.* Фауна Украины. Миксоспоридии (Миксоспореа).

Ivasyk V. M. Carp parasites in fish farms of the western regions of the UkrSSR and diseases caused by them // Trudy NII prud. i oz.-rechn. rybn. hoz.-va UkrSSR. — 1953. — Vol. 3. —P. 25–31. — Russian : *Ивасик В. М.* Паразиты карпа в рыбхозах западных областей УССР и болезни, ими вызываемые.

Kabata Z. Copepoda and Brachiura // Guide to the parasites of fishes of Canada. Part 2. Crustacea / Ed. L. Margoli, Z. Kabata Z. Can. Spec. Publ. Fish. Aquat. Sci., 1988. — P. 3–127.

Karataev A. K. Parasitic protozoans from fishes of Dnieper estuary and adjacent areas of the Black Sea : Avtoref. dis. ... candidate biol. science. — Kyiv, 1984. — 28. — Russian : *Каратаев А. К.* Паразитические простейшие рыб Днепровского лимана и прилегающих участков Черного моря.

Keys to the Cestode Parasites of Vertebrates / Eds L. Khalil, A. Jones, R. A. Bray. — Wallingford : CAB International, 1994. — 751 p.

Keys to the Trematoda / Eds D. I. Gibson, A. Jones, R. A. Bray // CABI Publishing and the Natural History Museum. — London, 2002. — **1.** — 521 p.

Lom J., Dykova I. Protozoan Parasites of Fishes // Developments in Aquaculture and Fisheries Science. — Amsterdam : Elsevier, 1992. — **26**. — 315 p.

Malevitskaya M. A. Parasitic diseases in young carp in fish farms of the eastern regions of UkrSSR // Trudy NII prud. i oz.-rechn. rybn. hoz.-va UkrSSR. — 1952. — Vol. 7. — P. 36–41. — Russian : *Малевицкая М. А.* Паразитарные заболевания молоди карпа в рыбхозах восточных областей УССР.

Markevich A. P. Parasite fauna of the freshwater fish of the Ukrainian SSR. — Kyiv : Izd-vo AN USSR, 1951. — 376 p. — Russian : *Маркевич А. П.* Паразитофауна пресноводных рыб Украинской ССР.

McDonald T. E., Margolis L. Synopsis of the parasites of fishes of Canada // Can. Spec. Publ. Fish. Aquat. Sci. — 1995. — Suppl. (1978–1993). — 265 p.

Moravec F. Nematodes of Freshwater Fishes of the Neotropical Region. — Praha : Academia, 1998. — 464 p.

Osmanov S. O. Parasites of fishes of Uzbekistan. — Tashkent : FAN, 1971. — 532. — Russian : *Османов С. О.* Паразиты рыб Узбекистана.

Pugachev O. N. Parasites of freshwater fishes of North-East Asia. — Leningrad : Zool. Inst USSR, 1984. — 156. Russian : *Пугачев О. Н.* Паразиты пресноводных рыб Северо-Востока Азии.

Roitman V. A., Beer S. A. Parasitism as a form of symbiotic relationship. — Moscow : Tovarischestvo nauchnyh izdaniy KMK, 2008. — 3000 p. — Russian : *Ройтман В. А., Беэр С. А.* Паразитизм как форма симбиотических отношений.

Rozum E. Yu., Onishchenko O. V. Distribution of postodiplostomosis in fish in water bodies of the northern-west parts of the Black Sea region // Proc. sci. — pract. conf. “Problems of fish health protection”. — Kharkiv, 2008. — P. 352–356. — Ukrainian : *Розум Є. Ю., Оніщенко О. В.* Поширення постодиплостомозу серед риб у водоймищах північно-західного Причорномор’я.

Solonchenko A. N. Helminths of fishes in the Sea of Azov. — Kyiv : Nauk. dumka, 1982. — 150. — Russian : *Солонченко А. Н.* Гельминтофауна рыб Азовского моря.

Strelkov Yu. A., Shulman S. S. Ecological and faunistic analysis of fish parasites in the Amur // Parazitol. coll. — 1971. — **25**. — P. 196–292. — Russian : *Стрелков Ю. А., Шульман С. С.* Эколого-фаунистический анализ паразитов рыб Амура.