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CRYPTOKOTYLE LÜHE, 1899 (TREMATODA: HETEROPHYIDAE): SPECIAL CHARACTERISTICS OF DEVELOPMENTAL BIOLOGY AND EPIZOOTIOLOGY

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This review presents the scientific studies data on the special characteristics of developmental biology and epizootiology of *Cryptocotyle* trematodes, which belong to *Heterophyidae* family and pose a threat to the health of the endotherms, including humans, i.e., it is a typical zoonosis. These trematodes are predominantly widespread in the Mediterranean region, namely, in the western Mediterranean region and the Aegean province. The trematodes of *Cryptocotyle* genus are found in Europe, Asia, North and South America, and Antarctica. They are typical biohelminths, i.e., they have a complicated life cycle, where the initial intermediate hosts are mollusks, the second ones – fish of different species, the definitive and final hosts are piscivorous birds, carnivorous animals (foxes, wolves, dogs, cats, etc.), and humans. Cryptocotylosis is remarkable for its seasonal prevalence, which depends on the climatic zoning of territories. For instance, in the territorial waters of Ukraine, the highest indices of cryptocotylosis invasion among Agonidae fish are mainly observed in summer and autumn, but the peak of the invasion comes in autumn. The parasitizing of *Cryptocotyle* trematodes in the organism of mollusks impacts the reproduction ability and behavioral specificities (motility) of the latter. The invaded fish have black pigment spots on the surface of their bodies – these are metacercariae. In the organism of definitive hosts, the agent is localized in the gastrointestinal tract and may cause inflammatory processes in the mucous membrane of the intestines and changes in parenchymatous organs, which demonstrates the toxic effect of the parasite on the host organism. The diagnostics of cryptocotylosis is based on detecting the agent in the host organism and its further taxonomic identification by its anatomic and morphological specificities. The pollution of the aqueous medium with organic and inorganic residues impacts the organisms of both hosts and parasites.

Key words: cryptocotylosis, biohelminth, zoonosis, intermediate hosts, definitive hosts.

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INTRODUCTION

The study of the biology of helminths is relevant not only for practical purposes but also for clarifying phylogenetic relations and the evolution of this group of organisms (Dogel VA, 1962).

B. Ransom (1920) did the first systematization of trematodes of *Heterophyidae* family and divided it into seven genera. Then, J. Ciurea (1924) conducted a detailed study of the morphological specificities of the development level and topography of the ventral sucker and the gonotyl, the last elements of the reproductive system, and used these data to divide the *Heterophyidae* family into five subfamilies, which also included *Cryptocotilinae* subfamily with *Cryptocotyle* genus.

Creplin (1825) first defined a new species of trematodes, *Cryptocotyle lingua* (called *Distoma lingua* at first by Creplin in 1825) in the intestines of the gull, *Larus marinus* (Stunkard WH, 1930). In 1903, Fischoeder changed its name to *Cryptocotyle lingua* (Ransom B, 1920). Later, this species of trematodes was found in the gastrointestinal tract of *Larus argentatus vegae*

Yamaguti (1939). In 1918, Wigdor found this species of trematodes in the dog's small intestines and mistakenly called this parasite *Hallum caninum* (Yoshimura K, 1965). The detailed morphology of *Cryptocotyle* genus, including *Cryptocotyle lingua*, *C. concava* and *C. jejuna* was described by F.N. Morozov (1952). The life cycle biology and the morphology were studied in detail and described in the publications of H.W. Stunkard, C.H. Willey (1929, 1930), and H.W. Stunkard HW (1929). A considerable contribution to the study of morphology and developmental biology of *Cryptocotyle lingua*, was made by E. Linton, who called it *Tocotrema lingua* (1915).

According to the current taxonomy, the trematodes of *Cryptocotyle* Lühe genus, 1899 belong to the Heterophyidae family. The genus consists of eight species: *Cryptocotyle concava* Creplin, 1825; *Cryptocotyle lingua* Creplin, 1825; *Cryptocotyle jejuna* Nicoll, 1907; *Cryptocotyle badamshini* Kurochkin, 1959; *Cryptocotyle cryptocotyloides* Issaitschikow, 1923; *Cryptocotyle delamurei* Jurachno, 1987; *Cryptocotyle quinqueangularis* Skrjabin, 1923; *Cryptocotyle thapari* McIntosh 1953; *Cryptocotyle ransomii* Isaitshikow, 1924 (Nicoll W, 1923; Morozov, 1952; Gibson D et al, 2002, 2005, 2008). The results of the recent morphological, molecular and genetic studies were used to describe a new species, *Cryptocotyle lata* sp. (Y.V. Tatonova, V.V. Besprozvannykh, 2019).

In the opinion of I. Martynenko (2016, 2017, 2019), the trematodes of *Cryptocotyle jejuna* Nicoll, 1907 and *Cryptocotyle ransomii* Isaitshikow, 1924 are identical species, as they have similar morphological traits.

THE MORPHOLOGY OF TREMATODES OF CRYPTOCOTYLE GENUS

The common morphological traits of *Cryptocotyle* genus are as follows: an oval or prolonged body; a medium-sized mouth sucker; a very short prepharynx; rather a small pharynx; the gut tube bifurcation is closer to the mouth sucker than to the ventral one; the gut branches are thin, going to the end part of the body and ending behind testes, bending under them. The ventral sucker is rudimentary, located in the anterior wall of the genital sinus behind the ventral sucker. The seminal vesicle is well developed, curved, and of more or less S-like form. The testes are in the back part of the body, of an irregular round or oval form, located opposite each other. The ovaries of irregular oval form are to the right from the median line and in front of the seminal receptacle (Morozov, 1952). A remarkable morphological trait of this genus is the gonotyl, connected to the back part of the ventral sucker and two side-wise testes (Ransom B, 1920).

The microscopic study of the morphological traits of the redia of *Cryptocotyle lingua* demonstrates that the mouth sucker is surrounded by numerous funnel-like sensor structures. The outer membrane of the body towards the back part forms a comb-like structure. Small spheric vesicles are present on the surface of the tegument in the main part of the redia. The genital pore is covered with epithelium; there is a cilium in the lumen (Irwin S et al, 1978).

THE DISTRIBUTION OF CRYPTOCOTYLOSIS IN THE BLACK SEA

The trematodes of *Heterophyidae* family are widespread only in four biogeographical realms – Palearctic, Neoarctic, Neotropic, and Eastern. Their distribution in the regions and within them is very uneven. The most significant number of trematodes of *Heterophyidae* family is in the Palearctic realm, consisting of three subrealms – the Mediterranean, Himalayan-Chinese, and Angara. The trematodes of this family are most widespread in the Mediterranean region, namely, in the western Mediterranean region (Algeria and the European coast of the Mediterranean Sea) and the Aegean province (the Black Sea coast of Romania, the Crimea, the Dnipro estuary) (Morozov, 1952).

Geographically, cryptocotylosis is considerably widespread on most continents. For instance, the trematodes of *Cryptocotyle* genus were registered in North America, Europe, and Asia (Ransom B, 1920; Wootton DM, 1957; Yoshimura K, 1965; El-Darsh H, Whitfield P, 1999; Lang T et al, 2001; Saeed I et al, 2006; Heuch PA et al, 2011; Christensen ND et al, 2015), in North America (Torres P et al, 1993; Gardner LS, Thew PT, 2006; Casalins L. et al, 2020) and even Antarctica (Zdzitowiecki K et al, 1989).

Relative geographically limited distribution of *Cryptocotyle* trematodes is related to the distribution of the initial intermediate hosts – mollusks, considering that these parasites are rather specific in their selection of the initial intermediate hosts, and their cercariae may develop only in the mollusks from genera *Littorina* and *Hydrobia*. However, *Cryptocotyle* genus is remarkable for its low specificity towards the second intermediate and final hosts. The second intermediate hosts for the trematodes of this genus are 59 species of fish, and the final hosts are 100 species of endotherms, both birds and mammals (Martinenko, 2016).

The trematodes of *Cryptocotyle* genus are primarily concentrated in the Aegean province, including the Black Sea waters, which also cover the coast of Ukraine (Naidenova NN, 1974; Kvach YV, 2004, 2007; Kvach YV et al, 2000, 2014; Goncharov et al, 2017).

The first data about the distribution of cryptocotylosis among Gobiidae family in the Black Sea were submitted by I.M. Isaychikov (1924; 1925) during the Azov–Black Sea expedition. The intermediate host of *C. cancavum*, defined by him, was *Perccottus glenii*. J. Ciurea (1924) found the trematodes of *C. jejuna* in *Larus argentatus cachinnans* and *Sterna hirundo* in the territory of Romania. Later, I. Radulescu, N. Vasiliu (1951) studied the parasite fauna of Gobiidae in the coastal waters of Romania and found that *Neogobius melanostomus* and *Pomatoschistus marmoratus* had the metacercariae of C. *cancavum*. Naidenova (1974) carried out a more detailed study of the helminth fauna of Gobiidae in the Crimean area of the Black Sea and noted the highest prevalence of the invasion in *Gobius ophiocephalus* – 91.5 %; the highest indices of invasion intensity were registered for *Neogobius fluviatialis* – 37–500 metacercariae. A considerable contribution to the study of the distribution of cryptocotylosis agent and its relevance in the ecosystem of the parasite fauna of Gobiidae in the Black Sea was made by Kvach (2004, 2007, 2014); in particular, he determined the circulation of two main species: *C. concavum* and *C. lingua*.

In the territory of Ukraine, the parasitizing of *C. jejuna* was registered in the Kerch Strait in the gull *Larus cachinnans.* Previously, the representatives of this species were not registered in this territory (Martinenko I, 2012). In the waters of the Dnipro-Buh estuary, there was a reported invasion of Gobiidae by *C. cancavum* and *C. jejuna* (*Neogobius melanostomum* – the prevalence of 59.2 %; *Neogobius fluviatialis* and *Mesogobius batrachocephalus* – the prevalence was 30.4 and 17 %, respectively) (Goncharov SL et al, 2017). The parasitizing of trematodes of *Cryptocotyle* genus was noted in Gobiidae in the Sea of Azov, where the prevalence was registered for *C. concavum* and *C. lingua* (Sarabeev VL, Domnich IF, 2001).

THE BIOLOGICAL SPECIFICITIES OF TREMATODES OF CRYPTOKOTYLE LÜHE, 1899

The life cycle of Cryptocotyle spp. The life cycle of a trematode of *Cryptocotyle* genus was first studied and described by Stunkard HW, Willey CH (1929, 1930). The study authors found that the initial intermediate hosts of this genus are estuarine and marine mollusks, *Littorina littorea* and *Littorina rudis*. The cercariae, which abandoned the mollusk, move freely in water via specific adaptation mechanisms and look for the second intermediate host – fish. The researchers proved experimentally that feeding estuarine fish to the cats infected the latter with a cryptocotylosis agent. After the latency period (from 7 to 20 days), there was a noted appearance of clinical symptoms in the invaded animals with the features of the gastrointestinal tract infection. The postmortem of the experimentally infected cats demonstrated the presence of sexually mature trematodes.

A considerable contribution to the study of the life cycle of *Cryptocotyle lingua* was made by Reimer LW (1970) and Yamaguti S (1975), who found that the initial intermediate hosts for this species of trematodes were mollusks *Littorina* and *Hydrobia ulvae* (*Peringia ulvae*) (Deblock S, 1980; Mattheus PM et al, 1985; Kristoffersen R, 1992; Lambert W et al, 2012, Zander CD et al, 2000). The use of mollusks *Boreoelona ussuriensis* by the trematodes of *Cryptocotyle lata* sp., serving as intermediate hosts, was determined in the freshwater bodies of the Far East of Russia (Tatonova YV, Besprozvannykh VV, 2019).

The life cycle of trematodes of *Cryptocotyle* genus consists of some stages of the parasite development, which take place in the host organism: after leaving the mollusk, when contacting the second intermediate hosts, fish, the parthenitas are fixed to its outer cover, and pass into the cyst stage, which is preserved till the parasite gets to the digestive system of the final host – another fish or a piscivorous bird (Golovin PV et al, 2020).

The initial intermediate hosts are mollusks, which get invaded by the cryptocotylosis agent, consuming the trematode eggs that fall into the water with the feces of the invaded birds. The mollusks can find the accumulations of the feces via chemotaxis and get infected by consuming them. The eggs can avoid floating to the water surface; they stick to the surface of rocks and algae consumed by the mollusks, which thus get invaded (Davies M, Knowles AJ, 2001).

Under favorable conditions, one trematode of *Cryptocotyle* can reproduce up to 15 thousand larvae a day via asexual reproduction (Sindermann, Rosenfeld, 1954). The five-year-long observation of the mollusks *Littorina littorea,* invaded by the trematode *C. lingua*, demonstrated that in one year, about 1.5 million cercariae come out of one mollusk, with the range of the daily synthesis of 3,000 cercariae during the first year, and up to 800 cercariae in the last year of the observations (Esch GW, Fernandez JC, 1993).

The second intermediate hosts for the trematode of *Cryptocotyle* genus are the representatives of ichthyofauna – the fish of natural and artificial water bodies (Kristoffersen R, 1992; Heuch PA et al, 2011). Different fish families can be intermediate hosts, namely, Gobiidae, Clupeidae, Gadidae, Percidae, Esocidae, and others (Mellegaard S, Lang T, 1999; Tolonen A, Karlsbakk E, 2003; Honcharov SL, 2019b). Being located on the surface of the invaded fish, the metacercariae promote the melanization around the cyst, so cryptocotylosis is referred to so-called black spot diseases (Sindermann CJ, Farrin AE, 1962).

The third and definitive host is mostly a piscivorous bird. Sexually mature trematodes parasitize in the gastrointestinal tract of birds (*Larus ridibundus*; *Larus dominicanus*; *Larus canus; Phalacrocorax carbo*; *Pelicanus*), which consume fish and get invaded (Ciurea, 1915a; Guildal JA, 1968; Threlfall W, 1982; Lothar WR, 2002).

There are communications about the possibility of metacercariae of *Cryptocotyle* genus invading foxes in Great Britain (Smith HJ, 1977; Saeed I et al, 2006), dogs in Hungary and Italy (Christensen N, Roth H, 1949; Nardi E,1962; Matskasi I, 1976), cats in Korea (Christensen N, Roth H, 1946; Sohn WM, Chai J, 2005; Chai JY et al, 2013); wolves in Russia (Kozlov DP, 1967); causing invasion and death of otters in Bolivia (Gardner LS, Thew PT, 2006); minks in Great Britain (McTaggart H,1958); dogs and rats in the Crimea (Ukraine) (Isaiychikov, 1924, 1925); marine mam-mals – *Eumetopias jubatus* in the Russian waters of the Bering Sea (Yurakhno MV, Stryukov AA, 2006).

Cryptocotylosis is a zoonosis disease, i.e., it poses a threat to human health (Chai JY, Jung BK, 2017). The invasion of people with cryptocotylosis, for example, *C. lingua*, was reported in Greenland and Alaska (Babbott FL et al, 1961; Rausch RL et al, 1967; Zimmerman MR et al, 1975). MR Zimmerman (1980) reported the finding of *C. lingua* eggs in a frozen Eskimo mummy, which was 1,600 years old. So there are reasons to believe that the trematodes of this genus are potentially dangerous for humans and endotherm animals (Goncalves MLS et al, 2003; Chai J et al, 2009; Moshu A, 2014; Lee Y et al, 2020).

Considering the specificities of the developmental biology of the trematodes of *Cryptocotyle* genus and the possibility of further invasion via stray dogs and cats, cryptocotylosis is a natural zoonotic disease (Kornyushin VV et al, 2013).

There were no considerable interspecies differences registered in the developmental biology of the trematodes of *Cryptocotyle* genus (Reimer LW, 1970; Bakke TA, 1972).

THE BIOLOGICAL SPECIFICITIES OF SPOROCYSTS AND REDIAE OF *CRYPTOCOTYLE GENUS*

RM Cable (1931, 1934) studied the specificities of *Cryptocotyle lingua* agent parasitizing in the organism of the initial intermediate host, a marine periwinkle – *Littorina littorea*, and found that maternal sporocysts and young rediae were localized in the lymph space of its liver, under the epithelium of the large bile duct and in the interparticle space of the organ. The histological examination of *C. lingua* redia demonstrated a low degree of differentiation and had only expressed muscle elements of the mouth sucker and intestinal branches. In the older rediae, the walls were more defined, and the cell nuclei were stained more intensively. By their size and form, diploid chromosomes (twelve) of *C. lingua* had similar characteristics to those of humans (Cable RM, 1931). The presence of acid phosphatase, which appears in the form of accumulations in the cells, was determined in the cytoplasm of cells and lysosomes of rediae of *Cryptocotyle* genus. Most accumulations are registered in the area of the pharynx and blind terminations of the intestinal branches. The wall of the redia body also had myelinated bodies and membrane granules (Krupa PL et al, 1968). The rediae of *C. lingua* takes place in two ways: the phagocytosis by apical cells in winding intestinal branches and the pinocytosis by the superficial membrane (tegument) of the parasite. The tegument and intestinal branches of the rediae have many hollows and folds, which increases the total adsorption area (Krupa PL et al, 1967). However, a prevalent part of nutrients, including glucose, gets into the organism of *C. lingua* redia via the surface of the parasite body (McDaniel JS, Dixon KE, 1967).

THE BIOLOGICAL SPECIFICITIES OF THE CERCARIAE OF *CRYPTOCOTYLE GENUS*

In the cercariae of *C. lingua*, developing in the last stages of the development, the morphological changes start in the back part of the body and progress to the primary end of the larva – eyespots, rudiments of mouth suckers, and cercarial structures appear (Cable, 1934).

The cercariae, which left the mollusk, are actively moving in water due to their well-developed dorsal and ventral striped longitudinal muscle cells with one myofibrilla in each. The cercaria tail of *Cryptocotyle* genus is well innervated due to the ventral and dorsal caudal nerves, which start in the nerve plexus behind the tailhead (Rees FG, 1975a). The cercaria tail of *Cryptocotyle* genus starts developing at the redia stage; this process is completed in the hemocoel of the mollusk. The growth of epidermal cells begins in the proximal part of the tail, followed by the development of the secretory cells, the primary function of which is to synthesize the secrete. The vesicular secretory bodies are dispersed throughout the entire cytoplasmic epidermis and form a proximal caudal extension together with transparent synthesizing bodies at the tailhead.

Further on, the vesicular and secretory bodies degenerate. With time, the longitudinal caudal muscles develop into cross-striped muscles typical for freely floating cercariae. Later, the nuclei of most muscle cells degenerate as a secondary excretory pore, formed on the back part of the cercaria body. The cercaria tail falls off at direct contact with the second intermediate host – a fish. The mechanical break in the place of the tail connecting to the cercaria body is related to the resistance to the immovable body of the fish. At first, a "wound zone", formed on the parasite's body is covered with a caudal pocket. Then the wound is covered with the layer of outer cytoplasmic epithelium (Rees FG, 1977). Using the tail, the cercaria can make active oscillating movements and move in the water, reaching its primary aim – the invasion of a fish (Chapman H, Wilson R, 1973).

The location of the sensory apparatus elements, sensillae, is considerably different in the cercariae of other species: *C. lingua* and C.concava. Although these trematodes belong to the same genus, the determination of sensillae topography is a relevant systematic feature (Sten›ko RP, 1985).

The cercariae of *C. lingua* are remarkable for the phototaxis phenomenon, which helps search for the second intermediate host – fish. Cercariae have two pigmented photoreceptors, located dorsally, and one more non-pigmented photoreceptor is located more ventrally to the middle part of the cercaria body. Each pigmented photoreceptor consists of two asymmetric pigment cells. The retina cells have a large number of mitochondria. The axonal projections of retina cells of even and uneven photoreceptors get to the cerebral ganglia through a pore. The even dorsal photoreceptors are sensitive to highly intense light, and a medium non-pigment photoreceptor – to less intense light and shadows (Rees FG, 1975b).

The muscle wall of the cercaria has a trait of slow contraction, and the muscles of the mouth sucker envisage stronger and faster contractions due to specific grooves formed by the circular location of the muscle fibrillae. The location of spikes around the grooves makes an efficient apparatus for penetrating the skin of fish (Rees FG, 1974).

The most significant number of the cercariae of *Cryptocotyle* genus is at a depth of 0–2 m, which is the depth where the highest indices of fish invasion were registered. At a depth of 2–4 m, the indices of fish invasion are lower because the concentration of cercariae is lower. This phenomenon is explained by the fact that the mollusks, the initial intermediate hosts of these trematodes, prefer shallow waters (Lysne D et al, 1995). It was also noted that large mollusks are invaded much more frequently than small ones; and the mollusks, protected from direct waves, are more invaded than those in the open waters (Lambert W et al, 2012). Similar results of the studies were noted by AI Granovitch, K Johannesson (2000), who found that four species of Littorina mollusks (*L. littorea, L. obtusata*, *L. fabalis* and *L. saxatilis*) were invaded by the trematodes, for instance, by *C. lingua*, more intensively at the coast, protected from direct waves, as compared to the population of the mollusks, located at the rocky coast of Sweden.

THE BIOLOGICAL SPECIFICITIES OF THE METACERCARIAE OF *CRYPTOCOTYLE GENUS*

The metacercariae, which have penetrated the tissues of the fish recently, do not have dark staining due to considerable melanization of the tissues surrounding the cyst. The outer envelope of old cysts is dark black (Honcharov SL, 2019b). This intense black color is acquired by the concentration of melanophores (Zander CD et al, 1984). The melanization of the capsules of the parasite occurs faster if the invaded fish are kept in darkness at a higher temperature in the water medium. The rate of the metacercariae development and the formation of the capsule wall also depends on the ambient temperature. The initial inhibition of the development may be related to the immune response of the fish organism to the penetration of the parasites (Wood, 1990).

The metacercariae of *C. concavum* is located in a dense cyst, consisting of four layers of parasitogenic origin, which are formed due to the cystogenic glands of the metacercariae. On the outside, the metacercaria is surrounded by a capsule, which originates from the host tissues, a connective tissue mostly. The release of the metacercaria from the capsule occurs under the corresponding temperature, physical and chemical conditions of the environment using the secrete, produced by special glands located at the main end of the metacercaria. The secrete from these glands is directly involved in the process of metacercaria excystment (El-Mayas H, Kearn G, 1995).

The transformation of the cercaria of *C. lingua* into the invasive form in the fish organism, a metacercaria, takes 38 days on average. The ovaries and testes are identified in 10 days. Up to Day 38, the cilias are formed in the lumen of the oviduct, but the genital chamber remains rudimentary. The oviduct and the sperm duct complete their development. The morphogenesis restarts in the intestines of piscivorous birds. Within the second day, the cilias in the female ducts become mobile. The fertilization occurs on days 2 and 3, and the eggs penetrate the uterus on day 3 (Rees FG, 1979).

THE BIOLOGICAL SPECIFICITIES OF THE MARITAS OF *CRYPTOCOTYLE GENUS*

Having invaded the organism of the definitive host (piscivorous birds, cats, and white laboratory rats), under the effect of bile acids, enzymes, and pH of the medium in the gastrointestinal tract, the metacercaria exits the cyst and attaches to the surface of the mucosa membrane. The trematodes attach to the mucosa membrane, in-between the villi of the intestines, not penetrating the submucosa and other layers of the entrodermal canal wall. Usually, the trematodes try to direct their main end toward the direction of the peristalsis of the intestines. The histological examination did not find considerable damage to the epithelium of the intestines. The trematodes become sexually mature after 72 h of staying in the gastrointestinal tract of the host (Stunkard HW, Willey CH, 1929). The abovementioned refutes the statement that the trematodes of *Cryptocotyle* genus become sexually mature in the depth of the mucosa envelope, getting deeper into the submucosa and muscle layers of the intestine wall (Ciurea J, 1915a, 1915b; Faust EC, Nishigori M, 1926). However, in the case of experimental invasion of the black-headed gull (*Lams ridibundus*) with the metacercariae of *C. jejuna*, the author reported that the parasites became sexually mature after four weeks of being in the organism of the bird (Rothschild M, 1938).

EXPERIMENTAL INVASION

The experimental work on simulating the life cycle of a cryptocotylosis agent was conducted by Ching H. (1978). The cercariae, isolated from a mollusk, *Littorina scutulata,* were used to invade young fish (*Leptocottus armatus*, *Oligocottus maculosus* and *Platichthys stellatus*). The invaded fish were fed to young gulls (*Larus glaucescens*) and from day 14 till day 21, the postmortem examination found sexually mature parasites in the anterior parts of the gastrointestinal tract.

The experiment successfully invaded chickens; sexually mature parasites in the chickens were found after 5–20 days. The invasion of the laboratory mice was not successful (Gorman AM, Moring JR, 1982). The possibility for *C. lingua* to become sexually mature in the organism of cats, white laboratory rats, and guinea pigs after the experimental invasion was reported by H.W. Stunkard (1930).

The experimental invasion of Peking ducklings with the metacercariae of *C. jejuna* and *C. concavum* demonstrated that the parasites grew to their sexual maturity in the gastrointestinal tract. During the latency period of 25 days, the survival rate of the parasites was 83 % (Honcharov SL, 2017a).

To study the effect of glucocorticoids on the clinical course of spontaneous cryptocotylosis in piscivorous birds, two-month-old birds (*Phalacrocorax auritus*) were invaded with the metacercariae of *C. lingua*. Prior to invading and during the latency period, the birds were administered the solution of dexamethasone. The experiment demonstrated that the birds, administered dexamethasone, had a much higher invasion rate than those not receiving this glucocorticoid. Thus, the author of the study believed that the rate of humoral immunity affected the degree and intensity of the invasion among the birds – the definitive hosts for *C. lingua* (Forzan MJ, 2000). Other communications report the possibility of experimental invasion of domestic ducks (Iskova NI, 1966) and pigeons (Naidenova NN, 1974).

DISTRIBUTION OF THE LARVAE IN THE HOST ORGANISM

The black epidermal cysts are clearly visible on the body surface of fish. Sometimes the metacercariae are found on the kidney surface of fish. These cysts penetrate deep into the tissues of the kidneys and are enclosed by the layer of the host's connective tissue.

The metacercaria, located on the inner surface of the kidneys, form the hollows that are additionally covered with a layer of melanophores (Zander CD et al, 1984).

Among the population of *Pomatoschistus microps* in the Baltic Sea, the metacercariae of *C. concavum* are specifically located on the surface of the kidneys and inside the parenchyma of the organ (Zander CD et al, 1984, 1999; Zander CD, 1998). In other species of Gobiidae, the metacercariae of *C. concavum* are located only on the surface of skin and fins (Zander CD et al, 1984).

The tissues of the kidneys allow the parasite to invade and accumulate the metacercariae in considerable amounts (up to 2,000 cysts) (Zander CD, Kesting V, 1996) and to create a specific strategy for improving the life cycle of the cryptocotylosis agent (Zander CD, 1998).

It was noted that in different species of the plaice (*Pleuronectes platessa* and *Platichthys flesus*), the prevalent concentration of the metacercariae was in different parts of the body: the most significant number was registered in the back part of the body (above the median line) or in the area of fins and gills, respectively (Broek van den WLF, 1979). It was found that the prevalent number of the metacercariae of *C. lingua* in the cod (*Gadus morhua*), kept in cages in the Norwegian natural waters, was located on the skin, in the dorsal part of the body (33 %). A considerably smaller number of larvae was found on the fins of the cod (18 %) (Lysne DA et al, 1994).

The study of Gobiidae (*Apollonia (Neogobius) melanostomus*) in the waters of the Sea of Azov found that the most significant number of the metacercariae was determined on the pectoral fins (38 % out of the total number of the defined larvae) and the tail fin (15 %, respectively). In general, the back part of the body of Gobiidae was infected by 32 % of the total number of the defined larvae, the abdominal part – 14.7 % of the metacercariae (Korniychuk J, Martynenko I, 2009).

The study of the distribution of the cryptocotylosis agent in the body of Gobiidae (*Mesogobius batrachocephalus*, *Neogobius melanostomum*, *Neogobius fluviatialis*) in the waters of the Black Sea and the Dnipro-Buh estuary (Ukraine) determined that the primary location of cryptocotylosis agents was a dorso-cranial part of the body. The highest indices of invasion were registered in the area of the first and second dorsal fins – 20.8 and 19.9 %, respectively. 19.4 % of the total number of the determined parasites were registered on the surface of the head. The area of the tail fin was also remarkable for rather high invasion indices – 15.1 %. The gills in the dorsally located areas had the lowest index of invasion – 11.2, 10.7 % of all the defined parasites of the investigated species were registered in the area of the pectoral fin. The lowest indices were remarkable for the area of the anal fin – 2.6 %. The study results showed that the cryptocotylosis agent may also be located in the areas not specific for its life cycle – the inner wall of the abdominal wall. It was found that only 0.3 % of the metacercariae were present on the inner wall of the abdominal wall (Honcharov SL, 2019b).

PHYSIOLOGY OF THE *CRYPTOCOTYLE SPP.*

The immunocytochemical study and the scanning laser microscopy of the maritas and cercariae of *C. lingua* and *C. concavum* found the presence of the neuromediators, serotonin and neuropeptide FMRF-amide in the central and peripheral parts of the nervous system of the parasites. The presence of serotonergic and peptidergic nervous endings near the muscle elements envisages that the mentioned neuromediators take part in the regulation of the contractile activity of the muscles of the body wall, fixing organs, and reproductive system of the parasites (Terenina NB et al, 2010). The study of the effect of biologically active substances – acetylcholine and serotonin – on the motility of the cercariae of *C. lingua* determined that the mentioned substances caused the prolonged duration of the active phase of swimming (Tolstenkov OO et al, 2010).

The lifetime, the intensity of the exiting, and the activity of the cercariae are affected by the ambient temperature, including water (Rea J, Irwin S, 1992b). At the temperature of water under 10 °C, the exit of the cercariae of *Cryptocotyle* spp. from the mollusks is considerably inhibited (Sindermann CJ, Rosenfield A, 1954; Sindermann CJ, Farrin AE, 1962).

The study of the activity of the exit of *C. concavum* from the mollusks in the waters of the White Sea in different seasons determined that in August, at the water temperature of 15–20 °C a day, 539 ± 67 (167–1121) cercariae exited the mollusk. In November, when the water temperature was about 1.5 °C, the number of cercariae exiting the mollusks fluctuated from 1 to 2. However, when these cercariae were placed in the marine water at 20 °C, 35–70 cercariae were released every seven days. In March, when the temperature of the marine water was 0.5 °C, no release of the cercariae from the mollusks was registered. However, when these mollusks were placed into the marine water with the temperature of 20 °C, there was a release of 10–30 cercariae on the first day, 2–5 on the second day, and since the third day the release of the cercariae ceased (Galaktionov K et al, 2006).

The cercariae of *Cryptocotyle* genus that get into water respond to mechanical oscillations and the decrease in light intensity with higher motility. There is a decrease in the motility of the cercariae with age and an increase in the ambient temperature. The activity of the cercariae is also provoked when the slime elements of the intermediate hosts, fish, including the amines with a long molecular chain, such as C7–C9, penetrate the water (Chapman HD, 1974).

The cercariae of *Cryptocotyle* genus are remarkable for the phototaxis phenomenon (Rosenqvist G, Johansson K, 1995), which was found when estimating the impact of shadow stimuli on the intensity of cercariae invasion of the pectoral fins of the trout (*Oncorhynchus mykiss*). During 60 minutes, the parasites and fins were subject to the impact of illumination or complete darkness with subsequent counting of the cercariae which invaded the trout fins. The study was conducted with the cercariae, aged 1, 12, and 24 h. It demonstrated that the increase in the frequency of the occurrence of fins in darkness served as a relevant stimulus for cercariae to invade the tissues of the intermediate host actively. The most active cercariae were 12-hour-old. With age, the ability of the cercariae to invade fish decreased rapidly (Rea J, Irwin S, 1992a).

The phototaxis allows for preserving the limited energy resources of the parasite due to the minimization of unnecessary motility and increasing the chances of the cercaria meeting its potential host. Getting older, the cercariae become less sensitive to shadow stimuli, especially the short-term ones (Rea J, Irwin S, 1991). The cercariae are acutely light-sensitive to lateral illumination. With age, the velocity of horizontal swimming toward the source of illumination decreases gradually. While swimming, the cercariae prefer shorter light waves (Rea J, Irwin S, 1992b).

To search for a host, the cercariae of *Cryptocotyle* genus use both active search strategy and passive waiting. A part of the passive waiting strategy is the ability of the cercariae to attack a host in response to the water currents, formed during its movement (Prokofiev VV, 2006).

Under stable temperature and salinity of water, the oxygen consumption rate is directly dependent on the size and age of a cercaria. The highest intensity of the energy exchange was observed during the first hours of the cercaria life. The cercariae of *C. lingua* rotate the active and passive phases of their floating. Due to this, the cercariae use their energy in a reasonable and economical way and prolong their lifetime. During free floating, the oxygen consumption rate remains at approximately the same level and decreases sharply when the cercaria dives to the bottom. Such cercariae lose their chance of invading fish (Prokofiev VV et al, 2001).

The metacercariae of *C. lingua*, isolated from the Atlantic cod (*Gadus morhua*), are relatively labile in terms of oscillations in ambient temperature. For instance, at 70–90 °C the metacercariae perished in 20 minutes; at 50 °C the death was registered in 2 h; at –80 °C the death was registered within 20 min, and at the range of –60–20 °C the death was registered in 2 h; if the metacercariae were kept in the depth of the muscle tissue at 5 °C, the latter manifested any signs of life for up to 9 days. The impact of low temperatures is manifested in the fragmentary layer separation of the elements of the metacercaria capsule and the formation of a great number of microcracks on the surface of the metacercaria tegument (Borges JN et al, 2015).

The study demonstrated that in the case of excystment of the metacercariae of *C. concavum in vitro* the most optimal temperature for the release of the metacercaria from the capsule was 40–42 °C on condition of the previous treatment with acid pepsin and further processing with alkaline salts of biliary acids. One minute later, the metacercariae in the pepsin became periodically active. The periods of activity, manifested in circular movements, lasted for 1–3 s and were interchanged with the rest periods of 30–40 s. At the pH index from 2.0 to 4.0, the metacercaria does not exit the capsule, but the excystment resumes and accelerates at pH over 4.0, and the peak values are registered in the pH range of 7.5–8.5 (El-Mayas H, Kearn G, 1995).

EPIZOOTIC SPECIFICITIES OF CRYPTOCOTYLOSIS AGENT

Prevalence of Cryptocotyle infection by season. The study of the merling (*Merlangius merlangus*) and pouting (*Trisopterus luscus*) in the Belgian waters of the North Sea, which were invaded with the cryptocotylosis agent, found that the most significant number of the invaded fish was registered in spring, the invasion prevalence fluctuated in the range of 5.9–6.19 %. In autumn, the number of the invaded fish was smaller – the invasion prevalence was 0.38–3.25 % (Van Hoey G et al, 2009).

The study of cryptocotylosis of Gobiidae in the Dnipro-Buh estuary (Ukraine) demonstrated two peaks of the increased invasion indices during the year – in summer and autumn. The maximal indices of the prevalence and intensity of the cryptocotylosis invasion were observed in autumn. The highest invasion was recorded for *Neogobius melanostomus*, the invasion prevalence was 72.7 %. In *Mesogobius batrachocephalus* and *Neogobius fluviatilis,* the invasion prevalence was 28.5 and 48.1 %, respectively. The lowest indices of the invasion for Gobiidae, as compared to other seasons, were recorded in spring. In *N. melanostomus*, the invasion prevalence for cryptocotylosis was 44.4 %, in *M. batrachocephalus* – 7.14 %, *N. fluviatilis* – 26.7 % (Honcharov SL, 2019d).

The study of the seasonal invasion of the Caspian gull (*Larus cachinnans*) with *C. jejuna* parasites in the Kerch Strait (Ukraine) demonstrated that the highest index of the prevalence and intensity of the invasion was registered in summer. The degree of the invasion among piscivorous birds was directly proportional to the use of invaded fish as feeds. The prevalent number of the invaded birds were nestlings and young birds of the same year, which older birds fed with Gobiidae, invaded by the metacercariae of *C. jejuna*. The invasion prevalence amounted to 100 %, and its intensity was 278–1,500 trematodes. Old birds mainly get invaded in winter, when the ratio of their food is limited to fish only (Martinenko I, 2018).

PREVALENCE OF *CRYPTOCOTYLE* INFECTION BY AGE

The study of the plaice (*Pleuronectes platessa* and *Platichthys flesus*), invaded by the cryptocotylosis agent, did not find any age-related specificities of fish invasion (Broek van den WLF, 1979). It was found that the cunner (*Tautogolabrus adspersus*), caught near the Newfoundland coast, was invaded by the metacercariae of *C. lingua*. The degree of fish invasion by the metacercariae depended on the age of the fish: the older fish was, the higher indices of invasion were (Sekhar SC, Threlfall W,1970).

The study of the age-related dynamics of Gobiidae fish invasion (*Mesogobius batrachocephalus*, *Neogobius melanostomum*, *Neogobius fluviatialis*) by the cryptocotylosis agent in the Dnipro-Buh estuary (Ukraine) demonstrated that the highest invasion was noted for fish, aged 6+–7+, and the most minor invasion – for those, aged 2+–3+. The study results showed that the older Gobiidae fish were, the higher the invasion indices by the metacercaria of Heterophyidae family trematodes were. The index of spots in different species of Gobiidae fluctuated depending on their age (Honcharov SL, 2019a).

PREVALENCE OF *CRYPTOCOTYLE* INFECTION BY SEX

The study of the three-spined stickleback (*Gasterosteus aculeatus*) in the Kandalaksha Gulf of the White Sea found that the fish was invaded by the cryptocotylosis agent, and the fish of both genders were invaded in the same way. This fact demonstrates the equal participation of male and female fish during the spawning season (Golovin PV et al, 2020).

It was found in the Gobiidae population in the Dnipro-Buh estuary (Ukraine) that the male fish were invaded by the cryptocotylosis agent 25.3 % more frequently than the female fish (Honcharov SL, 2019a). This phenomenon is explained by the fact that during the spawning season, the female fish only lay eggs, while the construction and protection of the nest until the larvae hatch are vested upon the male fish. While taking care of the nest, the male fish eat less and worse, moving along a small perimeter of the water body, they are exhausted and thus, become a more convenient target for the cercariae of *Cryptocotyle* (Naidenova NN, 1974).

THE EFFECT OF *CRYPTOCOTYLE* TREMATODES ON THE ORGANISM OF THE INITIAL INTERMEDIATE HOST – A MOLLUSK

The antagonistic nature of the relations in the parasite-host systems is often manifested in the decreased viability of the invaded organism. In particular, it is shown when the invaded host organism is affected by unfavorable environmental factors. The decrease in the viability and the ability of the invaded fish to adapt as compared to the non-invaded ones may have a considerable effect on the realization of the life cycle of the parasite (Vernberg WB, Vernberg FJ, 1963; Sousa WP, 1983; Sousa WP, Gleason M, 1989).

The study of the effect of extremely high temperatures (+ 42 °C) on the mortality rate of *Hydrobia ulvae* mollusks, invaded by *C. cancavum* trematodes, found that the mollusks had some thermoresistance as compared to non-invaded mollusks and those, invaded by other trematodes. These considerable differences in the thermoresistance of the host are explained by the fact that *C. cancavum* rediae induce the castration and accelerated growth of the mollusk and the enhanced resistance of the latter (Levakin IA, 2004). In its turn, the parasitic castration leads to the economy of energy and its redistribution, which is spent by a fertile mollusk for the reproduction purposes, thus increasing the resistance of the invaded mollusk (Fish JD, Fish S, 1974; Sousa, 1983; Gorbushin AM, 1997).

According to the communications of McDaniel JS (1969), the thermoresistance of *Littorina littorea* mollusks, invaded by *C. lingua,* were less resistant to higher temperatures (39, 40, and 41 °C) as compared to the mollusks, free from invasion.

The trematodes of *Cryptocotyle* are remarkable for the parasitic strategy, which lies in the behavioral changes among the intermediate hosts – mollusks, under the effect of the parasites in their body. As *C. lingua* parasitized among *L. littorea* population, it was noted that the invaded mollusks were actively moving from the low tide zone toward the open waters. This behavioral change is evolutionarily beneficial for the trematode. It increases the period of the mollusks staying in the water and thus the probability that the cercaria that has left the mollusk will meet its second intermediate host – the fish (Carpenter S, 2008). In winter, there was a decrease in the active migration of the Atlantic population of *L. littorea* mollusks, invaded by the cryptocotylosis agent. However, it was noted that the mollusks mainly were moving toward the open waters as compared to the mollusks, non-invaded by the parasites (Sindermann, 1964; Lambert TC, Farley J, 1968). According to the results, obtained by Seaman B. and Briffa M. (2015), *L. littorea* mollusks, invaded by *C. lingua*, behaved less carefully regarding the external stimuli than those mollusks free from the cryptocotylosis agent.

It was also noted that the parasite injured the gastrointestinal tract of the mollusk, which further impacted the metabolic processes of the intermediate host organism and its quick death (Carpenter S, 2008). However, the injury of the gastrointestinal tract of *Littorina saxatilis* mollusks, invaded by *C. lingua*, had almost no impact on the process of assimilating carbon and nitrogen that gets there along with the feeds, which is a long-term strategy of coexistence between the parasite and the host (Davis DS, Farley J, 1973).

The invasion of *C. lingua* in *L. littorea* mollusks demonstrated a decrease in the survival and the decrease in the formation of gametes among the invaded mollusks. It was determined that the invasion inhibited the growth and development of the mollusks and correlated directly with the reduced height of the shell and the color of the arm of the invaded intermediate hosts (Huxham M et al, 1993). According to the data of the studies of ET Zavras, AJ Hugo (1979), the color of the arm of *L. littorea* mollusk varies from white to brown and even red. No direct dependence of the color of the mollusk arm on the degree of its being invaded by *C. lingua* was determined. In the opinion of the study authors, the color of the arm depends on β-Carotene, obtained by the mollusks while consuming the algae, Chlorophyceae and Rhodophyceae, which are rich in carotenoids. While investigating the impact of the cryptocotylosis invasion on the glycogen content in the arm and digestive gland of *L. littorea* mollusk, Robson E, Williams I (1971) determined a considerable decrease in the level of the latter.

THE EFFECT OF *CRYPTOCOTYLE* TREMATODES ON THE ORGANISM OF THE SECOND INTERMEDIATE HOST – THE FISH

The trematodes of *Cryptocotyle* genus have a remarkable pathogenic impact on the second intermediate host. Young herring, *Clupea harengus* (L. 1758), experimentally invaded by the cercariae of *Cryptocotyle*, perished in 15–30 days (Sindermann CJ, Rosenfeld A, 1954; Sindermann CJ, Farrin AE, 1962; Sindermann CJ, 1964).

The high degree of the invasion by the metacercariae of *C. concavum* and *C. lingua*, located on the surface of the skin and fins of Gobiidae, makes the latter less mobile and thus a softer target for predators (Zander CD et al, 1999).

The biochemical study of the muscle tissue of the grass goby, *Zosterisessor ophiocephalus* (Pallas, 1814) and *Ponticola eurycephalus* (Kessler, 1874), invaded by the cryptocotylosis agent, found the increase in the activity of catalase (CAT), alanine transaminase (ALT), aspartate transaminase (AST), thiobarbituric acid-reactive substances (TBARS), and a decrease in the activity of glutathione reductase (GR), glutathione-S-transferase (GST), and superoxide dismutase (SOD). The abovementioned demonstrates the impaired exchange processes in the organism of the goby infected by cryptocotylosis (Skuratovskaya EN et al, 2020). In the case of intense invasion of the cod caught in the Bornholm Basin (the Baltic Sea), there were noteworthy organoleptic changes in the muscle tissue (Buchmann K, 1986).

The study of Shchepkina AM (1981) on the invasion of the goby, *Neogobius melanostomus,* by the metacercariae of *C. concavum*, found a decrease in the total number of lipids in the muscle tissue and skin which impacted the fleshing of the fish considerably. There is a decrease in the level of reserve lipids (triglycerides) predominantly. This fact has an absolutely negative effect on the degree of the preparedness of the goby to winter and on the possibility for some fish to survive this period, because in winter the energy provision for the fish is largely ensured by the fat reserves.

The study of the merling population (*Merlangius merlangus*) in the Belgian waters of the North Sea, invaded by *C. lingua,* found that a high degree of invasion had a considerable impact on the condition of the muscle tissue. However, in the researchers' opinion, the degree of invasion had no effect on the content of lipids in the hepatopancreas and the blood indices of the invaded fish (Declerck D, 1992).

The study of the sand goby, invaded by the metacercariae of *C. concavum*, demonstrated the decrease in the hepatosomatic index, which is an example of the parasites, impacting the endocrine system of the host (Read AF et al., 1990; Malek M, 2001). In the opinion of the study author, these phenomena occur due to the mechanical and toxic injury of the hepatopancreas of the goby by the parasites (Malek M, 2001). As for the decrease in the hepatosomatic index in the fish, there is a hypothesis that the weight of hepatopancreas decreases because the walls of the parasite's capsule can accumulate and neutralize not only the products of the parasite's vital functions but also those of the host, which decreases the burden on the detoxicating organ considerably and leads to its reduction (Benjamin LR, James BL, 1987).

The researcher, studying the plaice (*Pseudopleuronectes americanus*), invaded by the metacercariae of *C. lingua,* noted considerable hyperplasia of the surface epithelium of the fish skin, which, in the scientist's opinion, demonstrated the chronic clinical course of the disease (Smith GM, 1935).

The invasion of Gobiidae by the cryptocotylosis agent also leads to the decrease in the fertility of the females (Rosenqvist G, Johansson K, 1995). If the metacercariae are located on the surface of the eye retina, the fish lose their vision (Naidenova NN, 1974).

If the cercariae of *C. lingua* penetrated the organism of the thicklip gray mullet (*Chelon labrosus*), there was a response from the cellular and humoral immunity. For instance, under the experimental intra-abdominal administration of live and dead cercariae to the fish, there was a noted formation of the primary antibodies. After the invasion by the live cercariae, the peak values of the primary antibodies were noted in four weeks. If the live cercariae, previously treated with the ultrasound, and dead cercariae were administered, the titers of the antibodies were at their peaks five and seven weeks later, respectively. Here the titers of the primary antibodies were higher in the fish which were administered live cercariae. The enhanced secondary response of the immunity in the form of the antibody formation was the highest after the repeated administration of the live cercariae, previously treated with the ultrasound, which, in the researcher's opinion, was related to partial damage to the parasite's tegument. There was a noted increase in the number of leukocytes in the fish, administered the cercariae. However, no adhesion or any other response of the leukocytes of fish on the parasites was noted in the *in vitro* study (Wood, 1990). The highest titer of the antibodies in the organism of the mullet was registered after the administration of the content of the excretory vesicle of *C. lingua* metacercariae (Matthews RA, Matthews BF, 1993).

The study of the humoral response of the plaice (*Pleuronectes platessa*) to being invaded by the metacercariae of *C. lingua* determined the formation of the antibodies. The immunohistochemical studies of the antibodies found that these were macroglobulins, similar to immunoglobulin M (IgM) of the mammals. The ambient temperature directly impacted the rate of the synthesis by the host and the number of antibodies (Cottrell B, 1977).

The study of the impact of the temperatures on the invasion prevalence in the pipefish (*Syngnathus typhle*) by the metacercariae of *C. lingua* found that during the experimental keeping of the fish at the temperature above 18 °C, there was a decrease in the number of monocytes and lymphocytes in the blood as compared to the fish, kept at the temperature under 18 °C. Despite the decline in the level of cellular immunity, there was no statistically significant difference between the degrees of invasion prevalence in the two experimental groups (Landis SH et al, 2012).

The morphological study of the blood of the goby (*Mesogobius batrachocephalus*, *Neogobius melanostomum*, *Neogobius fluviatialis*), invaded by the cryptocotylosis agent, demonstrated the increase in the number of leukocytes, basophils, and pseudobasophils, eosinophils and pseudoeosinophils, band and segmentonuclear neutrophils, monocytes and the decrease in the content of hemoglobin, the number of erythrocytes and lymphocytes (Honcharov SL, 2018); the biochemical study of the blood of invaded goby showed the fluctuations in some indices, including the content of total protein, protein fractions. There was a noted impaired ratio of albumins and globulins. The decrease in the content of urea and glucose was registered along with the increase in the activity of aspartate aminotransferase and alanine aminotransferase enzymes (Honcharov SL, 2019e).

THE EFFECT OF *CRYPTOCOTYLE* TREMATODES ON THE ORGANISM OF THE THIRD INTERMEDIATE HOST – A PISCIVOROUS BIRD

The post-mortem examination of the dead body of the bald eagle (*Haliaeetus leucocephalus*), found frozen in Nova Scotia, determined extremely high exhaustion and the signs of enteritis. The parasitological studies demonstrated the invasion of the gastrointestinal tract of the bird with over 11,000 maritas of *C. lingua* (Smith HJ, 1978).

There was a reported case of *C. lingua* trematodes, parasitizing in the small intestines of the herring gull (*Larus argenatus)*, which was found at the coast of the Korean peninsula (South Korea). This bird was extremely exhausted. The cryptocotylosis agent was registered in association with other parasites (Lee Y et al, 2020). The hematological study of the northern fulmar (*Fulmarus glacialis*) in the Barents Sea found the associated invasion, including the maritas of *C. lingua* and *C. concavum*, described the decrease in the number of eosinophils and basophils in the blood, while the number of neutrophils was increased (Kuklin V et al, 2019).

The Peking ducklings, invaded by the cryptocotylosis agent, had a weakness, slower activity, and diarrhea on the third day. The immature trematodes, eliminated due to the increased peristalsis of the intestines, were registered in the watery fecal masses. No elimination of the parasites was found during diarrhea since the fifth day, which demonstrated that the parasites were firmly attached to the mucosa membrane of the intestines. The post-mortem of the invaded ducklings showed acute endoenteritis, manifested by the damage to the mucosa membrane of small intestines, swelling, hyperemia, and the formation of hemorrhages. The invaded ducklings were also found to have impaired liver (Honcharov SL, 2017b).

THE DIAGNOSTICS OF CRYPTOCOTYLOSIS

The diagnostics of cryptocotylosis is comprehensive, including the epizootic data, the clinical signs, the pathoanatomical changes, and the microscopy of the isolated larvae or mature trematodes to identify the species.

In the case of cryptocotylosis in fish, the clinical signs are less manifested and not always specific. The surface tissues of the fish – skin, fins, and gills – have a significant number of black cysts. The fish are invaded by the cryptocotylosis agent; these high indices of invasion intensity look like the fish is covered in black cysts. The inflammation of the surrounding tissues is usually not recorded in fish. If the metacercariae are located on the surface of the eye retina, the latter becomes dull, the goby lose their vision and die. In all these cases, they become easy prey of the piscivorous birds, which promotes the completion of the life cycle of the trematodes. Under high indices of invasion, the disease may be accompanied by the death of the fish. The post-mortem of the fish demonstrates exhaustion, and visible gelatinization of the scale. The black cysts are on the surface of their bodies, fins, and gills (Naidenova NN, 1974; Honcharov SL, 2019b).

The primary diagnostics method for cryptocotylosis is microscopy, used in routine laboratory work. This examination method allows determining the taxonomic nature of the cryptocotylosis agent using the anatomic and morphological traits. The microscopy is used to study the morphological traits of this species of trematodes in detail. Special attention is paid to the specificities of the excretory vesicle structure, the location and size of the intestine of the parasite. The structure of the reproductive system of the trematodes is studied in detail (Morozov FN, 1952).

In particular, the excystment, i.e., the isolation of the trematode larva from the cyst envelopes, is done after isolating the metacercariae from the adjacent tissues. The isolated cysts are placed into the 0.5 % chymotrypsin solution, heated up to 38–40 °C and kept for 7–10 min. Thus, the adjacent tissues start the lysis, and the cyst is easily extracted from the tissue residues with a slight mechanical impact. The isolated cysts are transferred to the specimen slide, and a thin layer of glycerol is added. The medical blood lancets are used to fix and tear the capsule; for convenience, they are fixed in the hemostatic forceps at the angle of 45 °C regarding the imaginary axis of its closed rods. One blood lancet was used to fix the metacercariae, and the other was to break the cyst wall carefully; within one minute the metacercaria left the cyst independently, without additional mechanical operations. The isolated metacercariae and mature trematodes were washed in the normal saline solution, stained with aluminous carmine (or other dyes), differentiated in the hydrochloric alcohol solution, and dehydrated in higher alcohols, clarified in clove oil and poured into balm (Soroka N, Goncharov S, 2015).

The molecular and genetic methods, for instance, the PCR, were used to determine the accurate taxonomic nature of the cryptocotylosis agents (Casalins L et al, 2020).

The single effect of 2,000 cercariae of *Cryptocotyle* genus on the organism of the gray mullet (*Chelon labrosus*) demonstrated the immune response due to the synthesis of humoral antibodies, sensibilized leukocytes, and cytotoxic serum factors. The titers of antibodies, measured with the passive hemagglutination, were at their peaks on week four after the invasion and were getting decreased by week 10. The study results demonstrated that using the cercarial agglutination as an express test was found unreliable (Wood BP, 1990; Wood B, Matthews R, 2006).

Therefore, cryptocotylosis is diagnosed based on the clinical signs and microscopy of the metacercariae and maritas obtained during the examination of the hosts of this parasite. The molecular and genetic methods of diagnostics are used as the method to confirm the species membership of the trematodes of *Cryptocotyle* genus. The serological methods of studies proved unreliable during the diagnostics of cryptocotylosis.

THE RELEVANCE OF ECOLOGICAL ASPECTS IN THE FORMATION OF THE SOURCES OF CRYPTOCOTYLOSIS INVASION IN NATURE

The distribution of the parasitic organisms depends, first and foremost, on the hosts in which they parasitize, i.e., mainly on the biotic factors, and this dependence will be more expressed in biohelminths than in soil-transmitted helminths. Thus, the helminths with three hosts are more dependent on other organisms than those with two hosts (Morozov FN, 1952).

The condition of the environment, namely the pollution with organic and other substances, affects both host and parasite. It was demonstrated that the cercariae of *C. lingua*, isolated from *L. littorea* mollusks from the polluted lagoon, showed slower velocity of the horizontal floating and a shorter lifetime than the cercariae isolated from the mollusks in clean water bodies. The studies demonstrated that the conditions of water body pollution affect the velocity of the cercaria movement, slowing its movement down, and do not affect the spatial orientation. The cercariae accumulate the pollutants from the initial intermediate hosts – mollusks. The pollutants impact the neuromuscular complexes, responsible for the movement but not the sensory structures. Considering the negative effect of the contaminants on the cercariae and a considerable number of the parasites in the polluted areas of the lagoon, a high concentration of the parasites is related to the constant input by the piscivorous birds (Cross MA et al, 2005).

The experimental study of the effect of heavy metals (zinc, iron, copper, and manganese) in the dose of 1–5 mg/l demonstrated the decrease in the lifetime of *C. lingua* cercariae. The negative effect of the heavy metals on the condition of the cercariae was manifested even after the exposition for 1 min. This rapid response of the cercariae to the effect of heavy metals is likely related to the ability of the external envelope of the parasite to adsorb the substances from the environment. In the opinion of the study authors, this ability of the cercariae may serve as a test system to evaluate the pollution of the water body (Cross MA et al, 2001).

While studying the effect of global warming on the infection status of the mudsnails (*Hydrobia ulvae*, *H. ventrosa*, *Littorina littorea*, *L. saxatilis* and *L. obtusata*) of the White Sea with the rediae including *C. lingua* and *C. concavum*, it was shown that the water temperature is a relevant factor, controlling the biology and functional activity of different stages of the lifetime of the trematodes. In particular, the increase in the water temperature in northern seas due to global warming will lead to a more intense process of invading hosts. This fact is conditioned by the prolonging of the period when the mollusks are invaded by the miracidia (during free-floating or penetration of the eggs) on condition of the increase in water temperature, thus increasing the number of the invaded mudsnails. There is also a prolonged period of the active cercaria phase in water which inevitably leads to a higher number of the invaded second intermediate hosts (fish) and, as a result, the increase in the number (density) of the invaded final hosts (migrating piscivorous birds). All in all, it leads to an increase in the number of parasite eggs in the environment, spread by the definitive hosts in the coastline biotopes (Galaktionov K et al, 2006). In the opinion of Lehikoinen E et al (2004), global warming will prolong the period when the migrating birds stay in the Arctic and Subarctic ecosystems imminently resulting in a higher number of the invaded populations.

There were reported cases of partial perishing of the Gobiidae populations in the Dnipro-Buh estuary (Ukraine) due to unsatisfactory hydrochemical indices in summer. A considerable amount of dead fish attracted the piscivorous birds who formed temporary feed colonies in some water bodies, thus creating the local sources of parasitic invasion via the penetration of the eggs of the agent to the water with the feces. For instance, it was determined that the invasion prevalence among the mentioned population of Gobiidae up to the fish kill phenomena was at the level of 26.6 %, and after the formation of the feed colonies of the piscivorous birds, the level of invasion prevalence increased rapidly to 60.3 %. Also, the over-saturation of water bodies with the biogenic residues and pollutants creates a sufficient feed basis for the development of the mollusks – the initial intermediate hosts for the trematodes of *Cryptocotyle genus* (Honcharov SL, 2019c).

THE PROBLEM OF CRYPTOCOTYLOSIS IN UKRAINE

The study of the cryptocotylosis distribution among the ichthyofauna in the Ukrainian territorial waters of the Black Sea was started by Isaychikov IM (1924; 1925) during the Crimean scientific expedition and it was found then that *Perccottus glenii* was an intermediate host for the trematodes of C. *cancavum.* Naidenova N. (1974) studied the parasite fauna of Gobiidae in the Black Sea near the Crimea in great detail and determined a considerable invasion of *Gobius ophiocephalus* and *Neogobius fluviatialis* by the metacercariae of *C. lingua* and *C. cancavum*. The issue of the distribution of parasitic diseases, including cryptocotylosis, among Gobiidae in the Odesa gulf of the Black Sea was studied by A. Chernyshenko (1949, 1955), who found the invasion of the goby with the metacercariae of C. *cancavum*, and Kvach Y (2007) was the first to register *C. lingua.*

Also, Kvach Y (2001, 2004) found the circulation of *C. lingua* and *C. cancavum* among Gobiidae in the Tuzla and the Tiligul estuaries of the Black Sea.

Noteworthy are the facts of finding *C. jejuna* in the yellow-legged gulls (*Larus cachinnans* Pallas, 1811) from the Kerch Strait, described by I. Martynenko (2012). In recent years, there have been no confirmed cases of *C. jejuna* parasitizing among the hydrobionts of Ukrainian water bodies. However, Goncharov SL et al. (2017) found *C. jejuna* parasitizing among the goby of *Neogobius melanostomum, Neogobius fluviatialis,* and *Mesogobius batrachocephalus* in the Dnipro-Buh estuary of the Black Sea. There is a marked tendency toward the annual increase in the invasion prevalence indices for cryptocotylosis among Gobiidae: in 2016, the invasion prevalence was 24.8 %, in 2017 – 34.1 %; in 2018 – 24.6 %; in 2019 – 37.1 %. The absence of violent oscillations of the invasion indices demonstrates the presence of the formed stationary source of invasion in this area of the Black Sea. The formation of the abovementioned source is mainly ensured by maintaining the level of the biogenic pollution of natural water bodies which is an element of anthropogenic burden. The over-saturation of water with organic and inorganic substances leads to the formation of a satisfactory feed depot and the existence conditions for the initial intermediate hosts of the Heterophyidae trematodes – the mollusks. The piscivorous birds also play a relevant role in maintaining and spreading the cryptocotylosis agents.

Geographically, the Dnipro-Buh estuary is formed by the Buh estuary, the Dnipro delta, and the Black Sea. The waters of the Southern Buh, the Inhul, and the Dnipro fall into the estuary, carrying many pollutants (compounds of phosphorus, ammonium nitrogen, sulfates, etc.) in the composition of surface and sewage runoffs (Pichura VI, et al, 2019). The piscivorous birds – the definitive hosts – play a considerable role in spreading the cryptocotylosis agent. The current climate conditions lead to the change in migration ways and borders for the migrating birds, which, during the ecological adaptation, have become the leading carriers of a considerable number of parasitic disease agents for the ichthyofauna in the natural waters of the south of Ukraine, including cryptocotylosis. The natural conditions of the landscape in the backwater system of the Dnipro and the Dnipro-Buh estuary formed the Black Sea biosphere reserve. This reserve is the territory for the migrating and non-migratory birds to nest. The latter has become the reason for the functioning of the natural stationary source of invasions. The formation completion and the full-fledged nature of the dynamic system of the invasion source in the biotope is indicated by the gradual increase in the invasion prevalence in our studies.

The Ukrainian researchers have studied the seasonal dynamics of cryptocotylosis among Gobiidae in detail. For instance, it was found that in the Dnipro-Buh estuary and the Black Sea, there were two peaks of the increased invasion indices during the year – in summer and in autumn. The maximal indices of the prevalence and intensity of the cryptocotylosis invasion were observed in autumn. The lowest indices of the invasion for Gobiidae, as compared to other seasons, were recorded in spring (Honcharov SL, 2019d).

The seasonal fluctuations in the Gobiidae invasion rates by the cryptocotylosis agent are directly dependent on the ambient temperature indices (Naidenova NN, 1974). It may be explained by the effect of the temperature oscillations on the biological rhythms of both parasites and hosts. The active consumption of the feed (mollusks) and subsequent invasion of the Gobiidae start with the beginning of the vegetation period, with the temperature increasing over 10–12 °C. Therefore, the maximal invasion rate occurs in spring and summer, but the highest indices of the invasion prevalence were registered in autumn, as the invasion takes place with the accumulation effect. It is undeniable that the previously invaded goby fish do not get rid of the parasites till the end of their lives; depending on the life cycles of the investigated trematodes, they are only constantly invaded. So, no considerable oscillations in the invasion prevalence are observed in Gobiidae during the year. The seasonality of the invasion has an immediate effect on the formation of the colonies of the piscivorous birds – the main definitive hosts of the cryptocotylosis agent. In the process of forming the parasite-host relations, the parasite adapted its life cycle so that it would be synchronized with the biological cycles of its hosts – mollusks, hydrobionts, and birds (Honcharov SL, 2019d).

In the Dnipro-Buh estuary and the Black Sea, Gobiidae fish, aged 6+–7+, were the most invaded by the cryptocotylosis agent. Less invaded were the fish aged 2+–3+. The study results showed that the older goby were, the higher the invasion indices by the metacercariae of Heterophyidae family trematodes were. This regularity was described and substantiated by VA Dogel (1962). The researcher stated that during the lifetime, the invasion of the subject took place with the accumulation effect. Some parasites are eliminated from the host's organism, but under repeated invasion their total number increases, and that happens every year (Dogel VA, 1962).

The index of spots in different species of Gobiidae fluctuated depending on their age. This fact is explained by the difference in the resistance ability of Gobiidae of different species to being invaded by the parasitic disease agents. Also, a number of factors affect the invasion state of Gobiidae, including the ratio type existing in specific conditions (bottom landscape, preference of hydrochemical indices of water, etc.). It should be noted that the rate of fish being invaded with parasitic disease agents depends on the seasonal and feed migrations as well. The larva stages of fish parasites are unevenly distributed in the depth of water. Therefore, even during a small migration, the fish are constantly invaded to a greater or lesser degree depending on the dispersion of the agent distribution in the environment of the hydrobionts. The type of nutrition, the behavioral reactions during the breeding season, and feed preferences also directly affect the invasion prevalence in the case of the parasitic diseases of fish (Honcharov SL, 2019a).

The studies on Gobiidae in the Dnipro-Buh estuary demonstrated that the prevalent location of the metacercariae of Heterophyidae trematodes was the dorsal part of the fish body including the area of the head and the gills; the invasion prevalence was 71.3 %. The invasion prevalence for the ventral part of the body was 28.4 %. The metacercariae were less frequently found on the internal part of the abdominal wall, the invasion prevalence – 0.3 %. The distribution of the metacercariae depends on the parasite's strategy of invading fish, which lies in the ability of the cercariae to perceive the movement and biochemical manifestations of their activity. These manifestations are the movements of the fish in their environment and the formation of water oscillations perceived by the parasites. Moving in the water, the goby can change the intensity of the light flow, analyzed by particular light-sensitive areas on the cercaria body. Also, the presence of the sialic acid in the composition of the superficial mucosa of the goby allows the parasites to differentiate between the fish as potential intermediate hosts and other objects which can move. These adaptive specificities of the cercariae were formed in the process of harmonizing the parasite-host system, which is dynamic and constantly improving. For instance, the photo- and geotaxis in the parasite larvae ensures the invasion of the fish and further implementation of the cycle of the cryptocotylosis development. It should be assumed that the location of the metacercariae in the dorsal part of the body will also be related to the thermotaxis, which can be observed in the cercariae of the trematodes of other species. This phenomenon is explained by the fact that the dynamic movement of the fish requires the largest group of muscles – the dorsal group. As the enhanced metabolism during the movement of the goby is accompanied by some heat formation and thus the increase in the total temperature of their body, it helps the cryptocotylosis cercariae get oriented during the invasion (Honcharov SL, 2019b).

In the case of cryptocotylosis in the blood of Gobiidae, caught in the Dnipro-Buh estuary and the Black

Sea, there was a noted decrease in the content of hemoglobin and erythropenia. The mechanical impact of the parasite larvae on the host organism causes leukocytosis. At the same time, there was a registered increase in the number of band and segmentonuclear neutrophils, basophils, and eosinophils in the blood of Gobiidae fish. There was a noted increase in the number of monocytes in the blood of fish which demonstrated the activation of the phagocytosis processes as a defensive function of their organism. The number of lymphocytes decreased insignificantly as compared to the control group of the fish (Honcharov SL, 2018). The biochemical study of the blood serum of the invaded fish demonstrated the decrease in the content of the total protein, albumins, and globulins of their blood serum. There was a noted insignificant increase in the scope of α- and β-globulins which demonstrated long-term inflammatory processes in the organism of Gobiidae. A minor increase in the content of γ-globulins in the blood serum was registered in the goby with cryptocotylosis. The decrease in the urea content in the blood serum of Gobiidae demonstrated the destructive processes in the hepatopancreas and as a result, the disruption of the detoxicating function. The glucose content in the blood serum also decreased which demonstrated their insignificant activity in hunting and low mobility. It is noteworthy that the activity of AST and ALT enzymes fluctuated considerably for the toad goby, round goby, and monkey goby (Honcharov SL, 2019e).

While studying the pathological effect of the cryptocotylosis agent on the organism of ducklings, Honcharov SL (2017b) registered the changes in the clinical condition, including the signs of the impairment in the gastrointestinal tract. The post-mortem examination of the experimentally invaded ducklings demonstrated the signs of endoenteritis and hemorrhagic enteritis, the secondary liver injury. The content of the intestines contained mature trematodes of *C. jejuna* and *C. ancavum*.

Considering the abovementioned, special attention should be paid to the parasitic diseases that were not widespread in the territory of Ukraine or were not registered in the ichthyofauna of the industrial fish in the south of Ukraine at all. The cryptocotylosis of Gobiidae is among these diseases. The agents of this disease are of great epidemiological relevance, so they require the attention of specialists.

Due to considerable biogenic pollution of the global waters, there are changes in the biosystems, which have been balanced for millennia. These changes are imminent to lead to disruptions in the dynamic system of the parasite-host relations formed in the process of the co-evolution of the parasites and hydrobionts. The pollution of water bodies with organic sewage, oil products, and heavy metals provokes changes in the aqueous ecosystem. These changes promote the inhibition or vice versa, the induction of the development of the benthos populations and other aqueous organisms, serving as the intermediate hosts for the parasites.

Thus, the study of special characteristics of the newly formed biocenotic relations between the parasite and the host in a stable biotope presents excellent interest in terms of the functioning of the parasite-host relations, the epizootiology of the parasitic diseases (cryptocotylosis), and the impact of helminths on the host organism.

Since the Heterophyidae trematodes have not been so widespread in the Dnipro-Buh estuary and some parts of the Black Sea (Kherson, Mykolayiv, Odesa regions), the study of the seasonal and age-related dynamics, the distribution of the agent's larvae in the organism of fish, the specificities of the clinical course of these parasitic diseases in association with others is of great relevance.

Despite a considerable amount of the scientific data and projects related to cryptocotylosis, highlighted in the publications of Ukrainian and international scientists, there are many issues that require investigations and clarifications. For instance, considering the great prevalence of the cryptocotylosis agent among the Gobiidae population in the Black Sea, the distribution of the parasites in the Sea of Azov, the estuaries, and the brackish waters of Ukraine is yet to be investigated on the modern level. The pathological effect of the cryptocotylosis agent on the tissues of the definitive host has not been described on the level of histological studies and in terms of the morphological and biochemical changes in the blood of the infected hosts. The cryptocotylosis agent is of epidemiological relevance and poses a threat to human health. Yet, at present, Ukraine does not have the regulatory and normative foundations and regulations to define the procedure of the veterinary and sanitary evaluation of fish products regarding cryptocotylosis. For instance, there are no studies on the modes of technological processing of fish and fish products that would guarantee reliable elimination of the parasites and their loss of viability in the raw material to obtain safe food products. The methods of laboratory diagnostics require improvement.

CONCLUSIONS

The review highlights the issues of the developmental biology and special characteristics of the epizootiology of *Cryptocotyle* trematodes, namely, the specificities of the seasonality, age-related dynamics, diagnostics, etc. Special attention is paid to the biological specificities of *Cryptocotyle* trematodes: the parasite's life cycle; the specificities of development in the organism of the intermediate hosts; the biochemical, morphological, and physiological adaptation of the trematodes.

The trematodes of *Cryptocotyle* genus were first described by Creplin in 1825, when he found them in the intestines of the piscivorous birds, the gulls, and described their morphological specificities. The trematode of *Cryptocotyle* genus is remarkable for its oval and prolonged body. It has a mouth sucker and a rudimentary ventral sucker. The seminal vesicle may have an S-like form.

The cryptocotylosis agent is widespread in international waters. Yet, the trematodes of *Cryptocotyle* genus got their most significant prevalence in the Mediterranean region, namely in the western Mediterranean and Aegean provinces, including the waters of the Black Sea near Romania, the Crimea, and the Dnipro delta.

The development cycle of the trematodes of *Cryptocotyle* genus is complicated and involves the initial intermediate host (marine and estuarine mollusks of Littorina and *Hydrobia ulvae* (*Peringia ulvae*). The mollusks get invaded while swallowing the eggs (passive invasion). In the organism of the mollusk, the parasite goes through many developmental stages: a miracidium, a sporocyst, a redia, and a cercaria. The second intermediate hosts are different species of fish, which get invaded by freely floating cercariae that have left the mollusk. The cercariae drop their tail and, on penetrating the body of the fish, they get transformed into the metacercariae and get isolated from the tissues of the fish using a double-walled capsule which goes through considerable melanization later. The definitive hosts are mostly piscivorous birds, which eat the fish, invaded by the metacercariae, and get invaded. The metacercariae reach their maturity in the gastrointestinal tract of the invaded birds, thus transforming into the maritas. The distribution of the parasites occurs when the eggs of *Cryptocotyle* trematodes penetrate the water bodies with the feces of the birds. The accidental (definitive) hosts for this species of trematodes may be cats, dogs, rats, wolves, foxes, minks, and humans. An experimental invasion of laboratory rats and guinea pigs, ducklings, and pigeons was successful.

The fish get invaded by the cercariae due to well-developed adaptation mechanisms of the parasite: the availability of photo- and chemotaxis.

In the case of fish cryptocotylosis, with the older age of the latter, the prevalence and intensity of the invasion increased; the indices of the spots did not always correlate with the age of fish and rather depended on the species membership of the fish. It was reliably found that the level of invasion is higher for males than for females in Gobiidae fish. This fact is related to the behavioral specificities during the spawning season, which facilitates the invasion of fish by the cercariae. The majority of the metacercariae are in the area of the head, the first and second dorsal fins.

The seasonality of the disease of the second intermediate host, fish, depends on the geographical and climatic location of the water bodies: in conditions of the North Sea, the sick fish are mainly registered in spring and in the Black Sea – in autumn. Among the young piscivorous birds, most birds with cryptocotylosis are registered in summer, and the older birds – in winter.

The cryptocotylosis agent, present in the organism of the initial intermediate host, the mollusk, leads to the decrease in the reproductive function of the latter and even to the loss of the ability to reproduce; it decreases the intensity of the growth and development of the mollusk, and the intensity of the metabolic processes; it decreases the thermoresistance of the mollusks and affects the behavioral characteristics of the intermediate host.

The effect of the trematode of *Cryptocotyle* genus on the organism of the second intermediate host, fish, is characterized by impaired metabolic processes, a decrease in the fleshing, and a decreased hepatosomatic index. The morphological study of the blood of the sick fish registered an increase in the number of leukocytes, basophils and pseudobasophils, eosinophils and pseudoeosinophils, band and segmentonuclear neutrophils, monocytes, and a decrease in the content of hemoglobin, the number of erythrocytes and lymphocytes; the biochemical study of the blood serum demonstrated the impaired ratio of albumins and globulins, the decrease in the content of urea and glucose and the increase in the activity of some enzymes. The death of the fish is possible at the high degree of invasion intensity.

When the cryptocotylosis agent is present in the organism of the definitive host, a piscivorous bird, it results in the inflammatory processes in the gastrointestinal tract: catarrhal inflammation of the mucosa of small intestines, impaired hepatobiliary tract, exhaustion, and high indices of the invasion and long-term clinical course – in the death of the bird.

Cryptocotylosis is diagnosed based on the detection of clinical symptoms (the presence of black pigment spots on the body of the fish) and the results of the microscopic study of the morphological features of the agent. The confirming diagnostics applies the molecular and genetic methods of investigation. The serological methods did not prove their efficiency in diagnosing cryptocotylosis.

The pollution of water bodies with organic and inorganic residues affects the intermediate and definitive hosts of the cryptocotylosis agent, the mollusks, fish, and piscivorous birds, as well as the parasites. For instance, the excessive saturation of water bodies with the pollutants leads to the impaired movements of cercariae, and the sensory characteristics of the parasite (the phototaxis ability) are not affected. The larva stages of the parasites, freely moving in the aqueous environment, can accumulate considerable amounts of heavy metals (zinc, iron, copper, and manganese), which reduces the lifetime of the latter. The changes in climate conditions, including global warming, have a significant effect on the distribution of cryptocotylosis in nature. The mentioned phenomenon promotes the formation of nesting and feeding colonies of the piscivorous birds in farther northern latitudes and the appearance of the cryptocotylosis agent in the water biotopes where it was not registered before. The excessive saturation of the aqueous environment with organic pollutants creates more comfortable development conditions for the initial intermediate host – the mollusks, which results in the formation of natural sources of the cryptocotylosis invasion in nature.

Therefore, the study of the developmental biology and epizootic specificities of the cryptocotylosis agent is of great interest to researchers worldwide, which is confirmed by a significant number of scientific publications and communications. The generalization of the available information about the trematodes of *Cryptocotyle* genus allows for determining insufficiently studied aspects of this invasion, namely, the reliable and substantiated taxonomy of the trematodes of *Cryptocotyle* genus; detailed and comprehensive study of the impact of the parasites on the host organisms, including humans; the development of reliable and highly sensitive methods of serological diagnostics, etc.

Cryptokotyle lühe, 1899 (trematoda: heterophyidae): особливості біології розвитку та епізоотології

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В огляді представлено результати наукових досліджень особливостей біології розвитку та епізоотології трематод роду *Cryptocotyle*, які відносяться до родини *Heterophyidae* та представдяють загрозу здоров᾽ю для теплокровних тварин, а також людини, тобто є типовим зоонозом. Ці трематоди поширені переважно в Західносередземноморській зоогеографічній напівобласті, а саме Західносередземноморській та Понт-Егейській зоогеографічних провінціях. Трематод роду *Cryptocotyle* реєструють у країнах Європи, Азії, Північної та Південної Америки, а також в Антарктиці. Трематоди *Cryptocotyle* є типовими біогельмінтами, тобто із складним життєвим циклом, де в ролі перших проміжних хазяїв виступають водні молюски, других – риби різних видів; дефінітивними та кінцевими хазяями є рибоїдні птахи, хижі тварини (лисиці, вовки, собаки, коти та ін.) і людина. Для криптокотильозу є характерною сезонність, що залежить від кліматичних зон. Зокрема, в територіальних акваторіях України найбільших значень криптокотильозної інвазії серед бичкових риб реєструють переважно влітку та восени, але пік інвазії припадає на осінь. Паразитування трематод *Cryptocotyle* в організмі молюсків впливає на відтворювальну здатність та поведінкові особливості (рухова активність). Інвазовані риби характеризуються наявністю чорних пігментних утворень на поверхні тіла – метацеркаріїв. В організмі дефінітивних хазяїв збудник локалізується в шлунково-кишковому тракті та може викликати запальні процеси слизової оболонки кишок і зміни в паренхіматозних органах, що свідчить про токсичний вплив паразита на організм хазяїв. Діагностика криптокотильозу базується на виявленні збудника в організмі хазяїв і подальшій його таксономічній ідентифікації за анатомо-морфологічними особливостями. Забруднення водного середовища органічними та неорганічними рештками впливають як на організм хазяїв, так і на самих паразитів.

Ключові слова: криптокотильоз, біогельмінт, зооноз, проміжні хазяї, дефінітивні хазяї.

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