Expansion of *Phalacrocorax carbo* in reservoirs of the North-Eastern Kazakhstan

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Abstract. Initial data regarding the helminth fauna of the great cormorant *(Phalacrocorax carbo)* in the Pavlodar region of Kazakhstan have been acquired. The parasite fauna of the great cormorant is influenced by its diet of fish and consists of two fully developed helminth species - the nematode *Contracaecum rudolphii Hartwich, 1964* and the cestode *Ligula interrupta Rudolphi, 1810*. An incidental finding was made when cestodes and their broken pieces were found in the intestines of cormorants. These cestodes were recognised as belonging to the genus *Cyathocephalus*, which is known to solely parasitize fish in its adult stage. *Metacercariae* of trematodes, specifically from the family Strigeidae, were found. These parasites are very new to fish intestines and are not commonly found in birds that consume fish. The growing population of great cormorants in the Ertis basin may introduce new kinds of helminths, some of which could have significant implications for the spread of diseases among animals. The prevalence of parasites in cormorants is a significant concern and has the potential to facilitate the transmission of nematodes and cestodes among other species, including fish-eating birds, poultry, fish, and aquatic invertebrates. This creates localised areas where nematodes and ligulidoses can thrive.

1 Introduction

There has been a noticeable rise in the population of the great cormorant in the reservoirs of the Pavlodar region in North-Eastern Kazakhstan in recent years. This expansion of the species is causing worry among the public and environmental services in the area [1-3]. During the summer of 2023, almost 4 thousand great cormorants were observed along the Ertis River in the Pavlodar region, both when rafting and during stationary observations [4]. In areas with a large population of cormorants, there is a concentration of several hundred individuals in the floodplain and riverbed. Ertis has a substantial negative impact on fish populations. Considering the typical daily requirement of a person for 350-500 g of food, cormorants have the capacity to extract about two tonnes of fish from the reservoirs of the

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Pavlodar region on a daily basis. During the autumn season, cormorants cause more than 130 tonnes of damage to fish populations in the Pavlodar region, exceeding the yearly fishing limit of 98 tonnes for the region.

The Great Cormorant, scientifically known as Phalacrocorax carbo, is a substantial aquatic bird that inhabits extensive regions ranging from Europe to Asia. The 2013 pan-European census revealed a substantial winter habitat for cormorants, spanning from the Baltic Sea to the Mediterranean and North Africa. The estimated population in January 2013 exceeded 1 million [5].

In the 1990s, there was a significant migration of this species towards the northern region of Kazakhstan. The establishment of new colonies and a series of long-distance flights were concurrent events [6]. During the latter half of the twentieth century. Great cormorants were rarely observed in the floodplain of the Ertis River between Ust-Kamenogorsk and Semipalatinsk. The construction of the Shulbinsky reservoir on the Ertis River in the 1980s led to an increase in the presence of cormorants. This was due to the formation of new fish communities and the availability of favourable eating conditions, which prompted the cormorants to start nesting in this area [7]. Significant alterations in the geographic range of the majority of aquatic colonial birds had place in the Upper Ertis basin. The Great cormorants *Phalacrocorax carbo*, which previously only nested on floating labzas in the delta of the Black Ertis and in the western half of Lake Zaisan, have now spread their nesting grounds to the Batinsky Islands deep within the Bukhtarma Reservoir. The ongoing observation of these birds' propensity to expand their range along the Ertis River has persisted in recent years [8].

The presence of the great cormorant in Kazakhstan is mostly attributed to the abundance of water bodies and aquatic biodiversity in the country. The aquatic environments in Kazakhstan offer optimal circumstances for the reproduction and natural habitat of this avian species.

The great cormorant plays a vital role in the water bodies' ecosystem by consuming fish, aquatic insects, and other aquatic species. Simultaneously, these avian creatures can exert a detrimental influence on the abundance of fish populations, and additionally serve as vectors and disseminators of many parasites.

Studies indicate that the cormorant population could potentially harbour a range of parasites, including as helminths, coccidia, and bacteria. Simultaneously, birds, acting as reservoirs of parasites, can facilitate the transmission of parasites within their own species as well as to other animals, including humans.

A total of 78 helminth species have been documented in cormorants in the Palearctic region. These include 45 species of trematodes, 23 species of nematodes, 6 species of cestodes, and 4 species of acanthocephalans [9-11]. A substantial portion of their species engage in parasitism, specifically targeting other avian species that consume fish. Different species of helminths can be discovered in various regions of Europe, infecting the great cormorant. They are widespread and can be found in both wintering areas and breeding sites [12].

An investigation into the dynamics of parasite dispersion among the great cormorant population might yield useful insights about the ecological impact of these birds and the overall health of the animals inhabiting the ecosystem, including domestic and game birds, as well as people, either directly or indirectly. Additionally, this research could aid in the development of strategies to manage parasites and their spread via birds, particularly those that have a wide range of movement.

The aim of our study was to investigate the parasitic fauna of the great cormorant on the floodplain of the Ertis River and evaluate the potential for disease outbreaks caused by medically and veterinary significant helminths.

2 Materials and methods

A total of 200 great cormorant specimens were examined using the comprehensive method of helminthological dissection. These specimens were obtained by shooting them in the Pavlodar region of Kazakhstan during the months of August and September. The shooting locations were around the lakes Auliekol, Shiganak, Karasor, and Kirpichnoe.

Lake Auliekol covers an area of 910 hectares and is situated in the Ekibastuz district of the Pavlodar region in North-Eastern Kazakhstan. Its coordinates are 52°11'03.4"N 74°46'04.9"E. The lake has a width of 3.1 km and a length of 3.81 km.

Lake Shiganak is situated in the Aktogay district of the Pavlodar region in North-Eastern Kazakhstan. It covers an area of 1280 hectares and has a length of 4.6 kilometres and a width of 5.1 kilometres.

Lake Karasor is situated in the Maysky district of the Pavlodar region in North-Eastern Kazakhstan. It has coordinates of 51°04'48.8"N 77°29'33.3"E and covers an area of 4430 hectares. The lake is 11 km wide and 6.27 km long.

Lake Kirpichnoe is situated in the Ertis district of the Pavlodar region in North-Eastern Kazakhstan. Its coordinates are 53°46'15.0"N 74°58'18.0"E. The lake has an area of approximately 1.5 hectares, with a width of 255 metres and a length of 104 metres.

The collection, fixation, and office processing of parasitological samples were conducted in accordance with established protocols [13-14]. The identification of helminths was conducted using keys and original descriptions [15-18]. We utilised the technology provided by the Scientific Centre for Biocenology and Ecological Research at Margulan University to identify parasites. Margulan University uses two types of microscopes: the MBS-100 Biolab, which is a trinocular stereoscopic microscope, and the MX-100T, which is a trinocular microscope made by West Medica.

In order to examine the parasitological material collected in this investigation, the following indicators were computed:

1) Invasion extensiveness refers to the proportion of persons infected with helminths in relation to the total number of individuals studied. The extent of invasion (E) was determined by applying the formula: $E = n/N \times 100\%$, where n represents the quantity of infected host individuals, and N stands for the total number of host persons examined.

2) Invasion intensity refers to the range of parasites present in a single infected host, ranging from the smallest to the largest number.

3) The abundance index (AI) refers to the quantity of parasites found in each unique host that was investigated. The abundance index (AI) was computed using the formula: $AI = m/N$, where m represents the count of identified helminths, and N is the total number of host individuals examined.

The studied birds were at least one year old. In addition, we conducted an analysis of the gastrointestinal tract contents to study the nutrition of the cormorant.

The quantitative data was subjected to statistical processing using established methods [19-23].

3 Results and discussion

Through helminthological autopsies conducted on adult great cormorants, two sexually mature helminth species were identified - *Contracaecum rudolphii Hartwich, 1964*, a nematode species, and *Ligula interrupta Rudolphi, 1810*, a cestode species. These species are recognised in the taxonomy based on the data from WoRMS [24].

The following data presents the quantitative ratio of helminths in model hemipopulations, as seen in Table 1.

Table 1. Findings from a comprehensive investigation on the parasitic worms in representative specimens of the great cormorant in the Ertis River basin

Sample №	**Sampling location**	**Nematodes species-individuals number**	**Cestodes species-individuals number**	**Other parasites species-individuals number**
1 (1)	Lake Auliekol	*Contracaecum rudolphii* - 70		
		male mature – 29		
		female mature – 41		
2 (2)	Lake Shiganak	*Contracaecum rudolphii* – 89 экз.		*Ichthyocothylurus sp.*, cysts – 3
		male mature – 27		
		female mature – 51		
		male immature – 1		*Ichthyocothylurus sp.*, cysts – 4
		female immature – 10		
3 (3)	Lake Karasor	*Contracaecum rudolphii* – 48		*Ichthyocothylurus sp.*, cysts with destructed membrane– 2
		male mature – 22		
		female mature – 23		
		male immature - 0		
		female immature – 3		
4 (51)	Lake Kirpichnoe	*Contracaecum rudolphii* – 87	*Ligula interrupta* - 1	*Cyathocephalus sp*. - 4
		male mature –11		
		female mature – 22		
		male immature – 19		
		female immature – 35		
5 (53)	Lake Auliekol	*Contracaecum rudolphii* – 33	*Ligula interrupta* - 2	
		male mature – 9		
		female mature – 22		
		male immature – 0		
		female immature – 2		
6 (52)	Lake Shiganak	*Contracaecum rudolphii* – 34	*Ligula interrupta* - 2	
		male mature – 9		
		female mature – 19		
		male immature – 1		
		female immature – 5		

Contracaecum rudolphii, a type of nematode, was found in the small intestine of 188 out of 200 cormorants that were studied. The number of specimens ranged from 33 to 89, with one host having 28 to 78 mature individuals in its intestines. Additionally, many birds had young immature specimens in their intestines as well. This species was first identified in the great cormorant and Bering cormorant during the 1970s in Yakutia and other regions, including Western Siberia [25].

The sex ratio of *C.rudolphii* in model hemipopulations, both overall and among mature nematode hemipopulations, exhibited random variations and showed no correlation with the presence of other helminth species or the number of roundworms in a single host. The male proportion in hemipopulations ranged from 27.27% to 48.89% (Table 2).

Table 2. Sex ratio of nematodes *Contracaecum rudolphii*

Sample №)	Nematodes number, samp.		males propotion, %	
	Mature	Total	Mature nematodes	Total
1 (1)	70	70	41,43±5,89	41,43±5,89
2 (2)	78	89	34,615±5,39	31,46±4,92
3 (3)	45	48	48,89±7,45	45,83±7,19
4 (51)	33	87	33,33±8,21	34,48±5,096
5 (53)	31	33	29,03±8,15	27,27±7,999
6 (52)	28	34	32,14±8,83	29,41±7,81

The prevalence of cormorants infected with contracecums was extremely high. Initially, it was seen that the invasion was quite broad, with nearly all adult birds being infected with nematodes. Furthermore, the intensity of the invasion and the abundance index were also notably substantial. The cestode *Ligula interrupta* was detected in a substantial proportion of the examined cormorant specimens, but with a very low population density, ranging from 1 to 2 individuals. The prevalence of infected individuals was lower compared to that of nematodes, and even lower was the index of number and severity of invasion (which is linked to the large size of individual strobili and restricted space in the intestines of birds) (Table 3).

Table 3. Indicators of infection of the great cormorant population with helminths *Contracaecum rudolphii* and *Ligula interrupta*

	Helminths species	
	Contracaecum rudolphii	***Ligula interrupta***
Number of infected hosts	188	156
Extensiveness of invasion (%)	94,0±1,68	78,0±2,93
Number of helminths	8881	261
Abundance index (samp.)	44.405±6,28	1,305±0,33
Intensity of invasion (samp.)	47,24±5,46	1,67±0,24

In our study on the species of contracecums found in cormorants, we relied on the morphological features of the helminths we discovered. Specifically, we observed that the gastric appendix is approximately 2-2.5 times longer than the oesophagus (as shown in Table 4). This is in contrast to other species of contracecums where the lengths of these structures are nearly equal. Additionally, we considered existing literature on the gastrointestinal tract specificity. In the guide to parasitic nematodes by K.I. Skryabin et al., the contracecums found in cormorants and other fish-eating birds in the former USSR are classified as *C.rudolphii*. Another species, which is also found in certain duck birds, herons, kites, and one species of pelicans but not in cormorants, is classified as *C.microcephalum* [26]. Subsequently, in subsequent editions of the book (both inside the post-Soviet region and internationally), we started to come across the distinct designation *C.rudolphi*. This name was bestowed following a thorough examination of the species, as a tribute to the author of the initial description.

Table 4 displays the dimensions of *Contracaecum rudolphii* nematodes found in great cormorants from the Pavlodar region.

Table 4. Sizes of nematodes Contracaecum rudolphii from the great cormorant from Pavlodar region

Parameters	**Sizes (mm)**	
	Females	**Males**
body lenth	28,7-47,2	23,2-32,3
Maximum width	0,9-1,55	0,8-1,2
Esophagus length	1,6-2,7	1,8-2,0
Ventricle length	0,12-0,2	0,13-0,15
Ventricular process length	3,2-5,3	3,6-4,0
Length of intestinal outgrowth	0,9-1,5	1,0-1,3
Tail length	0,4-0,9	
Distance from vulva to anterior end	8,4-15,4	
Egg sizes	0,07-0,084*0,028-0,035	
Spicule length		4,3-5,2

The *Ligula strobili* discovered in the model hemipopulations exhibited a width ranging from 7-8 to 12 mm, and a length of 25, 32.3, and 34 cm. A single specimen, containing a scolex, measured 4.3 cm in length. However, it appears to be a portion of an injured or dying organism, with the head end intact. The analysed cormorant populations experienced a significant infection rate in their definitive hosts, despite the relatively brief lifespan of the mature stage of cestodes belonging to the Ligulidae family (*Ligula* and *Digramma*). In fish, a mature plerocercoid with reproductive structures develops gradually over an extended period. However, in the final hosts, which are fish-eating birds, cestodes attain maturity within a very short time frame of 35-60 hours and thereafter perish within 2-4 days [27].

The identification of the sexually mature ligulids we discovered as belonging to the species *L.interrupta* is based on two longitudinal ventral grooves on the strobile, as well as the presence of two separate rows of reproductive complexes (in *L.intestinalis*, they form a single row that occasionally splits). The front end lacks unambiguous articulation, unlike *L. intestinalis*. The reproductive complexes are positioned posterior to the indistinct zone of false articulation.

An interesting discovery was made of cestodes and their fragments, detected in two specimens each in the intestines of two dissected cormorants from a specific group of populations. The specimens were classified as members of the genus *Cyathocephalus* based on their physical characteristics. It is worth noting that this genus is known to only parasitize fish in its adult stage [17]. The cestodes exhibited the following measurements: a width ranging from 3 to 5 millimetres, and a length ranging from 5.7 to 12.4 centimetres. They had a continuous, non-segmented construction, with a scolex that had a funnel form. At the end of the scolex, there was a single suction depression. The worms were adequately conserved, albeit with some signs of maceration - meaning they were partially impacted by the digestive enzymes in the cormorants' intestines after consuming the infected fish.

Trematode metacercariae were discovered in the intestines of cormorants, enclosed in a delicate, translucent cyst that is separate from the larva's body and can be easily damaged by mechanical means. Evidently, these individuals were members of the Strigeidae family, which have lately colonised the intestines of fish or are atypical parasites of fish-eating birds.

The observed scarcity of helminth parasites in the examined cormorants (with a sample size sufficient to yield statistically significant findings) appears to be linked to the specific characteristics of the habitats where the birds were found dead. The occurrence of *L.interrupta*, as opposed to *L.intestinalis*, in the intestines of sexually mature ligulids in cormorants may be attributed to the fact that the former species is more commonly found in slow-moving water bodies, whereas the latter is typically found on floodplains. A multitude of cormorants were captured in lakes of both floodplain and non-floodplain origin, as well as in sluggish streams. As per the findings of L.T. Bulekbaeva and N.E. Tarasovskaya [28], the percentage of cyprinid fish infested with plerocercoids is reported. The prevalence of Ligula intestinalis in floodplain biotopes varies from 1 to 3% of the captured population, with the level of infestation ranging from 1-2 to 5 larvae per fish. The dimensions of the plerocercoids ranged from 25 to 53 cm. Ligulosis was primarily observed between 2006 and 2008. It was detected in the settling lakes of the Pavlodar Aluminium Plant, which had water with high alkaline levels. These lakes housed a huge population of herring gulls, and at this time, several plerocercoids were identified in the abdominal cavity of deceased fish.

Contracecums have small crustaceans (Cyclops) as their initial intermediate hosts, followed by chironomids and dragonfly larvae as their second intermediate hosts. Fish, on the other hand, act as a reservoir host, allowing the infection to spread to fish-eating birds [29].

The high prevalence of two dominant species of helminths and the recent increase in the population of cormorants in the Pavlodar region may contribute to the unfavourable species composition of the helminth fauna in these birds. This increase in cormorant population began to recover in the summer of 2023 after a previous decline. Thus, it appears that when the population of cormorants is decreasing, the helminths found in these birds, which do not consist of any parasite specific to a particular species, tend to infect other fish-eating bird species that are more abundant.

All helminth species we have identified require fish as second intermediate hosts during their life cycles [30-32]. Among these, there are species whose larvae can induce illnesses and pathology in fish. For instance, the nematode *C. rudolphii* can diminish the market value of fish and potentially provide a risk to human well-being, causing serious gastrointestinal illnesses [33-34]. The parasitological findings acquired align well with the existing literature data on species discovered in Europe. Considering the life cycles of parasites observed in cormorants, it is evident that the floodplain of the Ertis River provides favourable conditions for their growth and development. Various hydrobiont species, such as carp and perch fish, as well as mollusks of the genus *Lymnaea*, have been observed as intermediate hosts in both the Ertis basin and all freshwater bodies. The collected data on the parasites of the great cormorant allowed for the addition of information regarding the helminth fauna of birds in Kazakhstan, particularly its epizootic status.

The limited diversity of helminth species seen in cormorants and the high prevalence of nematode infections are closely connected phenomena. According to A.F. Alimov [35], the species diversity of a community is influenced by the quantity and accessibility of essential resources. However, it is rare to find cases where resources are not utilised or are underutilised. In situations where the number of species decreases, the number of individuals within the remaining species tends to increase. In a previous study, N.E. Tarasovskaya and B.K. Zhumabekova observed a similar occurrence in various animal groups. These groups included domestic chickens, synanthropic rodents, domestic carnivores in urban areas, frogs, and fish in reservoirs with significant human influence. In these cases, the helminth population was inexplicably reduced [36]. Instances of severe infestation by any helminth species are not solely caused by a decline in the host organism's resistance, but also by an overall depletion of the parasitic fauna. This occurs when infection with certain helminth species is excluded and favourable conditions are provided for others. Typically, a significant presence of parasites - organisms that redistribute matter and energy at the highest level - serves as an indication of an elevated availability of trophic resources at a certain level of ecosystem functioning.

From an epidemiological perspective, the presence of a single, widely spread species of parasites causing high infection rates in cormorants can be considered as an unfavourable indicator. The nematode *C.rudolphii* has the potential to represent a threat to the invasion of commercial waterfowl and fish that act as reservoir hosts. The presence of larvae hampers the growth rate of young fish and diminishes the commercial value of the fish. The significant prevalence of fish-eating birds leads to a decrease in the worth of hunting trophies, such as the great and long-nosed merganser and grey heron. Additionally, it causes adverse circumstances for the white heron, a protected species in the Pavlodar region. There is a possibility of facultative infection in domestic ducks, which are kept in open water bodies during the summer. This infection can arise when the waterfowl consume aquatic invertebrates as direct intermediate hosts, rather than fish as reservoir hosts.

The prevalence of cormorants being infected with the fully developed stage of the tapeworm *Ligula interrupta* is a major factor in the development of widespread areas of ligulosis in several bodies of water. In these water bodies, the parasite life cycle is concluded through other avian species that consume fish. The swift dissemination of the parasitic worm, abbreviated lifespan, and high egg output of the ribbon-shaped variants of the tapeworm lead to the buildup of larval phases (plerocercoids) in fish, resulting in a decrease in its nutritional worth and market appeal. The migration of cormorants across bodies of water facilitates the spread of invasive infections over long distances and the establishment of new areas affected by ligulidosis.

4 Conclusion

The parasite fauna of the great cormorant is influenced by its diet of fish and consists of two mature helminth species - one nematode species called *Contracaecum rudolphii* (with an invasion rate of 94.0±1.68% and an average of 47.24±5.46 specimens) and one cestode species known as Ligula interrupta (with an invasion rate of 78.0±2.93% and an average of 1.67±0.24 specimens). The discovery of cestodes and their fragments in the intestines of cormorants, specifically identified as individuals of the genus *Cyathocephalus*, was an unexpected finding. It is worth noting that *Cyathocephalus* typically parasitizes only fish in its adult condition. The metacercariae of trematodes were discovered within a delicate, see-through cyst that is separate from the larva's body and can be easily damaged by mechanical means. Evidently, these individuals were representatives of the Strigeidae family, which have lately colonised the intestines of fish or are atypical parasites of fish-eating birds. The growing population of great cormorants in the Ertis basin, along with the limited variety of parasitic worms, may lead to the introduction of new species of worms, some of which may have implications for the spread of diseases among animals.

The prevalence of parasites in cormorants is a significant concern as it might potentially contribute to the transmission of nematodes and cestodes among other species such as fish-eating birds, poultry, fish, and aquatic invertebrates. This can result in the formation of clusters of nematodes and ligulidoses.

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