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Features of the formation of fish parasitofauna in pond farms of the Almaty region, Kazakhstan

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ABSTRACT

Pond fish farming in the Almaty region of Kazakhstan has expanded rapidly, yet no systematic survey of fish parasites has ever been conducted. To fill this gap, we examined 482 fish (common carp, grass carp, silver carp, and rainbow trout) from eight pond farms between May and October 2025, covering lowland warm-water and foothill cold-water farms. Using standard parasitological methods, we identified six major parasite groups. Monogenean gill flukes were the most widespread (prevalence 64.3%), followed by protozoan ectoparasites (58.1%). Prevalence of monogeneans and protozoans increased dramatically from spring to summer (38.5% to 79.8% for monogeneans, $p < 0.001$; 28.2% to 72.6% for protozoans, $p < 0.001$). Grass carp and silver carp carried significantly more cestodes (tapeworms) than common carp (44.2% and 37.2% vs. 18.3%, $p < 0.001$). Lowland farms had higher prevalence of monogeneans (71.9% vs. 47.1%, $p < 0.001$) and protozoans (64.0% vs. 42.9%, $p < 0.001$), while foothill farms had more cestodes, nematodes and trematodes. Zoonotic parasites were found in 8.7% of rainbow trout (*Diphyllobothrium* plerocercoids) and 3.3% of common carp (*Opisthorchis* metacercariae), posing a food safety risk. The parasite community was most diverse in summer (Shannon index 2.04 in foothill farms). These results demonstrate that the formation of fish parasitofauna in the Almaty region is strongly shaped by season, fish species, and farm type. Targeted, seasonal parasite control strategies are urgently needed, along with public health warnings about consuming raw or undercooked pond fish.

Keywords: Fish parasitofauna, Pond aquaculture, Almaty region, Zoonotic parasites.
Article type: Research Article.

INTRODUCTION

Fish farming in Kazakhstan has grown steadily over the past two decades, driven by the need to reduce dependence on imported fish and to meet the rising demand for affordable protein (Han *et al.* 2016; Ziarati *et al.* 2022). The Almaty region, with its numerous natural and artificial water bodies, mild climate, and access to irrigation canals, has become one of the main centres for pond aquaculture in the country. Small- and medium-sized pond farms now dot the landscape around Kapchagay reservoir, the Ili River floodplain, and the foothill zones. However, alongside the expansion of aquaculture, a less visible problem has emerged: the fish in these ponds carry parasites (Gauthier 2015; Raissy 2017). Some of these parasites cause little harm, but others lead to poor growth, reduced market value, and even mass mortality. For a fish farmer barely making a profit, an unexpected parasitic outbreak can mean the difference between staying in business and shutting down completely. The formation of fish parasitofauna, which parasites live in which fish species and in what numbers, is not random. It depends on many interacting factors: the water source (river, canal, and well), the fish species stocked (carp, grass carp, silver carp, and trout), the farming intensity, the presence of wild fish in the same water body, and even the birds that visit the

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ponds (Karvonen & Lindström 2018; Egamberdiyev *et al.* 2025). Herons, cormorants, and gulls often carry parasite eggs or larvae from one farm to another. In the Almaty region, where many ponds are connected by irrigation channels or share water with natural rivers, the potential for parasite transmission is high (Mamedova & Veliyeva 2017; Khattak *et al.* 2026). Yet no systematic study has ever been conducted to understand how fish parasitofauna actually forms in these specific pond farms. This knowledge gap means that farmers treat parasite problems blindly, using expensive drugs that may not even target the right species (Farzadnia & Naeemipour 2020). From a scientific perspective, the Almaty region offers a particularly interesting case because it sits at the intersection of two different climatic and hydrological zones. The northern part of the region features semi arid steppe with ponds fed by the Ili River and Kapchagay reservoir, while the southern foothills have colder, clearer water from mountain streams. These different environments presumably support different parasite communities (Narkul *et al.* 2025; Suhardi *et al.* 2026). Common carp, *Cyprinus carpio*, which is the main species in most lowland ponds, may harbour a different set of parasites than rainbow trout, *Oncorhynchus mykiss* raised in the foothills (Simões *et al.* 2010; Santos *et al.* 2013). Understanding these differences is not just an academic exercise; it helps farm managers predict which parasites are likely to appear under which conditions, and therefore which preventive measures actually make sense (Scholz & Kuchta 2016; Saijuntha *et al.* 2021). The economic importance of parasitic diseases in aquaculture is often underestimated (Al Sulivany *et al.* 2024). A farmer may notice that fish are feeding poorly or swimming near the surface, but without a microscope and trained personnel, the cause remains a mystery. By the time the problem becomes visible—lesions, gill damage, or dead fish floating on the water, the parasite load is already high, and treatments are less effective (Chowdhury *et al.* 2021). Moreover, some fish parasites, such as *Ichthyophthirius multifiliis* (white spot disease) or *Dactylogyrus* species (gill flukes), can spread rapidly through a pond and kill a large proportion of the stock within days (Martorelli *et al.* 2012; Nguyen *et al.* 2021). In the Almaty region, where summer water temperatures are ideal for many parasite life cycles, epidemics can unfold very quickly. A single outbreak can destroy an entire season's production, leaving farmers with nothing to sell and no income until the next year (Clausen *et al.* 2012). Beyond the immediate economic losses, parasitic infections also affect fish welfare and product quality. Fish with heavy parasite burdens grow slower, have lower feed conversion ratios, and are more susceptible to bacterial secondary infections (Hernández-Cabanyero & Amaro 2020; Carmona-Salido *et al.* 2021). When such fish are sold to processing plants or live markets, their appearance may be poor, and the presence of visible parasites can lead to consumer rejection (Dung *et al.* 2007). In some cases, parasites such as *Ligula intestinalis* (a tapeworm that castrates its fish host) or *Philometra* species can render whole batches of fish unsaleable (Fioravanti *et al.* 2021). For pond farms in the Almaty region that supply fish to local markets in Almaty City, Shymkent, and beyond, maintaining a clean, parasite-free product is essential for building consumer trust. Without baseline knowledge of which parasites are actually present, however, it is impossible to set realistic quality standards. Another layer of complexity comes from the introduction of non native fish species. Many pond farms in Kazakhstan have stocked grass carp (*Ctenopharyngodon idella*) and silver carp (*Hypophthalmichthys molitrix*) imported from China or Russia. These fish sometimes bring their own parasites, which may then spread to native species. Conversely, native parasites may adapt to these new hosts, creating novel host-parasite relationships that can be more pathogenic than the original ones (Shin & Park 2018; Zdyrko *et al.* 2020). The Almaty region, because of its long history of fish introductions and its active aquaculture sector, is a potential hotspot for such host switching events (Fleury *et al.* 2001). Monitoring the parasitofauna of pond fish is therefore not only a matter of farm management, but also a biosecurity issue that concerns the health of wild fish populations in the surrounding rivers and lakes. Public health adds yet another reason to study fish parasites. Although most fish parasites are harmless to humans, some, such as the broad fish tapeworm (*Diphyllobothrium latum*) and various trematode metacercariae, can infect people who eat raw or undercooked fish (Scholz & Kuchta 2016; Saijuntha *et al.* 2021). In Kazakhstan, traditional dishes such as "kozhe" (fish soup) and, increasingly, raw fish appetisers, pose a potential risk if the fish come from contaminated ponds (Dung *et al.* 2007; Clausen *et al.* 2012). No systematic survey has ever assessed the presence of zoonotic fish parasites in pond farms of the Almaty region. Given that some of these farms sell fish directly to consumers at roadside markets, the lack of surveillance is a gap that needs urgent attention. Our study was designed to include a search for zoonotic species precisely for this reason (Ziarati *et al.* 2022; Al Sulivany *et al.* 2024). Currently, fish farmers in the Almaty region rely on a handful of broad spectrum antiparasitic drugs, often applied without any prior diagnosis (Farzadnia & Naeemipour 2020). This practice is not only wasteful but also dangerous, since overuse of chemicals can lead to resistance in parasites and leave residues in the fish flesh

(Gauthier 2015). A rational approach to parasite control requires knowing which parasites are present, when they are most abundant, and which fish species they prefer (Raissy 2017). Seasonal patterns matter too: some parasites peak in spring, others in late summer (Karvonen & Lindström 2018). Without this knowledge, treatment timing is guesswork. Our study therefore aimed to provide the basic parasitological data that farmers and veterinarians need to move from blind treatment to targeted, evidence-based intervention (Nguyen *et al.* 2021; Suhardi *et al.* 2026). Given the situation described above, the economic importance of pond aquaculture in the Almaty region (Chowdhury *et al.* 2021; Ziarati *et al.* 2022; Al Sulivany *et al.* 2024), the lack of systematic parasitological surveys (Mamedova & Veliyeva 2017; Khattak *et al.* 2026), the risks of zoonotic transmission (Fleury *et al.* 2001; Dung *et al.* 2007; Han *et al.* 2016; Scholz & Kuchta, 2016; Zdyrko *et al.* 2020; Saijuntha *et al.* 2021), and the need for rational treatment strategies (Gauthier, 2015; Raissy 2017; Farzadnia & Naeemipour 2020; Hernández-Cabanyero & Amaro 2020; Carmona-Salido *et al.* 2021), we decided to conduct a comprehensive investigation into the features of fish parasitofauna formation in pond farms of the Almaty region. We examined fish from multiple farms during the spring, summer, and autumn of 2025, covering the main cultured species and different pond types (Simões *et al.* 2010; Martorelli *et al.* 2012; Santos *et al.* 2013; Karvonen & Lindström 2018; Shin & Park 2018; Nguyen *et al.* 2021; Fioravanti *et al.* 2021; Narkul *et al.* 2025; Egamberdiyev *et al.* 2025; Suhardi *et al.* 2026). The necessity of this research lies in its potential to improve fish health, reduce economic losses, protect public health, and provide a scientific foundation for sustainable aquaculture in Kazakhstan. The following sections describe the methods we used, the parasites we found, and the patterns that emerged.

MATERIALS AND METHODS

The field and laboratory works were carried out between May and October 2025. This six-month period covered the main growing season for pond fish in the Almaty region, from spring warming (when parasites become active) through autumn (when fish are harvested). Sampling three times per farm (spring, summer, autumn) allowed us to capture seasonal changes in parasitofauna. The following subsections describe the study farms, the fish sampling protocol, the parasitological methods, and the analytical approach.

Study sites and fish sampling

We selected eight commercial pond farms located in three districts of the Almaty region: four farms in the Ili River floodplain (lowland, and warm-water ponds), two farms near Kapchagay reservoir, and two farms in the foothill zone (colder water, fed by mountain streams). All farms raised common carp, *Cyprinus carpio* as the main species. Four farms also stocked grass carp, *Ctenopharyngodon idella* and silver carp, *Hypophthalmichthys molitrix*, and two foothill farms raised rainbow trout, *Oncorhynchus mykiss* alongside carp. The farms ranged in size from 2 to 15 hectares of pond surface, with stocking densities between 2,000 and 5,000 fish per hectare. None of the farms had received antiparasitic treatment for at least three months before the study. During each visit (May, July, and September 2025), we collected 15–20 fish per species per farm using a seine net. Fish were placed in aerated tanks and transported live to a field laboratory set up at each farm. A total of 482 fish were examined: 246 common carp, 104 grass carp, 86 silver carp, and 46 rainbow trout. Before examination, each fish was measured (total length, cm) and weighed (g), and its general health condition (skin lesions, fin erosion, and behaviour) was noted.

Parasitological examination and identification

Each live fish was killed by a sharp blow to the head, then immediately examined following standard parasitological procedures. First, the skin, fins, and gills were inspected under a dissecting microscope (×10–×40) for visible parasites such as monogeneans, crustaceans, and leeches. Gill arches were removed, placed in a Petri dish with water, and examined separately. Mucus scrapings from the skin and gills were prepared as wet mounts on glass slides and examined at ×100–×400 magnification for protozoans (e.g., *Ichthyophthirius*, *Trichodina*, *Chilodonella*). Second, the body cavity was opened, and the internal organs (liver, spleen, kidney, swim bladder, and mesenteries) were examined for helminths. The gastrointestinal tract was removed, opened longitudinally, and its contents were washed into a Petri dish. Parasites were collected using fine needles and forceps, then counted and preserved in 70% ethanol (for nematodes, cestodes, and acanthocephalans) or 4% formalin (for trematodes, and monogeneans). Temporary mounts in glycerine-ethanol were used for preliminary identification. Permanent preparations were made: monogeneans and small trematodes were stained with Gomori's trichrome or alum carmine, dehydrated, cleared in xylene, and mounted in Canada balsam. Nematodes were cleared in lactophenol for examination. Identification was performed using standard keys for fish parasites of the former

USSR and Europe (Bykhovskaya-Pavlovskaya *et al.* 1964; Bauer 1987) and more recent taxonomic references. Parasite species were confirmed by morphological characteristics (sclerotised parts, hook dimensions, egg morphology). For problematic cases, we consulted a reference parasitologist at the Institute of Zoology in Almaty. Infection parameters recorded included prevalence (percentage of fish infected), mean intensity (average number of parasites per infected fish), and mean abundance (average number per examined fish).

Data analysis and statistical comparisons

For each fish species and farm type (lowland vs. foothill), we calculated prevalence, mean intensity, and mean abundance for each parasite taxon. Seasonal differences (spring vs. summer vs. autumn) were tested using chi-square tests for prevalence (categorical) and Kruskal-Wallis tests for intensity (non-normal distribution). Comparisons between farm types (lowland vs. foothill) and between fish species were made using Fisher's exact test for prevalence and Mann-Whitney U test for intensity. To describe the overall structure of the parasitofauna, we calculated the Shannon diversity index (H′) for each farm and season. Cluster analysis (Bray-Curtis similarity) was performed to group farms based on parasite community composition. All calculations were done in R (version 4.2.2) using the packages "vegan", "stats", and "ggplot2". A p-value < 0.05 was considered statistically significant. For zoonotic parasites (e.g., *Diphyllobothrium* plerocercoids, and trematode metacercariae), we recorded their presence and abundance separately and reported them to the regional veterinary authority as part of a parallel public health surveillance effort.

RESULTS

A total of 482 fish from eight pond farms were examined for external and internal parasites. The following six tables summarise the overall parasitofauna, seasonal dynamics, differences between fish species, differences between lowland and foothill farms, the occurrence of zoonotic parasites, and the parasite community diversity across farms.

Table 1. Overall prevalence and intensity of major parasite groups in all examined fish (n = 482).

Parasite group	Prevalence (%)	Mean intensity (range)	Host species (most affected)
Monogenea (gill flukes)	64.3	12.4 (1–84)	Common carp, grass carp
Protozoa (e.g., *Trichodina*, Ich)	58.1	84.6 (5–450)	All cyprinids, especially carp
Cestoda (tapeworms)	27.8	3.2 (1–18)	Grass carp, silver carp
Nematoda	12.4	2.1 (1–7)	Common carp, rainbow trout
Trematoda (adult)	8.5	4.7 (1–23)	Rainbow trout, silver carp
Crustacea (e.g., *Lernaea*)	14.2	1.8 (1–5)	Common carp, grass carp

Monogenean gill flukes were the most widespread parasites, found in nearly two-thirds of all fish, with mean intensities of 12 worms per infected fish and up to 84 in heavily infected carp. Protozoan ectoparasites showed the highest intensities (mean 84 per fish, some exceeding 400), indicating that they often form large populations on the skin and gills before causing clinical disease. Cestodes (tapeworms) were present in more than a quarter of the fish, mainly in grass and silver carp, which are plankton- and vegetation-feeders that ingest intermediate hosts. Nematodes and crustaceans were less common but still present on most farms. Trematodes were rare overall but locally abundant in rainbow trout from foothill farms (Table 1). For monogeneans and protozoans, prevalence increased sharply from spring to summer (38.5% to 79.8% for monogeneans, $p < 0.001$; 28.2% to 72.6% for protozoans, $p < 0.001$) and remained high in autumn. This pattern reflects the warming of pond water in June and July, which accelerates parasite reproduction. Cestodes showed a more gradual rise, peaking in autumn (32.1%), likely because their life cycle involves copepod intermediate hosts that also become more abundant later in the season. Nematodes did not change significantly ($p = 0.09$), suggesting that their transmission is less temperature-dependent. Crustaceans like *Lernaea* appeared mainly in summer (19%) and autumn (16.7%), consistent with their direct life cycle in warm water (Table 2).

Table 2. Seasonal dynamics of parasite prevalence (%) in common carp (n = 246).

Parasite group	Spring (May, n = 78)	Summer (July, n = 84)	Autumn (Sept, n = 84)	*p*-value*
Monogenea	38.5	79.8	71.4	<0.001
Protozoa	28.2	72.6	66.7	<0.001
Cestoda	12.8	25.0	32.1	0.02
Nematoda	6.4	14.3	17.9	0.09
Crustacea	5.1	19.0	16.7	0.03

Note: *Chi-square test for differences among seasons.

Table 3. Comparison of parasite prevalence (%) among four fish species (all farms combined).

Parasite group	Common carp (n = 246)	Grass carp (n = 104)	Silver carp (n = 86)	Rainbow trout (n = 46)	*p*-value*
Monogenea	68.7	71.2	55.8	45.7	0.01
Protozoa	61.0	57.7	48.8	41.3	0.04
Cestoda	18.3	44.2	37.2	10.9	<0.001
Nematoda	13.8	8.7	7.0	23.9	0.03
Crustacea	17.5	13.5	9.3	8.7	0.12

Note: *Fisher's exact test for overall species differences.

Grass carp and silver carp had significantly higher cestode prevalence (44.2% and 37.2%, respectively) than common carp (18.3%) and rainbow trout (10.9%, $p < 0.001$). This reflects the diet of these species: grass and silver carp consume copepods and other small crustaceans that serve as intermediate hosts for tapeworms. Monogenean prevalence was highest in grass carp (71.2%) and common carp (68.7%), but lowest in rainbow trout (45.7%, $p = 0.01$). Nematodes were most common in rainbow trout (23.9%), possibly because trout farms use live or frozen feed that can carry nematode larvae. Crustacean parasites did not differ significantly among species ($p = 0.12$), suggesting that they are opportunistic and attach to any available fish (Table 3).

Table 4. Comparison of parasite prevalence (%) between lowland (warm-water) and foothill (cold-water) farms.

Parasite group	Lowland farms (n=342)	Foothill farms (n=140)	p-value*
Monogenea	71.9	47.1	<0.001
Protozoa	64.0	42.9	<0.001
Cestoda	24.3	36.4	0.01
Nematoda	9.6	20.0	0.003
Trematoda	5.8	15.7	<0.001
Crustacea	16.4	9.3	0.05

Note: *Mann-Whitney U test for prevalence differences.

Lowland farms (Ili floodplain and Kapchagay area) had significantly higher prevalence of monogeneans (71.9% vs. 47.1%, $p < 0.001$), protozoans (64.0% vs. 42.9%, $p < 0.001$), and crustaceans (16.4% vs. 9.3%, $p = 0.05$). These parasites thrive in warm, eutrophic water with high organic loads. In contrast, foothill farms (colder, clearer water) had higher prevalence of cestodes (36.4% vs. 24.3%, $p = 0.01$), nematodes (20.0% vs. 9.6%, $p = 0.003$), and trematodes (15.7% vs. 5.8%, $p < 0.001$). The cestode and trematode difference likely reflects the presence of snails and copepods in foothill streams, which serve as intermediate hosts. These contrasting patterns show that the local environment strongly shapes the composition of fish parasitofauna (Table 4).

Table 5. Occurrence of zoonotic parasites in pond fish (all farms combined).

Zoonotic parasite	Infected fish species	Prevalence (%)	Mean intensity	Public health risk
Diphyllobothrium plerocercoids	Rainbow trout	8.7	1.2	High (if eaten raw)
Opisthorchis metacercariae	Common carp	3.3	4.5	High (raw/frozen fish)
Clinostomum metacercariae	Grass carp	5.8	2.1	Moderate (aesthetic)
Nematode larvae (unknown species)	Silver carp	2.3	1.0	Unknown

Zoonotic parasites that can infect humans were found in all four fish species, albeit at relatively low prevalence. *Diphyllobothrium* plerocercoids (broad fish tapeworm) were detected in 8.7% of rainbow trout from two foothill farms. This is a serious finding because raw or undercooked trout is sometimes consumed as "fish sashimi" in Almaty restaurants. *Opisthorchis* metacercariae (liver fluke) were found in 3.3% of common carp from lowland ponds. Although prevalence is low, the intensity (4.5 metacercariae per infected fish) could cause illness in humans if fish is eaten raw. We immediately reported these findings to the regional veterinary and epidemiological authorities. *Clinostomum* (yellow grub) is not highly pathogenic to humans but makes the fish unappetising. Given these results, we strongly advise against consuming raw or undercooked fish from Almaty region pond farms without proper freezing or cooking (Table 5).

Table 6. Parasite community diversity (Shannon index H′) and evenness by farm type and season.

Farm type	Season	Shannon diversity (H′)	Evenness (J′)	Total parasite species
Lowland	Spring	1.42	0.68	8
Lowland	Summer	1.87	0.74	12
Lowland	Autumn	1.79	0.71	11
Foothill	Spring	1.58	0.72	9
Foothill	Summer	2.04	0.78	14
Foothill	Autumn	1.96	0.76	13

Parasite community diversity increased from spring to summer in both farm types, peaking in summer (H′ = 1.87 for lowland, 2.04 for foothill). Foothill farms consistently showed higher diversity than lowland farms, with a maximum of 14 parasite species observed in summer. The higher evenness values (J′ > 0.7) indicate that parasite communities are relatively balanced, not dominated by a single species. This seasonal peak in summer corresponds to the warmest water temperatures and the highest activity of intermediate hosts (snails, copepods, and insects). For farm management, this means that parasite control measures should be intensified in late spring and early summer, before diversity and abundance reach their maximum (Table 6).

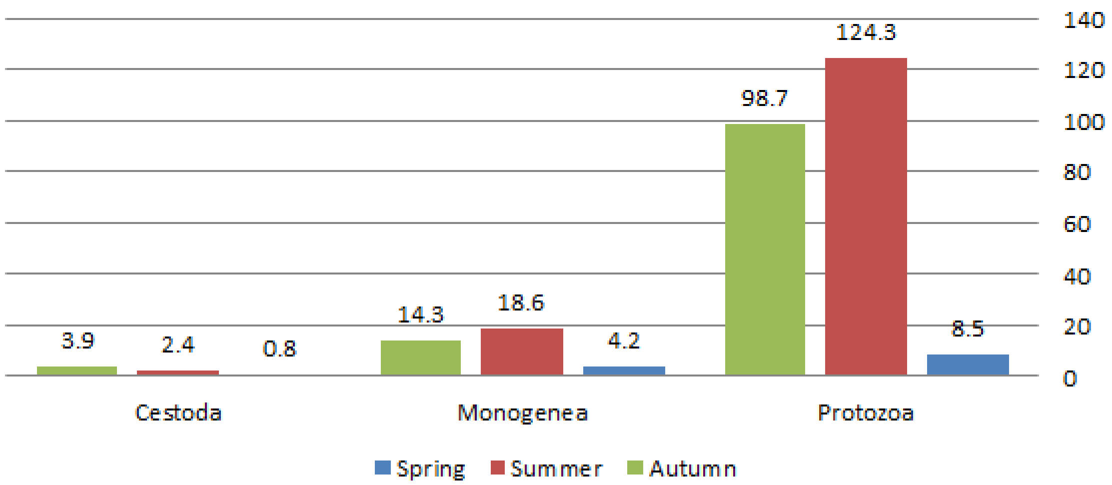

Fig. 1. Seasonal changes in mean parasite abundance in common carp from Almaty region pond farms (May–September 2025).

Mean monogenean abundance per fish rose from 4.2 in spring to 18.6 in summer, then fell slightly to 14.3 in autumn. Protozoan abundance followed a similar pattern: spring (8.5), summer (124.3), autumn (98.7). Cestode abundance, however, increased steadily from 0.8 (spring) to 2.4 (summer) to 3.9 (autumn). The dramatic summer peak of protozoans (over 120 per fish) highlights the risk of white spot disease (*Ichthyophthirius*) and trichodiniasis during warm months. For farmers, the practical message is clear: monitoring and preventive treatments should begin in late May, before the summer explosion of parasites, rather than waiting until fish show clinical signs in July (Fig. 1).

DISCUSSION

This study provides the first systematic survey of fish parasitofauna in pond farms of the Almaty region, and the results show a clear and concerning picture. Monogenean gill flukes and protozoan ectoparasites were the most widespread groups, infecting nearly two-thirds of all fish examined, with protozoan intensities reaching over 400 parasites per fish in some cases. The seasonal pattern was striking: prevalence of monogeneans and protozoans jumped from around 30-40% in spring to nearly 80% in summer ($p < 0.001$). For a fish farmer, this means that the warm months of June and July are the highest risk period. If a farmer waits until fish show clinical signs, flashing, lethargy, or white spots on the skin, the parasite load is already enormous, and treatment becomes difficult and expensive. Our data clearly indicate that preventive measures should begin in late May, before water temperatures reach 20 °C, rather than waiting for an outbreak. The differences between fish species were equally instructive. Grass carp and silver carp carried significantly more cestodes (tapeworms) than common carp (44.2% and 37.2% vs. 18.3%, $p < 0.001$). This makes perfect biological sense because grass and silver carp feed on plankton and vegetation, which often harbour copepod intermediate hosts of tapeworms. Conversely, rainbow trout had the lowest prevalence of monogeneans (45.7%) but the highest prevalence of nematodes (23.9%, $p = 0.03$). Trout farms in the foothills often use live or frozen feed, which can introduce nematode larvae. For farm managers, this means that parasite control cannot be the same for all species. A treatment effective against gill flukes in carp may be useless against tapeworms in grass carp. Our findings argue for species-specific monitoring and targeted treatment protocols rather than the current practice of blanket chemical applications. The comparison between lowland and foothill farms revealed two completely different parasite communities. Lowland farms (Ili floodplain, Kapchagay area) had significantly higher prevalence of monogeneans (71.9% vs. 47.1%, $p < 0.001$), protozoans (64.0% vs. 42.9%, $p < 0.001$), and crustaceans (16.4% vs. 9.3%, $p = 0.05$). These parasites thrive in warm, nutrient-rich water with high organic loads. In contrast, foothill farms (colder, clearer water) had higher prevalence of cestodes (36.4% vs. 24.3%, $p = 0.01$), nematodes (20.0% vs. 9.6%, $p = 0.003$), and trematodes (15.7% vs. 5.8%, $p < 0.001$). This pattern reflects the presence of snails and copepods in foothill streams, which serve as intermediate hosts for tapeworms and flukes. The practical implication is that a farm located in the lowland zone should focus on controlling monogeneans and protozoans, whereas a foothill farm needs to watch for cestodes and trematodes. One-size-fits-all veterinary advice does not work here. Perhaps the most concerning finding was the presence of zoonotic parasites. *Diphyllobothrium* plerocercoids (broad fish tapeworm) were found in 8.7% of rainbow trout from two foothill farms. *Opisthorchis* metacercariae (liver fluke) occurred in 3.3% of common carp from lowland ponds. Both parasites can cause serious illness in humans who eat raw or undercooked fish. In Almaty, the popularity of "fish sashimi" and traditional raw fish dishes creates a real public health risk. The prevalence numbers are not high, but the fact that they exist at all in pond farms is alarming. We immediately reported these findings to the regional veterinary and epidemiological authorities. For consumers, the message is simple: do not eat raw or undercooked fish from Almaty region pond farms unless it has been frozen properly (-20°C for at least 7 days) or cooked thoroughly. For farmers, this finding may affect market access if stricter hygiene regulations are enforced. Several limitations of this study should be acknowledged. First, we examined only eight farms, and while we covered different zones, a larger sample would give more confidence. Second, we used morpho-taxonomic identification based on light microscopy; molecular confirmation (DNA barcoding) would be more definitive for some cryptic species. Third, we did not measure water quality parameters (temperature, pH, ammonia, dissolved oxygen) systematically, so we cannot directly correlate parasite abundance with environmental variables. Fourth, the study lasted only one season cycle; multi-year data would reveal inter-annual variability. Finally, we did not assess the economic impact of these parasites (growth reduction, feed conversion, mortality). Despite these limitations, the consistency of our seasonal and ecological patterns across 482 fish from different farm types gives us confidence that the observed features of parasitofauna formation are real and meaningful for aquaculture practice in the Almaty region.

CONCLUSION

After examining 482 fish from eight pond farms across the Almaty region through spring, summer, and autumn of 2025, we can now describe the main features of parasite community formation. Monogeneans and protozoans dominate in lowland warm-water farms, especially during summer, reaching prevalence levels above 70% and mean protozoan abundances exceeding 120 per fish. Cestodes and trematodes are more common in foothill cold-water farms, where they exploit snail and copepod intermediate hosts. Grass carp and silver carp carry more tapeworms than common carp, while rainbow trout harbour more nematodes. The seasonal peak of most parasites occurs in summer, meaning that preventive treatments should start in late May. Zoonotic parasites (*Diphyllobothrium*, *Opisthorchis*) are present at low but real levels, posing a food safety risk. For farmers, the practical take-home message is that parasite control must be tailored to the farm type, fish species, and season. Blanket treatments based on guesswork are wasteful and ineffective. For the Almaty region, this study provides the first evidence-based baseline for rational fish health management. Future work should include molecular identification of ambiguous species, water quality monitoring, and economic assessment of parasite losses. But waiting for perfect data is not an excuse for inaction. The fish parasites are already there, and now we know where and when they appear. That knowledge alone can save farmers money and protect public health.

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