



Parasite Fauna of Chub *Squalius cephalus* (L., 1758) (Actinopterygii: Leuciscidae) from a Stream System in Kocaeli Province, Türkiye

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Abstract: The parasite fauna of chub *Squalius cephalus* from the Kaytazdere-Yalakdere stream systems, Sea of Marmara basin, Türkiye, was investigated. Totally, four digenean species (*Clinostomum complanatum*, *Tylodelphys clavata*, *Posthodiplostomum* sp. and *Ichthyocotylurus* sp.), one nematode species (*Rhabdochona denudata*), one monogenean species (*Dactylogyrus nanus*) and two myxosporean species (*Myxobolus* sp. 1 and *Myxobolus* sp. 2) were identified. Overall infection prevalence, mean intensity and mean abundance were 87.0%, 22.1 ± 2.5, 16.2 ± 2.0, respectively. *Myxobolus* sp. 2 was the most prevalent parasite species, followed by *Myxobolus* sp. 1 and *C. complanatum*. *Dactylogyrus nanus* was the most abundant parasite species, followed by *C. complanatum* and *Ichthyocotylurus* sp. The species *Thylodelphys clavata*, *Posthodiplostomum* sp., *Ichthyocotylurus* sp., *Myxobolus* sp. 1 and *Myxobolus* sp. 2 are new parasite records for *S. cephalus* as well as new geographical records in Türkiye.

Key words: Kocaeli, Digenea, Monogenea, Nematoda, Myxozoa

Introduction

The order Cypriniformes is the largest among the teleost fishes, with about 4.500 species, which are common in freshwaters, brackish waters and marine waters (CARROLL 1988, COLBERT & MORALES 1991). The subfamily Leuciscinae includes 324 valid species in the world and 121 native species widespread in Turkish waters (GELDIAY & BALIK 1999, Fricke et al. 2007, 2022, ÇIÇEK et al. 2020). The genus *Squalius* Bonaparte, 1837 consists of 20 valid species, including the chub *Squalius cephalus* (L., 1758), in Turkish waters. It has a wide distribution area, comprising the Baltic Sea, Black Sea, Mediter-

ranean Sea and Atlantic Ocean basins; it is one of the economically significant target freshwater fish species in Türkiye (TUIK 2020, FROESE et al. 2021).

Parasites have an important place among the sources of diseases in aquatic habitats. Until now, 35 parasite species (11 monogenean, 5 nematode, 4 digenean, 3 acanthocephalan, 8 cestode, 3 crustacean and 1 mollusc species) have been reported as parasites of *S. cephalus* from Türkiye (Table 1). However, comprehensive studies on the parasite fauna in the context of the ecological features of the chub have still been not completed so far. Thus, this study aimed to identify the parasitic fauna of *S. cephalus* from Yalakdere-Kaytazdere streams flowing into the

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Table 1. Parasite species reported in chub from different regions in Türkiye

Parasite Species	Region	Source
MONOGENEA		
<i>Dactylogyrus nanus</i> Dogiel & Bychowsky, 1934	Kaytazdere-Yalakdere Stream System	Present study
	Doğancı Dam Lake	Aydoğdu (2001)
	Susurluk Stream	Gürkan & Tekin Özcan (2012)
<i>D. elegantis</i> Gusev, 1966	Eastern Anatolia Region,	Koyun (2011)
<i>D. extensus</i> Mueller & Van Cleave, 1932	Hazar Lake	Aksoy et al. (2006)
<i>D. naviculoides</i> Ergens, 1960	Almus Dam Lake	Develi (2008)
	Almus Dam Lake	Turgut Neary et al. (2012)
<i>D. prostaе</i> Molnár, 1964	Murat River	Koyun (2011)
<i>D. vistulae</i> Prost, 1957	Almus Dam Lake	Develi (2008)
	Murat River	Koyun (2011)
	Almus Dam Lake	Turgut Neary et al. (2012)
	Doğancı Dam Lake	Aydoğdu (2001)
	Susurluk Stream	Gürkan & Tekin Özcan (2012)
	Orenler Dam Lake	Kurupınar & Öztürk (2009)
	Serban Dam Lake	Açıkkel & Öztürk (2011)
	Serban Dam Lake	Açıkkel (2011)
	Taşoluk Dam Lake	Yazmen (2012)
	Taşoluk Dam Lake	Yazmen & Öztürk (2014)
<i>Gyrodactylus prostaе</i> Ergens, 1964	Taşoluk Dam Lake	Yazmen (2012)
<i>G. scardiniensis</i> Glaser, 1974	Taşoluk Dam Lake	Yazmen (2012)
<i>Gyrodactylus</i> sp.	Serban Dam Lake	Açıkkel (2011)
<i>Paradiplozoon homoion</i> (Bychowsky & Nagibina, 1959)	Büyükçekmece Dam Lake	Yardımcı et al. (2018)
<i>Paradiplozoon Megan</i> (Bychowsky & Nagibina, 1959)	Doğancı dam Lake	Aydoğdu (2001)
	Susurluk Stream	Gürkan & Tekin-Ozan (2012)
DIGENEA		
<i>Clinostomum complanatum</i> (Rudolphi, 1814)	Kaytazdere-Yalakdere Stream System	Present study
	Central Anatolia Region	Şimşek et al. (2018)
<i>Tylodelphys clavata</i> (von Nordmann, 1832)	Kaytazdere-Yalakdere Stream System	Present Study
<i>Posthodiplostomum cuticola</i> (von Nordmann, 1832)	Kayseri Fish Market	Şimşek et al (2020)
<i>Posthodiplostomum</i> sp.	Kaytazdere-Yalakdere Stream System	Present study
<i>Ichthyocotylurus</i> sp.	Kaytazdere-Yalakdere Stream System	Present study
<i>Diplostomum</i> sp.	Orenler Dam Lake	Kurupınar & Öztürk (2009)
<i>Diplostomum</i> sp.	Keban Dam Lake	Dörücü & Ispir (2005)
<i>Diplostomum</i> sp.	Almus Dam Lake	Turgut & Özgül (2012)
<i>Allocreadium isoporum</i> (Looss, 1894)	Enne Dam Lake	Koyun (2001)
	Doğancı Dam Lake	Aydoğdu (2001)
	Taşoluk Dam Lake	Yazmen (2012)
CESTODA		
<i>Biacetabulum appendiculatum</i> Szidat, 1972	Serban Dam Lake	Açıkkel (2011)
	Serban Dam Lake	Açıkkel Yiğit & Öztürk (2016)
<i>Bothriocephalus acheilognathi</i> Yamaguti, 1934	Doğancı Dam Lake	Aydoğdu (2001)
	Orenler Dam Lake	Kurupınar & Öztürk (2009)
	Serban Dam Lake	Açıkkel (2011)
	Serban Dam Lake	Açıkkel & Öztürk (2011)
	Kunduzlar Dam Lake	Öztürk (2011)
	Karakaya Dam Lake	Örün et al. (2003)

Parasite Species	Region	Source
<i>Bothriocephalus</i> sp.	Taşoluk Dam Lake	Yazmen (2012)
<i>Caryophyllaeus brachycollis</i> Janiszewska, 1953	Serban Dam Lake	Açıkel (2011)
	Serban Dam Lake	Açıkel & Öztürk (2011)
	Serban Dam Lake	Açıkel Yiğit & Öztürk (2016)
<i>Caryophyllaeus laticeps</i> (Pallas, 1781)	Büyükçekmece Dam Lake	Yardımcı et al. (2018)
<i>Khawia armeniaca</i> (Cholodkovsky, 1915)	Karakaya Dam Lake	Örün et al. (2003)
<i>Ligula intestinalis</i> (Linnaeus, 1758) Gmelin, 1790	Almus Dam Lake	Develi (2008)
	Orenler Dam Lake	Kurupınar & Ozturk (2009)
	İvrindi Yeşilköy Pond	Bulgen (1999)
	Balıkesir Çaraplıpatlak Dam Lake	Torcu-Koç et al. (2006)
	Çamkoru Pond	Innal & Keskin (2006)
	Çamkoru Pond	Innal et al. (2010)
	Menzelet Dam Lake	Özcan et al. (2019)
	Kunduzlar Dam Lake	Özbek & Öztürk (2010)
<i>Proteocephalus</i> sp.	Almus Dam Lake	Turgut et al. (2011)
<i>Proteocephalus</i> sp.	Kunduzlar Dam Lake	Öztürk (2011)
NEMATODA		
<i>Rhabdochona denudata</i> (Dujardin, 1845)	Kaytazdere-Yalakdere Stream System	Present study
	Doğancı Dam Lake	Aydoğdu (2001)
<i>Eustrongylides excisus</i> Jägerskiöld, 1909	Büyükçekmece Dam Lake	Yardımcı et al. (2018)
<i>Eustrongylides</i> sp.	Susurluk Stream	Gürkan & Tekin Özcan (2012)
<i>Philometra ovata</i> (Zeder, 1803)	Enne Dam Lake	Koyun (2001)
	Seydisu Stream	Keskin (1988)
	Çamkoru Lake	Innal & Keskin (2005)
<i>Kalmanmolnaria intestinalis</i> (Dogiel & Bychowsky, 1934)	Yamula Dam Lake	Kılınçaslan (2007)
ACANTHOCEPHALA		
<i>Neoechinorhynchus (Neoechinorhynchus) rutili</i> (Müller, 1780)	Menzelet Dam Lake	Özcan et al. (2019)
	Murat River	Gül et al. (2017)
<i>Pomphorhynchus laevis</i> (Zoega in Müller, 1776)	Enne Dam Lake	Koyun (2001)
	Örenler Dam Lake	Kurupınar & Öztürk (2009)
<i>Pomphorhynchus</i> sp.	Aras River	Aslan (2009)
CRUSTACEA		
<i>Lernaea cyprinacea cyprinacea</i> Linnaeus, 1758	Üzünlü Lake	Erbatur et al. (2018)
<i>Lamproglena</i> sp.	Almus Dam Lake	Develi (2008)
<i>Argulus foliaceus</i> (Linnaeus, 1758)	Serban Dam Lake	Açıkel (2011)
	Serban Dam Lake	Açıkel & Öztürk (2011)
	Serban Dam Lake	Açıkel & Öztürk (2013)
MOLLUSCA		
Glochidia (larvae)	Sakarya River	Akmırza & Yardımcı (2014)
CNIDARIA		
<i>Myxobolus</i> sp. 1	Kaytazdere-Yalakdere Stream System	Present study
<i>Myxobolus</i> sp. 2	Kaytazdere-Yalakdere Stream System	Present study

Gulf of İzmit (Sea of Marmara) for the first time and to determine the infection descriptors with respect to the seasonal and host factors.

Materials and Methods

Yalakdere (40°39'50"N, 29°34'12"E - 40°36'19"N, 29°31'53"E) – Kaytazdere (40°41'06"N, 29°31'17"E, 40°39'26"N, 29°27'51"E) stream systems flow into the Sea of Marmara, Türkiye, and are located in the border of Kocaeli and Yalova provinces (Fig. 1). Totally, 147 chub *S. cephalus* were collected by local fishermen either by angling or scattering net in the period between May 2020 – June 2021. Fish were transported to the laboratory in dry ice box. Parasitological investigation was conducted at the Faculty of Agriculture at Kocaeli University in Kocaeli. All fish were weighed, total length measured and their sex was determined at post-mortem. The specimens in the samples were allocated to three length classes: ≤ 11.8 cm (Class I), 11.9–14.5 cm (Class II), and ≥ 14.6 cm (Class III). Dissections were executed using a dissecting microscope at magnifications up to x40 and x20 using standard parasitological techniques. Gills, fins, skin, urinary bladder, gall bladder, kidney, stomach, muscle, liver, intestine, gonads, mandible, chin, eye, mouth and brain of the fish were examined for ecto- and endoparasites within 48 h of capture. Parasite preparations were conducted according to methods indicated by PARADIZNIK & RADUKOVIC (2007) for the digeneans, MORAVEC & MUZZALL (2007) for the nematodes, LOM & DYKOVA (1992) for the myxosporeans and MALMBERG (1957) for the monogeneans. Parasite species, some of which at the generic level were identified using a Primostar FN 18 Carl Zeiss and Olympus BX51 light microscope. The parasite identification was realised according to the keys given by LOM & DYKOVA (1992) for myxozoans; YAMAGUTI (1963a) and MORAVEC (1994) for nematodes; BYKHOVSKAYA-PAVLOVSKAYA et al. (1964) and YAMAGUTI (1963b) for the monogenean; BYKHOVSKAYA-PAVLOVSKAYA & KULAKOVA (1987), MATTHEIS & ODENING (1980), MATTHEWS & CRIBB (1998), GIBSON et al. (2002) for the digeneans and other related publications. Calculation of infection prevalence (%), mean intensity and abundance values follow the definition given by BUSH et al. (1997). However, the overall mean intensity and mean abundance were calculated by excluding the myxosporeans as they were in numerous plasmodia forms. The intensity of infection of myxozoans was calculated according to GÜRKANLI et al. (2018).

Kruskal–Wallis test (nonparametric analysis of variance, ANOVA) was performed to find sig-



Fig. 1. Sampling areas in the Yalakdere – Kaytazdere streams system

nificant differences in the mean intensity values of parasites for fish length classes, sex and seasons. Mann-Whitney U test was applied to the pairs that made up the difference. All statistical analyses were performed at the significance value $P \leq 0.05$ using the statistical program IBM SPSS 28.

Results

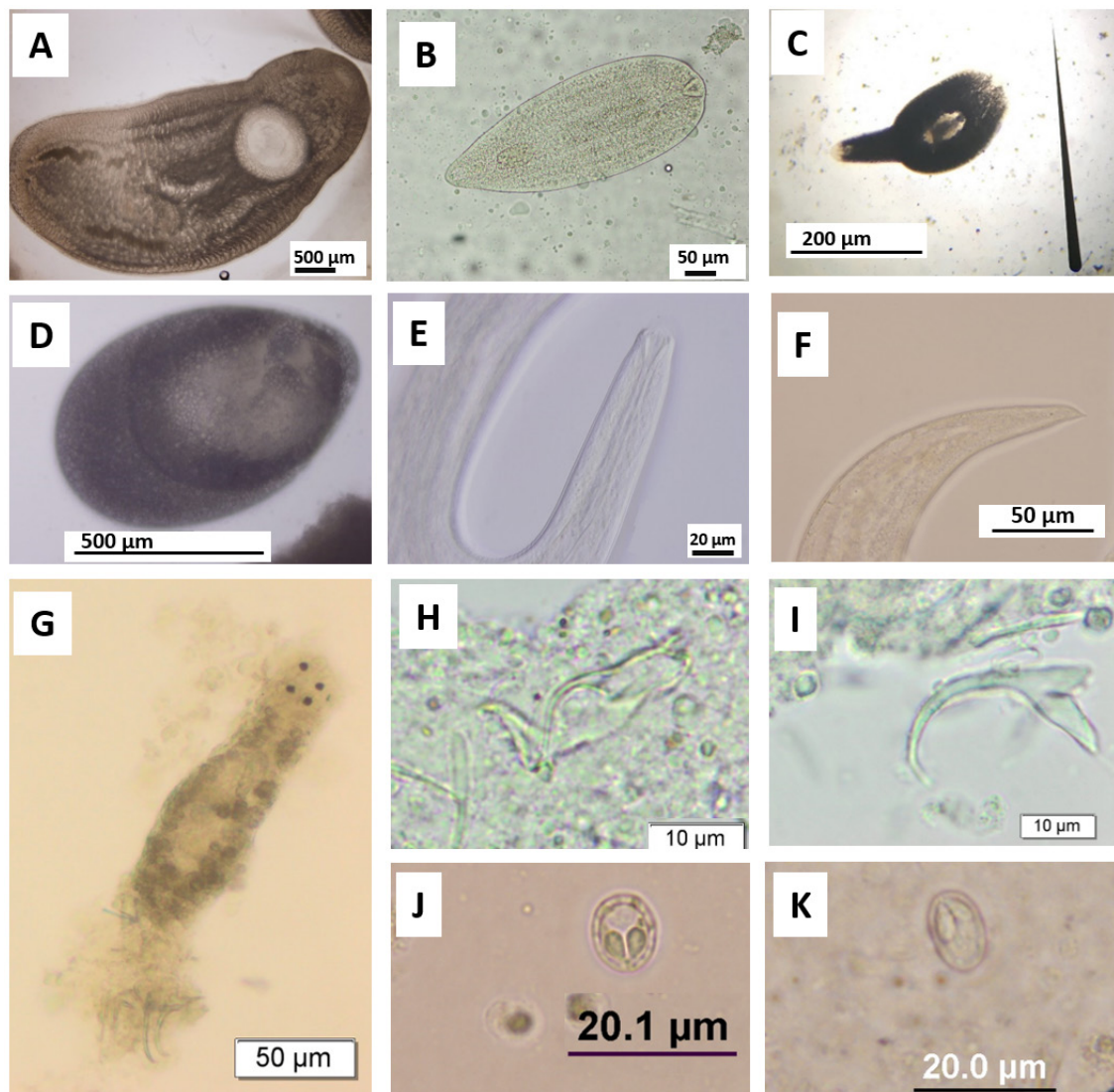
Eight parasite species comprising four digeneans, one monogenean, one nematode and two myxosporeans were identified from *S. cephalus*. These are *Clinostomum complanatum* (Rudolphi, 1814) Braun, 1899 (Fig. 2A), *Tylodelphys clavata* (von Nordmann, 1832) Diesing, 1850 (Fig. 2B), *Posthodiplostomum* sp. (Fig. 2C), *Ichthyocotylurus* sp. (Fig. 2D), *Rhabdochona denudata* (Dujardin, 1845) Railliet, 1916 (Fig. 2E, F), *Dactylogyrus nanus* Dogiel & Bychowsky, 1934 (Fig. 2G, H, I), *Myxobolus* sp.1 (Fig. 2J) and *Myxobolus* sp. 2 (Fig. 2K). The microhabitat, infection prevalence, mean intensity and mean abundance of the studied parasite species are provided in Table 2. Of them, the most prevalent parasite was *Myxobolus* sp. 2, *D. nanus* was the most intensive and abundant parasite species. Considering the parasite burden at the infracommunity level, it can be seen that the chub was mostly infected with two parasite species (Fig. 3).

The distribution of chub parasites with respect to season

The seasonal variations of the current infections are represented in Table 3. All parasite species, except *Posthodiplostomum* sp., which was found only in autumn, were presented in all seasons (Table 3). The overall seasonal infection prevalence was highest

Table 2. The overall infection prevalence (%), mean intensity and mean abundance, as well as the microhabitat of parasites from Yalakdere-Kaytazdere streams system in Kocaeli, Türkiye (SE=standard error)

Parasite species	Microhabitat	Prevalence (%)	Mean intensity \pm S.E	Mean abundance \pm S.E
<i>Clinostomum complanatum</i>	Operculum, mandible, muscle	50.3	12.0 \pm 1.4	6.1 \pm 0.8
<i>Tylodelphys clavata</i>	Eye	7.5	1.3 \pm 0.1	0.09 \pm 0.02
<i>Posthodiplostomum</i> sp.	Eye	0.7	1.0 \pm 0.0	0.006 \pm 0.006
<i>Ichthyocotylurus</i> sp.	Body cavity, stomach – intestine	21.0	9.6 \pm 3.5	2.0 \pm 0.8
<i>Dactylogyrus nanus</i>	Gills	40.8	18.5 \pm 2.8	7.6 \pm 1.4
<i>Rhabdochona denudata</i>	Stomach-intestine	17.0	3.0 \pm 0.8	0.5 \pm 0.1
<i>Myxobolus</i> sp. 1	Gills	51.0	2+	-
<i>Myxobolus</i> sp. 2	Kidney	63.9	2+	-
Overall (n=147)		87.0	22.1 \pm 2.5*	16.2 \pm 2.0*

* Excluding *Myxobolus* sp. 1 and *Myxobolus* sp. 2**Fig. 2.** Parasite species identified in *Squalius cephalus*: (A) *Clinostomum complanatum*, (B) *Tylodelphys clavata*, (C) *Posthodiplostomum* sp., (D) *Ichthyocotylurus* sp., (E) anterior view of *Rhabdochona denudata*, (F) posterior view of *R. denudata*, (G) *Dactylogyrus nanus*, (H) copulatory organ of *D. nanus*, (I) attachment apparatus of *D. nanus*, (J) *Myxobolus* sp. 1, (K) *Myxobolus* sp. 2

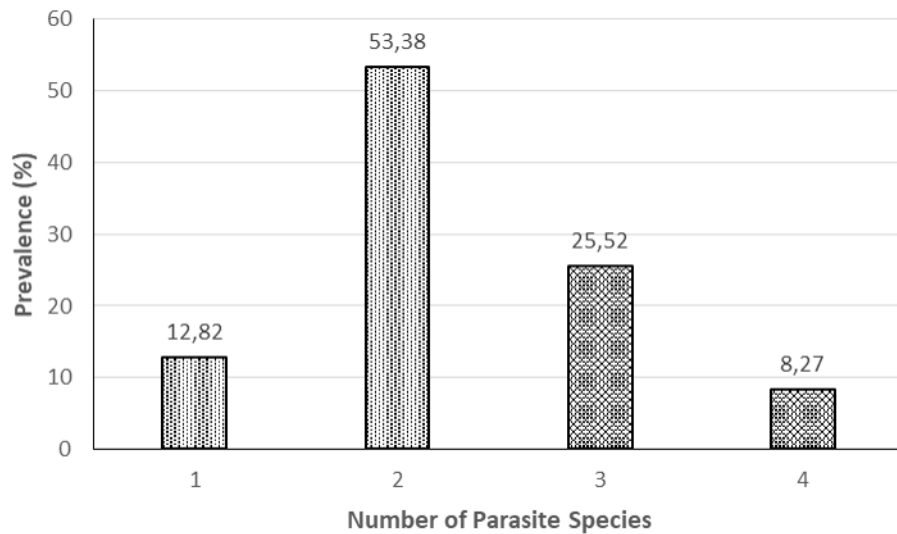


Fig. 3. Infection prevalence (%) with respect to the number of parasite species detected in the chub during the investigation period

in summer (100.0%), followed by autumn (95.0%), winter (77.7%), and spring (72.5%). Thus, most of the parasites were most prevalent in summer (Table 3). In addition, our analysis shows the presence of statistically significant seasonal differences ($p \leq 0.05$) in the infection characteristics (Table 3).

Distribution of parasites in relation to host length classes

A gradual increase in the infection characteristics as the length classes of fish increases was found. The maximum infection characteristics were at the Class III. The statistical analysis of the overall mean intensity by fish size classes shows statistically significant differences ($p \leq 0.05$). Details for individual parasite species were presented in Table 4.

Distribution of parasites in relation to host sex

The distribution of all parasites on male, female and unidentified sex of fish was calculated and the prevalence of infection was highest in female, followed by male and unidentified sex of fish (Table 5). Similarly, overall mean intensity values followed the same pattern, without any statistically significant difference ($p > 0.05$) (Table 5).

Discussion

Chub *S. cephalus* is known as a host of a wide variety of parasite species, monogeneans, digeneans, cestodes, nematodes, crustaceans, molluscs and acanthocephalans from Türkiye (Table 1). This study expanded the current parasite list with three digenean trematodes (*T. clavata*, *Ichthyocotylurus* sp. and *Posthodiplostomum* sp.), and two myxozoan

species (*Myxobolus* sp. 1, *Myxobolus* sp. 2) from a new host record in Türkiye. The Yalakdere – Kaytazdere streams system in the Marmara region of Türkiye is also a new geographical record for all parasite species found in the present study.

The dominating digenean *C. complanatum* has previously been reported from the operculum and the gill lamellae of *S. cephalus* (2.5%), *Scardinius erythrophthalmus* (L., 1758), *Sander lucioperca* (L., 1758), *Rhodeus amarus* (Bloch, 1782), *Lepomis gibbosus* (L., 1758), *Perca fluviatilis* L., 1758, *Rutilus rutilus* (L., 1758), *Alburnus alburnus* (L., 1758) and *Aphanius danfordii* (Boulenger, 1890), with varying infection descriptors in different localities in Türkiye (BURGU et al. 1988, ÇOLAK 2013, SOYLU 2013, 2014, ÖZER & ÖZTÜRK 2015, ŞİMŞEK et al. 2018, AYDOĞDU et al. 2020). In the present study, however, this parasite species has also been found in the mandible and muscle tissue of *S. cephalus*, which are new microhabitats for this species. The overall infection descriptors of this parasite (Table 2) are higher than those reported from all fish host species mentioned above by the respective authors. Furthermore, HARA et al. (2014) reported that the consumption of raw infected fish might cause parasitic laryngitis in humans. Therefore, more studies are needed on this parasite and fish.

Of the other digeneans, *T. clavata* has been reported in a wide variety of host fish species (ÖZER 2021). The present study is a new record of *T. clavata* as a parasite of *S. cephalus* from Türkiye. The prevalence and mean intensity (Table 2) were lower compared with the previous reports from *L. gibbosus*, *S. erythrophthalmus*, *P. fluviatilis*, *R. rutilus*, *Abramis*

Table 3. Infection prevalence (%), mean intensity (MI), and mean abundance (MA) values according to seasons throughout the sampling period in the Yalakdere-Kaytazdere stream system (SE=standart error)

Sampling periods	Summer (n=40) (23.0-26.0)			Autumn (n=40) (20.5-21.0)			Winter (n=27) (8.0-10.0)			Spring (n=40) (12.0-15.0)		
	P (%)	MI ± S.E	MA ± S.E	P (%)	MI ± S.E	MA ± S.E	P (%)	MI ± S.E	MA ± S.E	P (%)	MI ± S.E	MA ± S.E
Temperature range												
Parasite species	77.5	17.1 ± 3.0 ^a	13.2 ± 3.0	45.0	7.1 ± 1.0 ^{bcd}	7.1 ± 0.7	25.9	5.2 ± 0.8 ^c	1.3 ± 0.4	45.0	10.8 ± 1.7 ^{ad}	4.9 ± 0.6
<i>C. complanatum</i>	2.5	1.0 ± 0.0 ^a	0.02 ± 0.02	15.0	1.5 ± 0.2 ^a	0.22 ± 0.09	11.1	1.0 ± 0.0 ^a	0.11 ± 0.06	2.5	1.0 ± 0.0 ^a	0.025 ± 0.025
<i>T. clavata</i>	0.0	0.0 ± 0.0 [*]	0.0 ± 0.0	2.5	1.0 ± 0.0 [*]	0.02 ± 0.02	0.0	0.0 ± 0.0 [*]	0.0 ± 0.0	0.0	0.0 ± 0.0 [*]	0.0 ± 0.0
<i>Posthodiplostomum</i> sp.	35.0	13.5 ± 7.4 ^a	4.7 ± 2.7	20.0	9.0 ± 3.9 ^a	1.8 ± 0.9	11.1	2.0 ± 0.0 ^a	2.2 ± 0.1	15.0	5.1 ± 1.0 ^a	0.7 ± 0.3
<i>Ichthyocotylurus</i> sp.	90.0	22.5 ± 4.3 ^a	20.2 ± 4.0	37.5	10.3 ± 3.3 ^a	3.8 ± 1.4	11.1	12.0 ± 1.5 ^a	1.3 ± 0.7	15.0	18.8 ± 1.7 ^a	2.8 ± 1.1
<i>D. nanus</i>	30.0	3.3 ± 0.7 ^a	1.00 ± 0.32	17.5	3.8 ± 2.6 ^b	0.67 ± 0.50	11.1	1.0 ± 0.0 ^b	0.11 ± 0.06	7.5	1.6 ± 0.3 ^{ab}	0.12 ± 0.07
<i>R. denudata</i>	72.5	3+	-	65.0	2+	-	37.0	2+	-	25.0	2+	-
<i>Myxobolus</i> sp. 1	90.0	2+	-	92.0	2+	-	40.7	1+	-	25.0	1+	-
<i>Myxobolus</i> sp. 2	100.0	40.3 ± 5.6 ^a	39.3 ± 5.5	95.0	13.1 ± 2.5 ^b	9.8 ± 2.0	77.7	6.0 ± 1.6 ^c	3.1 ± 1.0	72.5	13.9 ± 2.5 ^{db}	8.7 ± 1.9
Overall												

There is no significant difference between the values with superscript indices represented by the same letter. *Insufficient number of values for statistical analyses.

Table 4. Infection prevalence (%), mean intensity (MI) and mean abundance (MA) of all parasite species according to length classes of fish from the Yalakdere-Kaytazdere streams system in Kocaeli, Türkiye (SE=standard error).

Fish length classes	Class I ≤ 11.8 cm (n=43)			Class II 11.9-14.5 cm (n=60)			Class III ≥ 14.6 cm (n=44)		
	P (%)	MI ± S.E	MA ± S.E	P (%)	MI ± S.E	MA ± S.E	P (%)	MI ± S.E	MA ± S.E
Parasite Species									
<i>C. complanatum</i>	25.6	6.8 ± 1.4 ^a	1.7 ± 0.5	53.3	8.9 ± 1.3 ^a	4.7 ± 0.9	70.5	17.1 ± 2.9 ^b	12.1 ± 2.3
<i>T. clavata</i>	9.3	1.2 ± 0.2 ^a	0.11 ± 0.05	5.0	1.3 ± 0.3 ^a	0.06 ± 0.04	9.0	1.2 ± 0.2 ^a	0.11 ± 0.05
<i>Posthodiplostomum</i> sp.	0.0	0.0 ± 0.0 [*]	0.00 ± 0.00	0.0	0.0 ± 0.0 [*]	0.00 ± 0.00	2.2	1.0 ± 0.0 [*]	0.02 ± 0.02
<i>Ichthyocotylurus</i> sp.	13.9	5.5 ± 1.4 ^a	0.7 ± 0.3	21.6	15.0 ± 8.3 ^a	3.2 ± 1.9	27.3	5.8 ± 0.9 ^a	1.6 ± 0.4
<i>D. nanus</i>	13.9	4.1 ± 1.1 ^a	0.5 ± 0.2	36.7	10.1 ± 1.7 ^a	3.7 ± 0.8	72.7	27.0 ± 4.6 ^b	19.6 ± 3.8
<i>R. denudata</i>	9.3	1.0 ± 0.0 ^a	0.09 ± 0.04	15.0	3.6 ± 2.0 ^{ab}	0.55 ± 0.34	27.3	3.1 ± 0.7 ^b	0.86 ± 0.29
<i>Myxobolus</i> sp. 1	53.4	2+	-	43.3	2+	-	59.0	2+	-
<i>Myxobolus</i> sp. 2	69.7	2+	-	50.0	2+	-	77.2	1+	-
Overall (n=147)	81.4	6.5 ± 1.2 ^a	3.3 ± 0.8	83.3	16.5 ± 3.2 ^b	12.4 ± 2.5	97.7	36.9 ± 4.9 ^c	34.3 ± 4.8

There is no significant difference between the values with superscript indices represented by the same letter. *Insufficient number of values for statistical analyses.

Table 5. Infection prevalence (%), mean intensity (MI), and mean abundance (MA) of all parasite species according to the sex of fish from the Yalakdere-Kaytazdere streams system in Kocaeli, Türkiye (SE=standard error).

Parasite Species	Female (n=67)			Male (n=68)			Unidentified (n=12)		
	P (%)	MI ± S.E	MA ± S.E	P (%)	MI ± S.E	MA ± S.E	P (%)	MI ± S.E	MA ± S.E
<i>C. complanatum</i>	58.2	11.7 ± 1.4 ^a	6.8 ± 1.1	44.1	13.1 ± 3.0 ^a	5.7 ± 1.5	41.6	8.4 ± 3.8	3.5 ± 1.9
<i>T. clavata</i>	7.4	1.4 ± 0.2 ^a	0.10 ± 0.04	7.3	1.2 ± 0.2 ^a	0.08 ± 0.04	8.3	1.0 ± 0.0	0.08 ± 0.08
<i>Posthodiplostomum</i> sp.	1.5	1.0 ± 0.0 [*]	0.01 ± 0.01	0.0	0.0 ± 0.0 [*]	0.0 ± 0.0	0.0	0.0 ± 0.0 [*]	0.0 ± 0.0
<i>Ichthyocotylurus</i> sp.	17.9	4.4 ± 0.6 ^a	0.7 ± 0.2	26.4	13.5 ± 5.9 ^a	3.5 ± 1.7	8.3	2.0 ± 0.0	0.1 ± 0.1
<i>D. nanus</i>	50.7	21.9 ± 4.5 ^a	11.1 ± 2.6	36.7	12.9 ± 2.1 ^a	4.7 ± 1.1	8.3	41.0 ± 0.0	3.4 ± 3.4
<i>R. denudata</i>	20.8	2.3 ± 0.6 ^a	0.4 ± 0.1	11.7	4.6 ± 2.2 ^a	0.5 ± 0.3	25.0	1.6 ± 0.6	0.4 ± 0.2
<i>Myxobolus</i> sp. 1	55.2	2+	-	50.0	2+	-	33.3	2+	-
<i>Myxobolus</i> sp. 2	64.1	2+	-	67.6	2+	-	41.6	1+	-
Overall (n=147)	91.0	24.5 ± 3.8 ^a	19.4 ± 3.2	83.8	21.0 ± 3.8 ^a	14.8 ± 2.9	83.3	13.0 ± 9.0	7.5 ± 5.4

There is no significant difference between the values with superscript indices represented by the same letter. *Insufficient number of values for statistical analyses.

brama (L., 1758), *Esox lucius* L., 1758, *Silurus glanis* L., 1758, *S. lucioperca* (L., 1758), *Blicca bjoerkna* (L., 1758) and *Squalius carinus* Özuluğ & Freyhof, 2011 (Çolak 2013, SOYLU 1995, 2013, 2014, Öztürk et al. 2011, SOYLU et al. 2017). However, they were higher than those from *Alburnus istanbulensis* Battalgi, 1941, *C. carpio* L., 1758, *Vimba vimba* (L., 1758), *Tinca tinca* (L., 1758) from Türkiye (SOYLU 2003, ÖZTÜRK et al. 2011, ŞİMŞEK 2013). In the present study, *Posthodiplostomum* Dubois, 1936 and *Ichthyocotylurus* Odening, 1969 parasites were identified to generic level only. Previously three *Posthodiplostomum* spp. and one *Ichthyocotylurus* species were reported from other host fish species in Türkiye (ÖZER 2021). The prevalence and mean intensity values of our *Posthodiplostomum* sp. were very low (Table 2) and lower than those previously reported for *P. cuticula* (von Nordmann, 1832) from *B. bjoerkna*, *Cobitis turcica* Hankó, 1925, *S. erythrophthalmus*, *R. rutilus* and *V. vimba* (UZUNAY & SOYLU 2006, SOYLU 2014, KIRANKAYA & EKMEKÇI 2011, ALTAN & SOYLU 2018). The infection prevalence and mean intensity values of our *Ichthyocotylurus* sp. (21% and 9.6 ± 3.5) were higher than that of the previously reported for *Ichthyocotylurus variegatus* (Creplin, 1825) from *S. erythrophthalmus* (0.02% and 5.0) (KAHVECİ 2004).

Digeneans have a complex life cycle with more than one host and the differences in the infection characteristics could be related to several factors such as host hibernation, spawning and maturity, changes in the immune response at different temperatures and ages and the feeding habits of the host (ROHDE 1993, ÖZER & ÖZTÜRK 2005, KOPRIVNIKAR & POULIN 2009, KOPRIVNIKAR et al. 2010). KOPRIVNIKAR et al. (2010) explained the seasonal variations by changes in hydrological conditions such as the temperature, which influence the abundance and distribution of free-living stages of the parasites and the completion of the digenean life cycle. In our study, we believe that especially the temperature could be one of the triggering factors for the fish host feeding on infected intermediate hosts, causing differences in the prey seasonal occurrences, directly affecting the infection characteristics in *S. cephalus*. The highest infection characteristics of all digenean species found were in the Class III of the fish hosts. This can be linked to a longer period of infected prey availability and a greater probability that the largest *S. cephalus* encounter higher amount of parasites (KRIST & LIVELY 1998).

Monogeneans are generally known to be restricted to a particular host species (ÖZER & ÖZTÜRK 2005). GIBSON et al. (1996) reported that *D. nanus* was specifically found on the fish genera *Abramis*

Cuvier, 1816, *Alburnus* Rafinesque, 1820, *Blicca* Heckel, 1843, *Leuciscus* Cuvier, 1816, *Rutilus* Rafinesque, 1820, *Sarcocheilichthys* Bleeker, 1860 and *Varicorhinus* Rüppell, 1835. It has previously been reported from the gills of *S. cephalus* (Syn. *Leuciscus cephalus*) from two different localities in Türkiye (AYDOĞDU 2001, GÜRKAN & TEKİN-ÖZAN 2012). This study confirms its site and host specificity and expands the knowledge on its geographical distribution in Türkiye. Its infection prevalence (40.8%) was higher than that of previous reports (27.8% and 37.6%, respectively) from the same host species (GÜRKAN & TEKİN-ÖZAN 2012, AYDOĞDU 2001). It should be stated that the previous reports and ours were conducted at the same geographical region of Marmara and this similarity is a possible result of being sampled in this geographical area. Water temperature is one of the most important factors affecting the density of monogenean species on fish for this reason some parasite species can reach the highest infection values in summer and some others in winter in relation to their hatching and survival success at preferred water temperature levels (HANZELOVA & ZITNAN 1985, KOSKIVAARA et al. 1991). ÖZTÜRK & ÖZER (2014) have found significant seasonal impacts on the variation of several *Dactylogyrus* spp., winter having higher infection characteristics than the other seasons at the lower Kızılırmak Delta in Türkiye. In this study, however, we found that the prevalence and mean intensity values of *D. nanus* were the highest in summer and lowest in winter (Table 3). Our findings differs from the study of GÜRKAN & TEKİN-ÖZAN (2012) who established the highest infection characteristics of this parasite species on the same host fish in spring without any parasite individuals in summer. Even though, they attributed the seasonal differences to water temperature levels, they did not provide such data to make any comparison between both studies, but, based on our results, we can say that *D. nanus* can survive all year round between 8.0–25.5°C. A consistent increase in the infection characteristics of gill infecting *D. nanus* was found as the length of the infected host fish increased. We believe that this situation was resulted from a greater accumulation period and/or larger space for feeding and breeding as was explained for gill infecting trichodinid parasites of fishes by ÖZER (2003a). In the present study, infection was found in the female hosts. This could be explained by the hormonal differences in sexes and (or) more successful shoaling behaviour of female fishes resulting higher transmission of parasites between hosts. ÖZER (2002) reported heavier infections with *D. extensus* Mueller & Van Cleave,

1932 and *D. anchoratus* (Dujardin, 1845) on male *C. carpio* because of such hormonal differences. On the other hand, RICHARDS et al (2010) found higher infection values of *Gyrodactylus turnbulli* Harris, 1986 on female *Poecilia reticulata* Peters, 1859 than that of males and attributed that this resulted from sex-specific differences in shoaling behavior in favour of females.

Rhabdochona denudata was found in the intestine of *S. cephalus* with the prevalence of infection and mean intensity values 17% and 3.0 ± 0.8 , respectively. It has been previously reported from *Barbus plebejus* Bonaparte, 1839 (15.4%), *B. lacerta* Heckel, 1843 (15.4%), *Luciobarbus mursa* (Güldenstädt, 1773) (25%), *Alburnus mossulensis* Heckel, 1843 (4.9%), *A. alburnus* (41.7%), *S. cephalus* (27.3%), *Capoeta antalyensis* (Battalgil, 1943) (86.6%), *C. trutta* (Heckel, 1843) (5.4%) and *C. capoeta* (Güldenstädt, 1773) (12%) from Türkiye (AYDOĞDU 2001, AYDOĞDU & SELVER 2006, ASLAN 2009, AYDOĞDU et al. 2011, KOYUN et al. 2015, TUNÇ & KOYUN 2018, KOYUN et al. 2019, ÇELİK & OĞUZ 2021). When compared, our results are higher than those reported from *A. mossulensis* and *C. trutta* but lower than those reported from *S. cephalus*, *C. antalyensis* and *A. alburnus*. This parasite species has been recorded all year round with higher values in summer (Table 1). This can be attribute to the increasing feeding activities of fish host during this period. The recorded highest infection prevalence at Class III can also be attributed to higher consumption of infected intermediate hosts such as mayfly larvae involving the complex life cycle of this nematode species.

Myxobolus Bütschli, 1882 is the largest myxosporean genus; its members have been reported from a wide variety of mostly freshwater fish inhabiting different geographic regions (LONGSHAW et al. 2003, EIRAS et al. 2005, 2014). Almost fifteen *Myxobolus* spp. have been reported from various freshwater and marine fish in Türkiye (ÖZKAN 2015, ÖZER & OKKAY 2018, ÖZER et al. 2018, ŞİMŞEK 2019, YARDIMCI et al. 2020, BÖLÜKBAŞ et al. 2020, ÖZER 2021). In the present study, two morphologically distinct *Myxobolus* spores were identified at generic level. Of them, *Myxobolus* sp.1 was recovered from the gills and *Myxobolus* sp. 2 from kidneys of the host. Hitherto, no data have been recorded on the presence of *Myxobolus* spp. as parasites of *S. cephalus* from Türkiye; thus, both parasites are new records for this host fish species in Türkiye. Moreover, two species were the most prevalent parasites but with moderate infection intensities. Myxosporean taxonomy is primarily based on the spore

morphology but MOLNAR et al. (2006) mentioned that there were unreliable descriptions of spores about the occurrence of *Myxobolus* spp. in chub. In the last decades, the species identifications have been more supported by molecular-based studies along with traditional methods. FIALA et al. (2015) indicated that the traditional classification is artificial and does not reflect phylogenetic relationships. Thus, additional molecular studies are needed to clarify the actual species identity of *Myxobolus* sp. 1 and *Myxobolus* sp. 2. Myxosporean parasites of freshwater fishes comprise two-stage life cycles, with a myxosporean stage in fish and an actinosporean stage in invertebrate alternate hosts. Both *Myxobolus* species were found all year round but were more prevalent in the summer and spring. The prevalence values of both species were highest in the Class III and similar in both fish sexes. According to ROCHA et al. (2011), environmental factors, mainly the temperature but also some chemical and biological factors can influence the myxosporean life cycle. Thus, we believe that the alternate hosts of both myxosporean species were presented all year round in the sampling locality, which enabled them to complete their life cycle with higher prevalence when the temperature is higher and the food consumption increased. The highest infection prevalence found can be explained either by the fact that the fish have acquired more parasites with age or that the parasites have proliferated over time within their host as proposed (LOM & DYKOVA 1992, HALLETT et al. 1997). In our study, the prevalence values of individual parasite species were similar between the sexes of the host fish and this was the case for *Sphaerospora elegans* Thélohan, 1892 and *Myxobilatus gasterostei* (Parisi, 1912) infections at both sexes of *Gasterosteus aculeatus* (L., 1758) in the Black Sea (ÖZER 2003b). Fish host size and sex related seasonal variations in parasite infections have also been reported for the myxosporeans *Ceratomyxa merlangi* Zaika, 1966 and *Myxidium gadi* Georgévitch, 1916 in *Merlangius merlangus* from the Black Sea (ÖZER et al. 2017).

In conclusion, this is the first comprehensive study on the parasite fauna of *S. cephalus* and the parasite relationships with the seasonal and host related interactions in the studied stream system. This study expands our knowledge by adding *S. cephalus* as a new host and geographical records for *T. clavata*, *R. denudata*, *Posthodiplostomum* sp., *Ichthyocotylurus* sp and *Myxobolus* sp. 1 and *Myxobolus* sp. 2 in Türkiye.

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