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Original paper

Influence of the seasonal and host related factors on the metazoan parasites of *Chelon saliens* (Mugilidae) in the Turkish coast of the Black Sea

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ABSTRACT. The leaping mullet *Chelon saliens* is one of the economically significant fish species and the revealing its parasite fauna in relation with some ecological and host related factors will provide new data for our current knowledge. A total of 165 leaping mullet were collected from Sinop coasts of the Black Sea in the period from September 2015 to August 2016 and investigated for parasites. Eleven parasite species including *Myxobolus parvus*, *Myxobolus* sp., *Sphaerospora mugilis* (Myxozoa), *Ligophorus szidati*, *Solostamenides mugilis* (Monogenea), *Schikhobalotrema sparisomae*, *Saccocoelium tensum*, *Saccocoelium obesum* (Digenea), *Hysterothylacium aduncum* (Nematoda), *Neoechinorhynchus* sp. (Acanthocephala) and *Ergasilus lizae* (Copepoda) have been identified. The overall infection prevalence, mean intensity and mean abundance values were 65.5%, 26.2 and 17.2, respectively. The overall infection prevalence was dominated by *L. szidati*, followed by *M. parvus* and Digenea-group. On the other hand, the overall mean intensity values were dominated by Digenea-group, followed by *L. szidati* and *E. lizae,* respectively, while the mean abundance values were dominated by *L. szidati*, followed by Digenea-group and *E. lizae*. The infection indices of all identified parasites were also calculated in relation with length classes and sex of fish as well as season and the differences were evaluated statistically. Seasonally significant differences in the infection prevalence and mean abundance were found for Digenea-group, *Ligophorus szidati* and *Neoechinorhynchus* sp. These differences were also significant in the length classes of Digenea-group and *Ligophorus szidati.* This study is the first investigation on seasonal and host related dynamics of parasites of *C. saliens* in the southern coasts of the Black Sea and all investigated factors were found to influence the infection indices of dominating parasite species.

Keywords: *Chelon saliens*, parasite fauna, host-parasite interrelationship, Black Sea

Introduction

Members of the family Mugilidae are cosmopolitan teleost fishes which extensive and semi-intensive exploitation has been practised for centuries worldwide. The leaping mullet, *Chelon saliens* (Risso, 1810), is an economically important widespread marine and brackish water fish species in the Mediterranean Sea and the Black Sea. Due to their commercial values, studies on parasitic infections on mugilids have been conducted to reveal their occurrences [1,2] and impacts on health status of mugilids [3]. The parasite/host relation is one of the key indicators of environmental conditions structuring complexity of the aquatic systems [3]. Moreover, parasites can have direct negative influence on growth, fecundity, survival, feeding conversion efficiency, and therefore severely compromise the health of their hosts, even inducing mortality [3,4]. Of the known 20 genera and 71 species, Mugilidae are represented by 6 species namely *Mugil cephalus* Linnaeus, 1758, *Chelon labrosus* (Risso, 1827), *Chelon auratus* (Risso, 1810), *Chelon ramada* (Risso, 1827), *C. saliens* and *Planiliza haematocheila* (Temminck and Schlegel, 1845) in the Black Sea [5,6]. Despite several studies on the parasite fauna of mugilids in the Black Sea [2,3,6,7,9], it is obvious from current literature that comprehensive studies on the parasite fauna of leaping mullet *C. saliens* are needed due to its ecological and economical importance.

The objectives of this study were to investigate the parasite fauna of *C. saliens* collected from the southern coasts of the Black Sea for the first time and to extend our knowledge about their seasonality and host-parasite interrelationships.

Materials and Methods

The parasite fauna of the leaping mullet *C. saliens* collected by commercial fishing vessels was determined seasonally throughout from September 2015 to August 2016 in the southern Black Sea off Sinop, Turkey (42°05'68''N 35°10'55''E). Fish were measured in their total length using a Vernier calliper to the nearest 1 mm, allocated to three length classes of ≤25.0 cm, 25.1–29.9 cm and ≥30.0 cm and sexed at the laboratory. A total of 165 fish individuals including 73 in autumn (18.5–35.0 cm; 50 female, 23 male), 62 in winter (22.0–32.0 cm; 32 female, 30 male), 10 in spring (25.6–30.0 cm; 6 female, 4 male) and 20 in summer (24.1–33.5 cm; 9 female, 11 male) were investigated. The skin, fins, gills, eyes (lens and vitreous humour), body cavity and visceral organs (stomach, intestine, liver, gall bladder kidney and gonads) were examined under a dissecting microscope for parasites. Whole contents of the stomach and intestine were emptied and tissues were scraped with a scalpel and parasites were determined by screening all smears prepared from each organ of fishes using a light microscope at 100× to 400× magnifications. Parasite species identification was conducted using a phase contrast Olympus microscope (BX53) equipped with a digital camera (DP50) and drawing attachment. To facilitate parasite species identification, digeneans were stained with aceto-carmine; monogeneans were fixed under the cover slip by adding a drop of ammonium picrate-glycerine to the edge of the cover slip; nematodes were repeatedly washed in 0.9% saline solution, fixed in 70% ethanol and cleared with lactophenol; acanthocephalan individuals were fixed in 70% ethanol and cleared in glycerol (25–100%) and 70% ethanol fixed copepod and cnidarian spores were later studied in temporary mounts. Species identification was realised in accordance with Radujkovich et al. [10], Jones et al. [11], Oğuz and Bray [12], Blasco-Costa et al. [13] for digeneans; Dmitrieva and Gerasev [7], Sarabeev et al. [8], Rubtsova et al. [14], Sarabeev et al. [15], Ramon and Diego [16], Özer and Yılmaz Kırca [17] for monogeneans; Koie [18] for nematodes; Yurakhno and Ovcharenko [9], Lom and Dykova [19], Sitja-Bobadilla and Alvarez-Pellitero [20], Bartošová et al. [21], Özer et al. [22] for cnidarians; Amin [23], Tkach et al. [24] for acanthocephalan and Amado and Rocha [25] for copepoda. Infection prevalence (%), mean intensity and abundance follow the recommendations by Bush et al. [26]. These indices of infections of digeneans (*Sc. sparisomae*, *Sa. tensum*, *Sa. obesum*) were given for pooled data as a group rather than by species due to difficulties in exact species identification of the same genus when they are alive. Seasons were distinguished according to calendar months and monthly data obtained from both parasite and fish hosts were pooled, calculated and presented seasonally. Water temperature (ºC) values (Tab. 1) were obtained from local branch of Turkish State Meteorological Service.

Quantitative Parasitology 3.0 software [27] was used to calculate Sterne's exact 95% confidence limits for prevalence, bootstrap 95% confidence limits (number of bootstrap replications = 2.000) for mean abundance (Mean A) and mean intensity (Mean I). The differences in prevalence values between sampling seasons, sex and length categories of mullets were determined by Fisher's exact test while the differences in mean abundance and intensity were performed by the bootstrap two-sample t test at the significance level of 5%.

Ethical standards

Fieldwork was run according to acceptable relevant ethical standards.

Results

A total of 11 parasite species were identified including three digeneans, three myxosporean, two monogenean, one nematode, one acanthocephalan and one copepod (Fig. 1) and their microhabitats, infection prevalence (%), mean intensity and mean abundance values are presented in table 1. If the number of parasite species in the individual leaping mullet host (infra community) is regarded, a gradual decrease was apparent as the number of co-existing parasites increased and the majority of hosts were infected mostly with one and secondly with two parasite species (Fig. 2).

Overall infection prevalence (%) and abundance values of leaping mullet parasites

The overall infection prevalence, mean intensity and mean abundance values were 65.5% (exact 95% confidence limits 57.9–72.4), 26.2 (bootstrap 95%

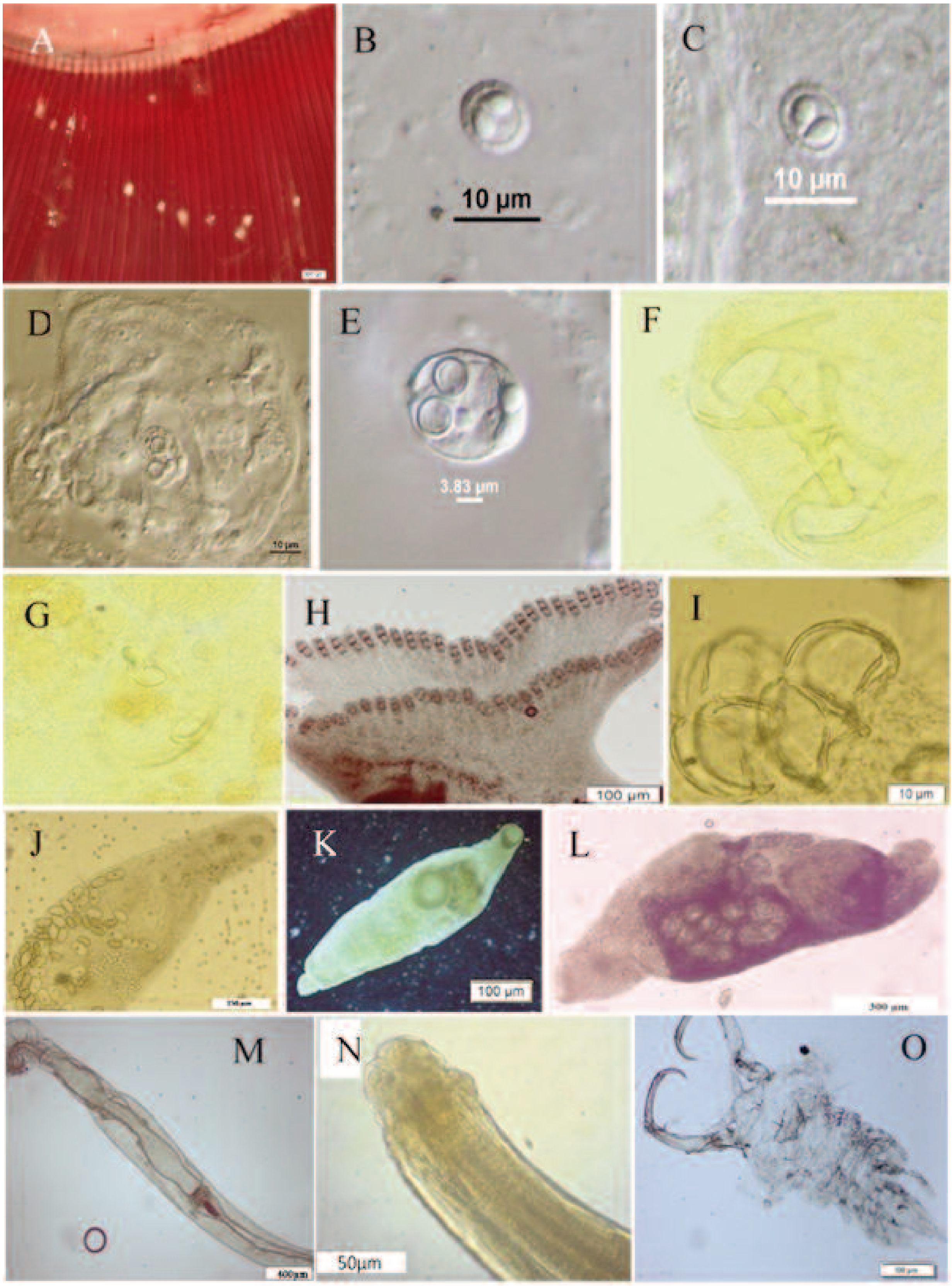

Figure 1. Parasite species identified from *C. saliens.* **A.** Cysts of *Myxobolus parvus* on the gills, **B.** *Myxobolus parvus*, **C.** *Myxobolus* sp., **D.** Sporoblast of *Sphaerospora mugilis*, **E.** *Sphaerospora mugilis*, **F.** Haptor of *Ligophorus szidati*, **G.** Copulatory organ of *L. szidati*, **H**. Haptor of *Solostamenides mugilis*, **I.** Clamp of *S. mugilis*, **J.** *Saccocoelium tensum*, **K.** *Saccocoelium obesum*, **L.** *Schikhobalotrema sparisomae*, **M.** *Neoechinorhynchus* sp., **N.** Anterior end of *Hysterothylacium aduncum*, **O.** *Ergasilus lizae*

Table 1. Parasite species identified in *Chelon saliens* and their microhabitats, overall infection indices

Species	Microhabitat	Prevalence (%) CI	Mean I CI	Mean A CI
Myxobolus parvus Shulman, 1962	Gills, kidney, gall bladder, lower jaw	22.4 (16.6–29.3)	Numerous plasmodia and spores	Numerous plasmodia and spores
Myxobolus sp.	Urinary bladder	6.7 (3.4–11.7)		
Sphaerospora mugilis (Sitja-Bobadilla and Alvarez-Pellitero 1995) Bartasova et al. 2013	Kidney	0.6 (0.04–3.4)	Several plasmodia and spores	Several plasmodia and spores
Ligophorus szidati Euzet and Suriano, 1977	Gills	57.0 (49.0–64.5)	20.2 (15.3–25.9)	11.5 (8.6–15.2)
Solostamenides mugilis (Vogt, 1879) Unnithan, 1971	Gills	0.6 (0.04–3.4)	1.0	0.1 (0.0–0.2)
Saccocoelium tensum Looss, 1902 *Saccocoelium obesum* Looss, 1902 *Schikhobalotrema sparisomae* (Manter, 1938) Skrjabin and Guschanskaja, 1955	Intestine	21.8 (15.9–28.7)	22.8 (10.3–50.3)	5.0 (2.0–12.2)
Neoechinorhynchus sp.	Intestine	9.1 (5.3–14.4)	3.9 (2.4–6.4)	0.4 (0.1–0.6)
Hysterothylacium aduncum (Rudolphi,1802)	Intestine	2.4 (0.8–6.2)	3.3 (1.5–5.7)	0.1 (0.02–0.2)
Ergasilus lizae Krøyer, 1863	Gills	4.2 (2.0–8.6)	5.1 (2.5–9.7)	1.5 (0.07–0.5)
Overall		65.5 (57.9–72.4)	26.2 (20.1–36.0)	17.2 (12.6–23.3)

confidence limits 20.1–36.0) and 17.2 (bootstrap 95% confidence limits 12.6–23.3), respectively. The infection prevalence was dominated by monogenean *Ligophorus szidati*, followed by myxosporean *Myxobolus parvus* and Digenea-group, while the others were rare throughout the investigation period (Tab. 1). On the other hand, the mean intensity values were dominated by Digenea-group, followed by *L. szidati* and *E. lizae*, respectively, while the mean abundance values were

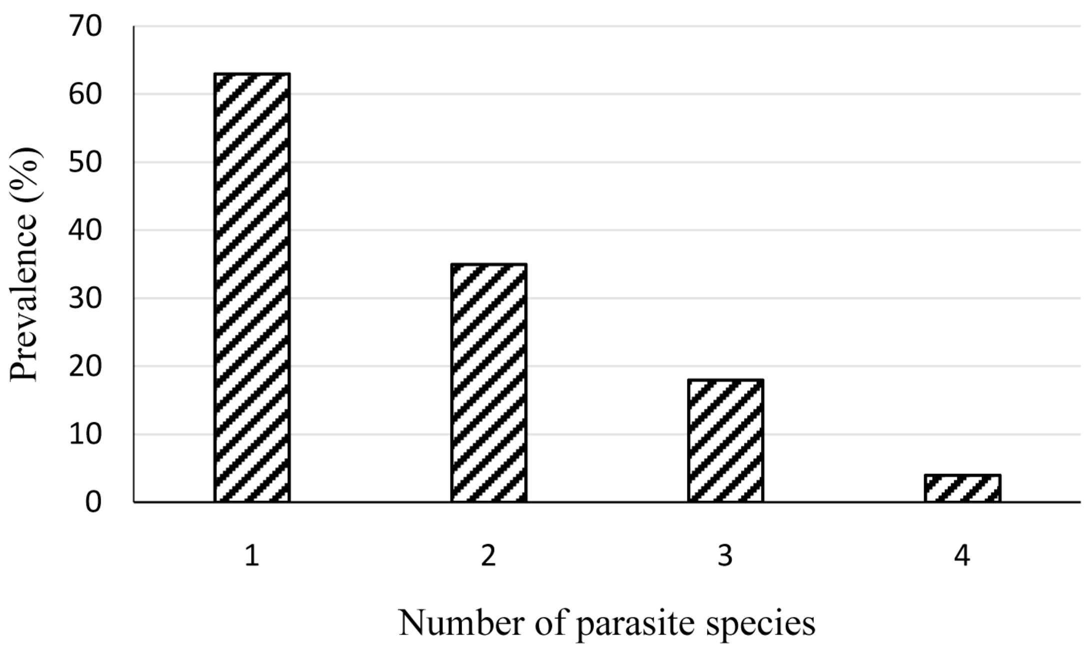

Figure 2. Infection prevalence (%) with respect to the number of parasite species detected in the leaping mullet throughout the investigation period

Table 2. Parasite species identified in *Chelon saliens* and their infection indices according to seasons

Species	Winter (n=62) (7.8–12.2°C)			Spring (n=10) (13.2–17.3°C)		
	P (%) CI	Mean I CI	Mean A CI	*P* (%)	Mean I CI	Mean A CI
Myxobolus parvus	25.8 (15.8–38.0)	–	–	0	–	–
Myxobolus sp.	4.8 (1.3–13.4)	–	–	0	–	–
Sphaerospora mugilis	0	–	–	0	–	–
Ligophorus szidati	71.0 (58.1–81.1)	25.9 (19.0–34.1)	18.4 (13.1–25.7)	70.0 (38.0–91.2)	5.7 (1.8–11.2)	4.0 (1.2–8.7)
Solostamenides mugilis	0	0	0	0	0	0
Digenea-group	27.4 (17.5–40.2)	29.6 (5.9–76.4)	8.1 (1.4–23.6)	60.0 (29.0–84.9)	40.3 (6.0–135.1)	24.2 (3.7–99.7)
Neoechinorhynchus sp.	16.1 (8.6–27.3)	4.8 (2.8–8.4)	0.8 (0.3–1.6)	20.0 (3.6–55.3)	2.0	0.4 (0.0–1.3)
Hysterothylacium aduncum	4.8 (1.3–13.0)	3.3 (1.0–5.3)	0.2 (0.02–0.6)	10.0 (0.5–44.6)	3.0	0.3 (0.0–0.9)
Ergasilus lizae	11.3 (5.4–21.6)	5.1 (2.4–9.2)	0.6 (0.1–1.4)	0	0	0
Overall	85.5 (74.3–92.4)	32.7 (23.1–48.3)	27.9 (19.4–41.5)	90.0 (55.3–99.4)	32.1 (8.1–99.7)	28.9 (7.4–89.8)
Species	**Summer (n=20) (22.6–26.2°C)**			**Autumn (n=73) (16.8–20.2°C)**		
	P (%) CI	Mean I CI	Mean A CI	*P* (%)	Mean I CI	Mean A CI
Myxobolus parvus	0	–	–	28.8 (18.9–40.3)	–	–
Myxobolus sp.	0	–	–	11.0 (5.1–20.3)	–	–
Sphaerospora mugilis	0	–	–	1.4 (0.08–7.0)	–	–
Ligophorus szidati	55.0 (32.0–75.5)	12.7 (6.4–22.8)	7.0 (3.0–14.3)	43.8 (32.8–55.5)	18.2 (10.8–32.1)	7.9 (4.3–14.7)
Solostamenides mugilis	0	0	0	1.4 (0.08–0.7)	1.0	0.01 (0.0–0.04)
Digenea-group	20.0 (7.1–42.3)	9.3 (5.0–16.2)	1.9 (0.4–4.8)	9.6 (4.5–18.9)	4.4 (2.4–6.7)	0.4 (0.1–0.9)
Neoechinorhynchus sp.	10.0 (1.8–31.9)	2.5	0.3 (0.0–0.9)	2.7 (0.4–9.3)	1.0	0.02 (0.0–0.07)
Hysterothylacium aduncum	0	0	0	0	0	0
Ergasilus lizae	0	0	0	0	0	0
Overall	55.0 (32.0–75.5)	16.5 (10.7–25.8)	9.1 (4.8–15.7)	47.9 (36.2–59.6)	17.6 (10.4–31.2)	8.4 (4.6–15.5)

dominated by *L. szidati*, followed by Digenea-group and *E. lizae*. (Tab. 1).

The distribution of leaping mullet parasites with respect to season

Ligophorus szidati, *Neoechinorhynchus* sp. and Digenea-group parasites were present in four seasons while the rest were found only in some seasons (Tab. 2). Digenea-group, *Neoechinorhynchus* sp. and *H. aduncum* had their highest prevalence values in spring while *L. szidati* had its highest prevalence value in winter and *M. parvus* and *Myxobolus* sp. in autumn (Tab. 2). *Ergasilus lizae*, *Sp. mugilis* and *So. mugilis* were found only one season throughout sampling period (Tab. 2). While there is a statistically significant difference in the prevalence values between seasons in Digenea-group, *L. szidati* and *Neoechinorhynchus* sp. ($P<0.05$), there is no significant difference between seasons in other parasite species (Fisher's exact test, $P>0.05$) (Tab. 3). The mean intensities of *L. szidati, Neoechinorhynchus* sp. and *H. aduncum* in winter, and Digenea-group in spring were at their maximum values (Tab. 2). While there are statistically significant differences in the mean intensity values between seasons in *L. szidati* and *Neoechinorhyn-*

Table 3. Comparative differences in prevalence (P %), mean intensity (Mean I) and mean abundance (Mean A) of parasite species in fish samples relative to season, fish size and sex of host, * level of significance with $P<0.05$

Parasite species	Variable	P (%)	Mean I	Mean A
Myxobolus parvus	Seasons	0.846	–	–
	Length classes	0.190	–	–
	Sex of host	0.707	–	–
Myxobolus sp	Seasons	0.225	–	–
	Length classes	0.159	–	–
	Sex of host	0.363	–	–
Ligophorus szidati	Seasons	0.012*	0.007*	0.000*
	Length classes	0.000*	0.133	0.000*
	Sex of host	0.001*	0.871	0.131
Digenea-group	Seasons	0.001*	0.637	0.000*
	Length classes	0.005*	0.591	0.006*
	Sex of host	0.121	0.933	0.647
Neoechinorhynchus sp.	Seasons	0.018*	0.000*	0.000*
	Length classes	0.386	0.667	0.470
	Sex of host	1.000	0.152	0.230
Hysterothylacium aduncum	Seasons	0.458	1.000	0.646
	Length classes	0.595	0.508	0.437
	Sex of host	1.000	0.500	0.720
Ergasilus lizae	Seasons	–	–	–
	Length classes	0.172	0.455	0.769
	Sex of host	0.701	0.509	0.914
Overall	Seasons	0.000*	0.048*	0.000*
	Length classes	0.000*	0.146	0.000*
	Sex of host	0.013*	0.699	0.619

chus sp. ($P<0.05$), there is no significant difference between seasons in the rest of parasites ($P>0.05$) (Tab. 3). The mean abundance of *L. szidati*, *Neoechinorhynchus* sp. and Digenea-group in winter were at their maximum values (Tab. 2). While there are statistically significant differences in the mean abundance values between seasons in Digenea-group, *L. szidati* and *Neoechinorhynchus* sp. ($P<0.05$), there is no significant difference between seasons in *H. aduncum* ($P>0.05$) (Tab. 3).

The distribution of parasites with respect to the length classes of the host fish

There was a clear decrease in the infection prevalence of *L. szidati*, *E. lizae*, *M. parvus* and *Myxobolus* sp. as the length of leaping mullet increased, however, Digenea-group had its highest infection prevalence in the middle length class of host fish (Tab. 4). While there are statistically significant differences in the prevalence values between length classes in Digenea-group and *L. szidati* ($P<0.05$), there is no significant difference between length classes in in the rest of parasite species ($P>0.05$) (Tab. 3).

The distribution of parasites with respect to the sex of the host fish

Digenea-group, *E. lizae* and *M. parvus* had higher prevalence values in female while *L. szidati*, *Neoechinorhynchus* sp., *Myxobolus* sp. and *H. aduncum* had higher prevalence values in male hosts (Tab. 5). It must be mentioned that *So. mugilis* and *Sp. mugilis* was found once only on male and female host, respectively (Tab. 5). While there are

Table 4. Parasite species identified in *Chelon saliens* and their infection indices according to host length classes

Species	≤25.0 cm (n=26)			25.1–29.9 cm (n=94)			≥30.0 cm (n=45)		
	P (%)	CI Mean I CI	Mean A CI	P (%)	Mean I CI	Mean A CI	P (%) CI	Mean I CI	Mean I CI
M. parvus	34.6 (18.8–54.2)	–	–	22.3 (14.7–31.8)	–	–	15.6 (7.4–28.7)	–	–
Myxobolus sp.	15.4 (5.4–34.3)	–	–	5.3 (2.1–12.0)	–	–	4.4 (0.8–15.2)	–	–
Sp. mugilis	0	–	–	0	–	–	2.2	–	–
L. szidati	80.8 (61.7–92.1)	28.5 (18.6–40.7)	23.0 (14.3–35.0)	62.8 (52.5–72.1)	19.9 (14.3-28.1)	12.5 (8.4–18..0)	31.1 (18.5–46.6)	9.5 (5.8–15.7)	2.3 (1.4–5.5)
So. mugilis	0	0	0	1.0	1.0 ± 0.0	0.01 ± 0.01	0	0	0
Digenea-group	11.5 (3.2–30.3)	4.7 (4.0–5.3)	0.5 (0.0–1.3)	30.9 (22.2–40.9)	26.4 (11.2–59.7)	8.1 (3.1–18.8)	8.9 (3.1–20.8)	10.0 (4.5–15.5)	0.9 (0.2–2.4)
Neoechinorhynchus sp.	0	0	0	12.8 (7.0–21.1)	3.8 (2.0–7.2)	0.5 (0.2–1.0)	6.7 (1.8–18.5)	4.3	0.3 (0.0–0.6)
H. aduncum	0	0	0	2.1 (0.3–7.2)	2.0	0.04 (0.0–0.1)	4.4 (0.8–15.2)	4.5	0.2 (0.0–0.7)
E. lizae	11.5 (3.2–30.3)	3.3 (1.0–5.6)	0.4 (0.04–1.3)	4.3 (1.4–10.4)	6.5 (3.0–12.5)	0.3 (0.06–0.8)	0	0	0
Overall	80.8 (61.7–92.1)	29.2 (19.9–43.0)	23.6 (15.1–36.2)	73.4 (63.3–81.4)	29.2 (20.5–44.5)	21.4 (14.6–32.6)	40.0 (26.4–55.4)	10.8 (7.1–15.6)	4.3 (2.3–6.9)

Table 5. Parasite species identified in *Chelon saliens* and their infection indices according to sex

Species	Female (n=97)			Male (n=68)		
	P (%) CI	Mean I CI	Mean A CI	P (%) CI	Mean I CI	Mean A CI
M. parvus	23.7	–	–	20.6	–	–
Myxobolus sp.	5.2	–	–	8.8	–	–
Sp. mugilis	1.1	–	–	0.0	–	–
L. szidati	46.4 (36.5–56.7)	20.5 (13.6–31.2)	9.5 (6.0–14.9)	73.5 (61.8–83.1)	19.6 (14.5–27.6)	14.4 (10.1–20.6)
So. mugilis	0	0	0	1.5 (0.08–0.7)	1.0	0.01 (0.0–0.04)
Digenea-group	25.8 (17.9–35.5)	22.8 (6.4–59.2)	5.9 (1.7–17.2)	14.7 (7.8–22.5)	24.9 (5.4–82.5)	3.7 (0.6–15.4)
Neoechinorhynchus sp.	9.3 (4.7–16.8)	2.2 (1.3–3.3)	0.2 (0.08–0.4)	10.3 (4.9–19.7)	5.6 (2.8–10.1)	0.6 (0.2–1.3)
H. aduncum	2.1 (0.3–7.0)	4.5 (2.0–7.0)	0.1 (0.0–0.3)	2.9 (0.5–10.7)	2.0	0.06 (0.0–0.2)
E. lizae	5.2 (2.0–11.6)	4.0 (2.0–6.2)	0.2 (0.05–0.5)	2.9 (0.005–10.0)	8.0	0.2 (0.0–1.1)
Overall	57.7 (47.4–67.6)	27.6 (18.4-43.5)	15.9 (10.5–26.4)	76.5 (64.7–84.5)	24.6 (17.6–36.6)	18.8 (13.1–28.1)

statistically significant differences in the prevalence values between sex of host fish in *L. szidati* ($P<0.05$), there is no significant difference between different sexes of host fish in the rest of parasite species ($P>0.05$) (Tab. 3).

Discussion

The current study is the first to report the parasite fauna and their occurrences in relation with seasonality and host factors of sex and length classes of leaping mullet *C. saliens* which were collected from the southern coastal area of the Black Sea. A wide variety of parasite species belonging to three myxosporean, two monogenean, three digenean trematodes, one nematode, one acanthocephalan and one copepod were identified in this comprehensive study. Total number of identified parasites (11) is lower than that previously reported from the Mistras Lagoon (Sardinia – western Mediterranean) by Merella and Garippa [28] and more than those from Greek coasts of Aegean Sea [29], the Dardanelles strait at Çanakkale, Turkey [30], the Mediterranean coasts of Italy [31] and we believe that this may be resulted from possible differences in prey availability and environmental factors in above mentioned sampling areas. In the infra community level, most of the fish were found to be parasitized by 1 species as was dominated by *L. szidati* and Digenea-group members, the previous being an ectoparasite on the gills and the latter being an endoparasite group in the intestine of host fish. Similarly, two dominating parasite species were reported on the gills of *C. aurata* and *M. cephalus* collected from Kızılırmak delta located by the Black Sea [2,17].

Monogeneans are known to be common parasites of fish, however, strict host-specificity is a common phenomenon among monogeneans. All known species of the members of the genus *Ligophorus* are strictly specific to mugilids, including *L. szidati* which is specific to *C. aurata* (type host) and *C. saliens* being the other host together with *P. haematocheila* (Syn: *L. haematocheilus*) [8]. *Ligophorus szidati* was previously reported from *C. aurata* and *C. ramada* from the Aegean Sea and the present study is the first record on *C. saliens* collected from the Turkish coastal areas of the Black Sea. Infection indices in relation with season and some host factors in the present study showed that this parasite species was present all year round with preferences to winter season as well as male and shortest length class of *C. saliens*. Studies providing such data for *Ligophorus* species on mugilid hosts are rare [2,7,17,28,32]. Dmitrieva and Gerasev [7] reported prevalence 40% and 100% for *L. euzeti* and

L. acuminatus on the gills of *C. saliens*, respectively, in the northern coasts of the Black Sea. Merella and Garippa [28] reported *L. szidati* infections on *C. aurata* located in the Mistras Lagoon at the western Mediterranean Sea and prevalence, mean intensity and abundance values were 63%, 32.3±49.7 and 20.3±42.1, respectively. Özer and Yılmaz Kırca [2] reported year-round occurrence of *L. cephali* on *M. cephalus*, higher in autumn and winter, in the Lower Kızılırmak Delta located by the southern Black Sea in Turkey and concluded that it was well adapted to low level of temperatures in autumn and winter. In the current study, the infection prevalence, mean intensity and abundance values of *L. szidati* in Sinop coasts of the Black Sea were very similar to those reported in the Black and Mediterranean Seas by the above-mentioned authors. Sex of mullet in the present study revealed statistically significant occurrence on male fish than that of female, however, there is no such data available in the literature to make any comparison.

Another monogenean *S. mugilis* (syn. *Microcotyle mugilis*) has been reported from several mugilid species thus far from different geographical areas [2,17], however, this study is the first to report its occurrence on the gills of *C. saliens*. Current literature shows that it has a wide host range and our finding on *C. saliens* despite only once appearance with one specimen extends probably its host range. Very low level of infection indices of this parasite in Sinop coasts of the Black Sea is even lower than those reported in the Black and Mediterranean Seas from different host fishes [2,12,17,28,29].

Digenean parasites *S. obesum, S. tensum* and *Sc. sparisomae* have so far been reported from several mugilid species including *C. saliens*, *C. aurata*, *C. ramada*, *C. labrosus* and *M. cephalus* from different geographical areas [12,13,28–30,33–35]. It must be reminded that we created a collective Digenea-group to comprise above mentioned digeneans rather than species by species in the present study due to the difficulties in precise species identification when they are counted alive. However, we can emphasise that *Sc. sparisomae* was the dominant species over *Saccocoelium* spp. in term of individual parasite number. Thus, our comparable seasonal and host related digenean occurrences mainly corresponds to *Sc. sparisomae*. When compared with the prevalence and intensity values of Digenea-group members from several other studies, our data are lower than those of *S. obesum* from *C. labrosus* [35], *S. tensum* from *C. saliens* [29], *Sc. sparisomae* from *C. saliens* [12] and higher than those reported for *Sc. sparisomae* from *C. saliens* [30]. Statistically significant differences were found on seasonal and host length related occurrences of our Digenea-group and some authors correlated these differences to several factors such as host hibernation, spawning and maturity of the host fish, changes in the immune response of fish at different temperatures and ages, and the feeding habits of the host fish [36–38]. All digeneans identified here occurred at higher infection levels in winter and spring indicating preference with lower temperature values and Koprivnikar [38] explained this situation by changes in hydrological conditions such as temperature and salinity which influence the abundance and distribution of free-living stages of the parasites and the completion of the digenean life cycle. Moreover, we believe that above mentioned hydrological factors, especially temperature that is accepted to be one of the triggering factors for food consumption of fish host over infected intermediate hosts, caused differences in seasonal occurrences of food preys which directly affected infection indices in *C. saliens*.

Acanthocephalans are among the commonly reported parasites of mugilids including *C. saliens* in different geographical areas Keser et al. [30], Aydoğdu et al. [35], Sasal et al. [39]. Infection prevalence and intensities of *Neoechinorhynchus* sp. in the present study have some similarities and differences to those reported by Aydoğdu et al. [35] and Sasal et al. [39] with respect to overall, seasonality and host related occurrences. Acanthocephalan life cycle includes several hosts and this life cycle is affected by differing hydrological conditions such as temperature [40] which caused significant differences in seasonal occurrences of our infection indices in *C. saliens*.

Ergasilid copepods have been reported from a variety of finfish reared in brackish and marine waters and *E. lizae* has been reported from several mugilid species excluding *C. saliens* [2,17,29 ,41–43]. However, this study provides the first record of this parasite species from *C. saliens*. Above mentioned authors reported higher values of infection prevalence values along with similar intensities of this parasite to that of our study from different environments with different salinity and temperature regimes, however, low levels of intensities (max. 50.0% in *C. aurata*) are very usual for this large-sized parasite. Here in the present study, this parasite occurred only in winter in contrast to all-year round occurrences in *M. cephalus*. This parasite also occurred only in small sized host fish but at both sexes of *C. saliens* in the present study, however, there is no study providing such comparable data. It should be bared in mind, despite these low-level occurrences, that ergasilid copepods have been reported from a variety of finfish reared in brackish and marine waters and outbreaks of disease caused by ergasilids are a major source of copepod-induced mortality in brackish water finfish culture.

Hysterothylacium aduncum is a generalist nematode registered from many marine fish species [44]. It lives as sexually mature adults in the digestive tracts of marine teleost fishes [45] and it occurs as larvae in marine invertebrates and fish [18]. This species occurred only in winter and spring at larger sized host fish without any significant difference between both sexes of *C. saliens* in very low levels in the present study. Despite lacking comparative information about its presence on any mugilid fish species in the Black Sea, there is a vast number of literatures on the infections of this parasite in several fish species without any mugilids [46] and a gadid fish *Merlangius merlangus* from different areas of the Black Sea [47]. When infection prevalence and intensities compared, our data of *H. aduncum* in *C. saliens* were lower than those provided by above mentioned authors and it is likely that these differences were resulted from migratory behaviours of mugilids in their life span between freshwater and marine environments and different feeding habits of mugilids which excluded some intermediate hosts of *H. aduncum*.

Members of the class Myxozoa are among the most cosmopolitan parasites of fish and the genus *Myxobolus* is the largest within this class with 856 known species in freshwater and marine environment from all over the world [48,49]. The genus *Sphaerospora*, which includes some pathogenic species that cause significant impacts on fisheries and aquaculture, is one of the most polyphyletic taxa and exemplifies the current challenges facing myxozoan taxonomists [21] and it comprises about 80 nominal species [50]. The genus *Polysporoplasma* (Sphaerosporidae) comprises two nominal species, *S. sparis* and *S. mugilis*, and based on their sequence data and absence of unique morphological and developmental traits of *Polysporoplasma* spp. Bartošová et al. [21] proposed that the genus *Polysporoplasma* be suppressed to become a junior synonym of *Sphaerospora.* Thus, the two former *Polysporoplasma* spp. became *S. sparis* n. comb. and *S. mugilis* n. comb. Another myxosporean *Myxobolus parvus* has been reported from several mugilid fishes [48,51] and from 14 Black Sea fish species including *C. saliens* [22]. On the other hand, *S. mugilis* (Syn: *P. mugilis*) was originally reported from the kidney of *C. aurata* in the Mediterranean Sea by Sitja-Bobadilla and Alvatrez-Pellitero [20] and since then, it has been reported from the kidney of *C. aurata, C. ramada* and *C. labrosus* in the Mediterranean Sea and *C. aurata* and *C. saliens* in the Black Sea [22,52]. There is another *Myxobolus* species identified to genus level based on spore morphology in the urinary bladder of *C. saliens* here in the present study and we believe that it is a new record for science; however, further molecular studies are required to make a clear description here. The infection prevalence of 22.4% for *M. parvus* in the present study seems to be lower but still within the range when compared with Yurakhno [53] (19.0%) and Özer et al. [22] (34.61%). *Myxobolus* sp. had an infection prevalence of 6.7% in the present study and there is no possibility to make any comparisons in the literature. *Sphaerospora mugilis* was found only once at the infection prevalence of 0.6% in the present study and previously reported infection prevalence values were between 2–8 % in the Mediterranean Sea and about 11% in the Black Sea ([53] and 14% in the Mediterranean Sea [20], our prevalence is much lower than the range reported by above mentioned authors.

According to Rohde [36], parasites may infect both sexes differently, because male and female fish often have different feeding habits. In our study, host sex did not have a significant influence on the infection parameters of most parasite species, except *L. szidati*, on *C. saliens*, suggesting that habitat use and diet are similar for both sexes of this host fish species.

The data presented here provided the first detailed information about the parasites of rarely investigated mugilid fish species *C. saliens* and their host related as well as seasonal interactions in the Black Sea. Variables for the infection parameters revealed clear patterns especially for the ectoparasitic *L. szidati* that it has the ability to hatch all year-round at all length classes. The endoparasitic complex Digenea-group and *Neoechinorhynchus* sp. were included in the food web that *C. saliens* requested all year round for the three length classes, however, the rest of the parasites had some preferences either for season or length classes of host fish. This is also the first report of *L. szidati, Sc. sparisomae*, *S. tensum* and *S. obesum* in the Turkish coast of the Black Sea and *C. saliens* is the new host record for the rest of the parasites which were previously reported from other host fish species in the Black Sea.

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