Acta Aquatica Turcica
E-ISSN: 2651-5474 16(4), 498-505 (2020) DOI: https://doi.org/10.22392/actaquatr.729206

Some Parasitological Features of *Paradiplozoon bliccae* (Monogenea: Diplozoidae) Infestation in *Pseudophoxinus burduricus* - An Endemic Fish Species from Doğanbaba Creek (Lake Salda, Turkey)

Deniz İNNAL[1*], Mehmet Can ÜNAL[1], Duygu Ceren ÇAĞLAN[1], Kristína CIVÁŇOVÁ[2], Özlem ÖZMEN[3]

[1]Burdur Mehmet Akif Ersoy University, Arts and Sciences Faculty, Biology Department, 15100, Burdur, Turkey
[2] Masaryk University, Faculty of Science, Department of Botany and Zoology, Kotlářská 2, 611 37, Brno, Czech Republic
[3]Burdur Mehmet Akif Ersoy University, Faculty of Veterinary Medicine, Department of Pathology, 15100, Burdur, Turkey

*Corresponding author: innald@gmail.com

Research Article

Received 29 April 2020; Accepted 21 July 2020; Release date 01 December 2020.

How to Cite: İnnal, D., Ünal, M.C., Çağlan, D.C., Civáňová, K., & Özmen, Ö. (2020). Some parasitological features of *Paradiplozoon bliccae* (Monogenea: Diplozoidae) infestation in *Pseudophoxinus burduricus*-an endemic fish species from Doğanbaba Creek (Lake Salda, Turkey). *Acta Aquatica Turcica*, *16*(4), 498-505 https://doi.org/10.22392/actaquatr.729206

Abstract

This study was aimed to identify *Paradiplozoon bliccae* (Monogenea: Diplozoidae) in an endemic fish species *Pseudophoxinus burduricus* (Teleostei: Cyprinidae) and to describe parasite's prevalence and intensity of infection. *P. burduricus* specimens were collected between January 2014 and February 2015 in Doğanbaba Creek (Yeşilova-Burdur). A total of 60 *P. burduricus* specimens were examined for monogenean parasites. During the course of surveys, diplozoid specimens were collected from the gills of these fish and examined microscopically for identification. *Paradiplozoon bliccae* specimens were isolated from the examined fish. Prevalence, intensity, and seasonality of infection, age classes, and sex compositions of the infected population have been calculated. It has been recorded that the highest point of prevalence being in summer and the highest invasion value in the two-age class of fish. Hyperaemia, haemorrhage, and atrophy of the gills were observed during pathological examination of the parasite infested fish individuals.

Keywords: Monogenea, Diplozoidae, Burdur,endemic

Doğanbaba Çayı (Salda Gölü, Türkiye)'nın Endemik balık türü *Pseudophoxinus burduricus'ta Paradiplozoon bliccae* (Monogenea: Diplozoidae) Enfeksiyonunun Bazı Parazitolojik Özellikleri

Özet

Bu çalışmada endemik bir balık türü olan *Pseudophoxinus burduricus* (Teleostei: Cyprinidae) 'da bulunan *Paradiplozoon bliccae* (Monogenea: Diplozoidae) bireylerinin tanımlanması ve parazitin enfeksiyon prevalansının ve yoğunluğunun belirlenmesi amaçlanmıştır. *P.burduricus* örnekleri Ocak 2014 ile Şubat 2015 arasında Doğanbaba Deresi'nden (Yeşilova-Burdur) toplanmıştır. Monogenean parazitleri açısından toplam 60 *P. burduricus* örneği incelenmiştir. Balık solungaçlarından diplozoid örnekleri toplanmış ve tespit için mikroskobik olarak incelenmiştir. *Paradiplozoon bliccae* örnekleri balıklardan izole edilerek enfeksiyon prevalansı, şiddeti ve mevsimselliği, yaş sınıfları ve enfekte olmuş populasyonun cinsiyet kompozisyonları hesaplanmıştır. En yüksek prevalans değeri yaz mevsiminde ve en yüksek istila değeri iki yaş balık sınıfında kaydedilmiştir. Parazit bulaşmış balık bireylerinin patolojik olarak incelenmesi ile solungaçlarda hemoraji, solungaç atrofisi gözlenmiştir.

Anahtar Kelimeler: Monogenea, Diplozoidae, Burdur, endemik

INTRODUCTION

Monogenea is a diverse group of ectoparasites most of which predominantly live on the gills, skin arches, and fins of a fish. A few may invade the rectal cavity, ureter, body cavity, and even the blood vascular system. World widely about 4,000 to 5,000 species of monogeneans have been described on fishes from freshwater and marine systems also at different temperature ranges (Reed et al., 2009a; Reed et al., 2009b).

Monogenean parasites transmit to another host via contagion and many of them are host specific. They have no intermediate hosts; new hosts are infected by tiny free-swimming ciliated larvae or oncomiracidia (Reed et al., 2009a; Kearn, 2011; Kearn, 2014; Bommakanti, 2016).

Diplozoids (subfamily Diplozoinae) as blood-feeding ectoparasites have a unique position in monogeneans with having unusual body morphology and a direct life cycle. They invade mainly the gills of cyprinid fishes. The life cycle includes permanent fusion of two larval forms that later turn into a single worm. Adults have the specific hook-like structure, use two haptors with four pairs of clamps to attach to fish gills, and create a X-shaped body (Pečínková et al., 2007; Hodová et al., 2018). Infected gills are pale, bloody, damaged and with excessive mucous secretion resulting in decreased gill respiratory function and mortality (Reed et al., 2009b; Al- Nasiri, 2010).

It is known that diplozoons infect a large number of fish species in Europe (Matějusová et al., 2001; Matějusová et al., 2004; Stavrescu-Bedivan and Aioanei, 2008; Stojanovski et al., 2010; Konstanzová et al., 2017) in Asia (Soylu, 2009; Ahmad et al., 2015; Al- Nasiri and Balbuena, 2016; Jirsová et al., 2018) and Africa (Dos Santos et al., 2015; Gilbert and Avenant-Oldewage, 2016a-b).

P. bliccae belongs to the *Paridiplozoon* genus from the Diplozoidae family. Several parasitological studies have been conducted on monogenean parasites in Turkey (Özer et al., 2004; Öztürk and Altunel, 2006; Soylu, 2009; Koyun, 2011; Soylu, 2012) and only a few *Paradiplozoon* species were reported.

Paradiplozoon homonion had been previously reported by Soylu and Emre (2007) from *Pseudophoxinus antalyae* and *Cyprinus carpio* in Kepez Pond; by Koyun and Altunel (2007) from *Alburnus alburnus* in Enne Dam Lake; by Öztürk (2011) from *Rutilus rutilus* in Manyas Lake; by Akmirza and Yardimci (2014) from *Abramis brama* and *Blicca bjoerkna* in Sakarya river; by Öztürk and Özer (2014) *from Scardinius erythrophtalmus* in Lower Kizilirmak and by Altan and Soylu (2018) in *Blicca bjoerkna* from Akgöl Lake.

Aydoğdu et al. (2001) found *P. megan* from *Squalius cephalus* in Doğancı Dam lake. *P. megan* was also reported in Susurluk Stream (Gürkan and Tekin-Ozan, 2012). *P. bingolensis* was described as a new species of genus in *Garra rufa* from Murat River (Civáňová et al., 2013). *P. bliccae* has been firstly reported from *Squalius fellowesii* in Doğanbaba creek (Ünal et al., 2017).

Pseudophoxinus is represented by 18 species in Anatolia, where an important diversification center for this genus is. Except for two of this species, all of them are endemic to Anatolia (Küçük et al., 2012; Küçük et al. 2013). Burdur spring minnow *P. burduricus* (Teleostei, Cyprinidae) is an endemic fish species of Turkey. It is known from several freshwater systems in Central Anatolia and in the surroundings of Lake Salda and Lake Burdur basins; Karamanlı stream, Düğer spring, Değirmendere stream, Sazak spring near Lake Yarışlı. The conservation status of the fish has been referred to category E - endangered fish (Freyhof, 2014).

There is a limited number of studies on the biological features, distribution (Küçük et al., 2012; Gülle et al., 2016), identification (Küçük et al., 2013), and length-weight relationship (Yoğurtçuoğlu et al., 2016, Ilhan and Gücer, 2018) of *P. burduricus*. And except the Innal et al. (2017), there are no data related to the parasites on *P. burduricus*.

The parasites in threatened fish species need to be investigated for the management and conservation of fish populations in natural waters (Aydoğdu et al., 2015). As mentioned above, Innal et al. (2017) recorded *Lernea cyprinacea* with the highest prevalence of 28.3 % on *P. burduricus* from Düger Spring Creek (Burdur-Turkey). The objective of this work was to investigate parasite infection of gill from *P. burduricus* in Doğanbaba Creek (Yeşilova-Burdur).

MATERIALS and METHODS

Fish sampling and dissection

Pseudophoxinus burduricus specimens were collected by electrofishing method in Doğanbaba Creek (37°35´48.35”N, 29°38´24.89” E) from January 2014 to February 2015. A total of 60 *P. burduricus* were investigated for the presence of parasite specimens. Fish specimens were transported in an oxygenated 20-litre aquarium filled with stream water. They were maintained in the aquarium for 2-3 hours and subsequently anaesthetized by MS-222. Following a standard parasitological method for the detection of diplozoid species, all *P. bliccae* specimens were removed from the gills. Monogeneans were isolated in the laboratory using a dissecting needle and stereomicroscope. To evaluate pathology, gills samples infected with the parasites were fixed in 10% neutral formalin and routinely processed.

Five micron sectioned and stained with haematoxylin eosin. The gills were examined before and after the removal of the parasites**.** Infected gills of fishes were examined under microscope. Fish age and sex were noted. Fish age was determined by using method of Lagler (1956). Fish were dissected and classified according to sexual states (immature, mature, female, and male). Prevalence, intensity, and seasonality of infection, age classes, and sex compositions of the infected population have been investigated. Prevalence (Pr %), as the percentage of hosts infected with a particular parasite species or taxonomic group and intensity (Int), as the number of individuals of a parasite species in/ on a single infected host was calculated following Bush et al. (1997). A Kruskal–Wallis test was applied to find significant differences in the prevalence of the parasite species for host fish size, ages, and seasons. The differences in parameters were considered significant at $P<0.05$.

RESULTS

This study presents the first investigation of the monogenean fauna occurring on the gills of endemic *Pseudophoxinus burduricus* species inhabiting Doğanbaba Creek. The monogenean parasite *Paradiplozoon bliccae* was found on 14 of 60 *P. burduricus* (23.33 %). A total of 86 specimens were recovered from gills of 14 fish. Prevalence and intensity of infection in different age groups and sex classes of fish species are shown in Table 1 and Table 2, respectively. Seasonal variation of infection and mean intensity are shown in Table 3.

Four age classes were determined in captured specimens of *P. burduricus*. The age group I was dominant in the population with 35 individuals and 5 of them were infected. The prevalence of infection and infection intensity was higher among age group II. There were significant differences ($p<0.05$) in the infection rates of *P. bliccae* between ages. No diplozoon was found in juvenile individuals and the group of age III.

Table 1. Prevalence and intensity of infection among different age groups of *P. burduricus*

Ages	N	N'	P	Total	Int.
0	6	0	0	0	0
I	35	5	14.29	24	4.8
II	17	9	52.94	62	6.89
III	2	0	0	0	0
Total	60	14	23.33	86	6.14

0 – I – II – III – age categories, N – total number of fish in the age category, N' – Number of infected fish, P Prevalence (%), Total – number of recovered parasites, Int. – intensity of infection

Among examined population of *P. burduricus*, male individuals had superiority in numbers (35 from 60). But female hosts had higher levels of infection. Among all infected fishes, 8 were female, and 6 were male. The prevalence rates of female and male individuals are 42.11 % and 17.14 %, respectively. The differences in *P. bliccae* parasitic infections and the sex of the fish hosts is statistically significant ($p<0.05$). Results are presented in Table 2.

Table 2. Prevalence of infection in sex groups of *P. burduricus*

Sex	N	N'	P
Immature	6	0	0
Female	19	8	42.11
Male	35	6	17.14
Total	60	14	23.33

N – total number of fish, N' – Number of infected fish, P – Prevalence (%)

The seasonal prevalence and intensity related to *P. bliccae* infection are shown in Table 3. Prevalence value was highest (45.45 %) in the summer and lowest (0 %) in autumn and it increased in winter (25.93 %). There were significant differences ($p<0.05$) in the infection rates of *P. bliccae* between seasons.

Table 3. Seasonality of infection and mean infection intesity for *P. bliccae* in *P. burduricus*

Season	N	N'	P	Total	Int.
Spring	27	7	25.93	36	5.14
Summer	11	5	45.45	27	5.4
Autumn	4	0	0	0	0
Winter	18	2	11.11	23	11.5
Total	60	14	23.33	86	6.14

N – total number of fish, N' – Number of infected fish, P – Prevalence (%), Total – number of recovered parasites, Int. – intensity of infection

Mean intensity reached a peak in winter (11.50 %), but then decreased in spring and it fell to the lowest level in autumn (0 %). The total number of *P. bliccae* was 86 whereas the maximum abundance was recorded during spring (36) and the minimum values were obtained during autumn (0); in winter, there were found 23 individual on only two host specimens.

Gross examination of the gills of *P. burduricus* revealed *P. bliccae* attached to the gills. Parasites were generally localised at filament extremities and caused irregular appearance at the gills. More than one parasite was observed on the same fish. Marked swelling, hyperaemia, and in some case haemorrhages were observed at the gills that parasites attached area. Besides, atrophy was noticed the filaments after removal of the parasites (Figure 1). Microscopical examination revealed desquamation at the epithelial layer of the gills. Hyperaemia, haemorrhage and oedema were common histopathological findings at the parasite attachment site. In some cases slight to moderate leukocyte inflammation at these areas.

Figure 1. (A) Slight hyperaemia, haemorrhage (white arrow), and irregular appearance of the gills after removing the parasites (black arrow), (B) macro appearance of the parasites that collected from the gills, (C) attached parasite (arrow) on the gill

DISCUSSION

Monogenea is a group of species-rich parasitic flatworms consisting of many described species that are commonly found on fishes and lower aquatic invertebrates. Due to having their high-degree host specificity, parasitic monogeneans are used as excellent biological indicators to unveil host-species relationships (Kmentová et al., 2016). The presence of monogeneans is regarded as a sensitive biological indicator for the health situation of their habitat (Stojanovski et al., 2009).

In this study, monegean parasite *P. bliccae* was found in *P. burduricus*. This is a typical blood-feeding ectoparasite from Diplozoidae family (Polyopisthocotylea, Monogenea) which have an obvious specificity for host species. *P. bliccae* specimens were reported from some different fish species in Europe and Asia (Matějusová et al., 2001; Al-Nasiri, 2009; Sobecka et al., 2014). Ünal et al. (2017) recorded *Paradiplozoon bliccae* for Turkey parasite fauna firstly from the gills of *Squalius fellowesii* (Cyprinidae) in Doğanbaba Creek (Yeşilova-Burdur).

Herein, a total of 86 parasites attached to the gill of their hosts were obtained from 14 infected fish specimens with a prevalence 23.3 % and quite high mean intensity of infection 6.14. According to the data collected so far, different infectious densities were detected in different fish species. Ünal et al. (2017) found that prevalence and mean intensity were 28.3 % and 3, respectively in *Squalius felowesii*. Al-Nasiri (2009) recorded *P. bliccae* with their percentage incidence of infection: from *Cyprinion macrostomum* (13.7 %) and *Cyprinus carpio* (18.2 %) in Tigris river passing through Tikreet city,

Salah Al-Deen province. Sobecka et al. (2014) reported *P. bliccae* from *Leuciscus idus* in Lake Dabie, Poland with prevalence of 1.81 % and mean intensity of 1.50.

Many factors affect the prevalence of paradiplozoon infection in freshwater fishes. There are several studies that reveal these relations (Koyun and Altunel, 2007; Aydoğdu et al., 2008; Tombi et al., 2014; Gilbert and Avenant-Oldewage, 2016b).

Of 60 *P. burduricus* classified according sex combination, 35 male and 19 female fish specimens, carried 6 and 8 *P. bliccae*, respectively. There was no infection in any of 6 immature individuals. Prevelance was found to be higher in females (42.11 %) than in the males (17.14 %). Contrary of these results, male dominancy in infection was reported in studies of Tunç and Koyun (2018) about *P. homoion* in *Alburnus mossulensis* (47.61 %) and Ünal et al. (2017) concerning *P.bliccae* (52.9 %) in *S. felowesii*.

The ages of examined specimens ranged from 0 to III and total prevalence was 6.14 %. The one age class showed dominancy in the population (35 specimens). In our study highest prevalence is reported to be 52.94 % in the two age class while in Ünal et al. (2017) maximum prevalence were reported in the four-age group of *Squalius fellowesii* (50 %).

In terms of seasonality, in this study prevalence of *P. bliccae* was the highest (45.45 %) in the summer and mean intensity reached a peak in winter (11.5 %). The maximum abundance occurred during spring and minimum during autumn with no parasitism. Ünal et al. (2017) repoted that *P. bliccae* prevalence was in the highest value in summer.

According to previous studies dealing with other *Paradiplozoon* sepecies, conclusions show that water temperature may affect parasitism. For example, *P. homoion* has been reported in different fish species. Pečínková et al. (2005) found *P. homoion* specimens in *Gobio gobio* with highest prevalence 93.33 % in winter. In Soylu (2007), maximum of monthly prevalence was recorded in January (79.3 %) and lowest in May (43.2 %) from *Pseudophoxinus antalyae* while Koyun and Altunel (2007) reported maximum in summer in *Alburnus alburnus* (69.0 %). Öztürk and Özer (2014) found highest infection percentages in *Scardinius erythropthalmus* and *Vimba vimba* in summer 54.6 % and in spring 21.1 %, respectively. By Gilbert and Avenant-Oldewage (2016a), infestations of *Paradiplozoon icthyoxanthon* in *Labeobarbus aeneus* were most intensive (90.0 %) in the summer. Stojanovski et al. (2010) observed differences in invasion of *P. ergensi* according to the season in *Leuciscus cephalus albus* from Lake Ohrid and reported highest value in spring (25.0 %).

There are several studies interested in *Pseudophoxinus* parasites in Turkey. By Soylu and Emre (2007), *Paradiplozoon homoion, Dactylogyrus ergensi,* and *Dactylogyrus sphyrna* were reported on the gills of *Pseudophoxinus antalyae* from Kepez I Hydro Electric Power Plant Loading Pond (Antalya, Turkey). Soylu (2007) found that *P. antalyae* were infected by *P. homoion* with an overall prevalence of 54.6 %. Aydoğdu et al. (2011) reported that *Contracaecum* sp. larvae attached in the abdominal cavity of *Pseudophoxinus battalgilae* that lived in Antalya Bay with a total prevalence 47.6 %. Aydoğdu et al. (2014) conducted a study in İncesu Stream – Konya Province and four parasitic helminth species were detected; *Asymphylodora imitans* (28.2 %), *Bothriocephalus acheilognathi* (1.08 %) and *Pomphorhynchus laevis* (52.1 %) in the intestines of *Pseudophoxinus crassus* while *Gyrodactylus latus* (5.4 %) in the gills of host fishes. The study was carried out in Düger Creek by Innal et al. (2017) and *Lernaea cyprinacea* were found in *P. burduricus* overall prevalence (28.3 %) as mentioned above. Lesley, Aydoğdu, and Emre (2015) dissected *Pseudophoxinus fahrettini* and found 11 specimes of *Pomphorhynchus spindletruncatus* with 31.4 % prevalence from Aksu, Pazarköy.

Our work, for the first time, shows that the occurrence of *P. bliccae* hosted by *P. burduricus* contributed to the knowledge of distribution of this parasite in Turkey. Additionally, our results have indicated that both seasonal and host factors (age and sex) may influence the levels of infection of *P. burduricus* with this parasite species. Even if there is a need to investigate additional material for species identification and molecular analyses together with a wide geographical investigation to obtain more information about monogenean fauna in the inland waters of Turkey.

Acknowledgments: This study was sponsored by MAEU BAP, Turkey (Project No: 0217 YL 14).

REFERENCES

Ahmad, F., Sofi, T.A., Fazili, K.M., Sheikh, B.A., Sofi, O.M.U.D., & Jaswal, K. (2015). Comparative karyological analysis of three Diplozoon species (Monogenea, Diplozoidae), gill parasites of *Schizothorax* species – first report from the Kashmir Valley, India. *Scientia Parasitologica*, *16*(3), 71-82.

Akmirza, A., & Yardımcı, R.E. (2014). Fish parasites of the Sakarya River, Turkey. *Journal of Academic Documents for Fisheries and Aquaculture*, *1*, 23-29.

Al-Nasiri, F.S. (2009). Diplozoid species (Monogenea) parasitizing gills of some cyprinid fishes from Tigris river passing through Tikreet city, Salah Al-Deen province. *Iraqi Journal of Agricultural Science*, *14*(5), 182-186.

Al-Nasiri, F.S. (2010). First record of *Paradiplozoon amurensis* (Monogenea: Diplozoidae) in Iraq from gills of the cyprinid fish *Cyprinion macrostomum*. *Parassitologia*, *52*, 439- 440.

Al-Nasiri, F.S., & Balbuena, J.A. (2016). *Paradiplozoon iraqensis* n. sp. (Monogenea:Diplozoinae) from *Cyprinion macrostomum* (Cyprinidae) in the Tigris River, Iraq. *Acta Parasitologica*, *6*(2), 291-298.

Altan, A., & Soylu, E. (2018). Composition and structure of parasite communities in white bream *Blicca bjoerkna* from Lake Büyük Akgöl, Sakarya-Turkey. *Ege Journal of Fisheries and Aquatic Sciences*, *35*(2), 199-206. https://doi.org/10.12714/egejfas.2018.35.2.14

Aydoğdu, A., Yıldırımhan, H.S., & Altunel, F.N. (2001). Occurrence of helminth in chub (*Leuciscus cephalus*) of the Dogancı Dam Lake, Turkey. *Bulletin of the European Association of Fish Pathologist*, *21*(6), 246-251.

Aydoğdu, A., Emence, H., & Innal, D. (2008). Gölbaşı Baraj Gölü (Bursa)'ndeki eğrez balıkları (*Vimba vimba* L., 1758)'nda görülen helmint parazitler. *Türkiye Parazitoloji Dergisi*, *32*(1), 86-90.

Aydoğdu, A., Emre, Y., Emre, N., & Altunel, F.N. (2011). The Occurrence of helminth parasites (Nemathelminthes) in some freshwater fish from streams discharging into Antalya Bay in Antalya, Turkey: Two new host records from Antalya. *Turkish Journal of Zoology*, *35*(6), 859–864.

Aydoğdu, A., Erk'akan, F., Keskin, N., Innal, D., & Aslan, I. (2014). Helminth communities of the Turkish endemic fish, *Pseudophoxinus crassus* (Ladiges, 1960): four helminth parasites for a new host record. *Journal of Applied Ichthyology*, *30* (5), 937-940. https://doi.org/10.1111/jai.12442

Aydoğdu, A., Keskin, N., Erk'akan, F., & Innal, D. (2015). Occurence of helminth parasites in the Turkish endemic fish, *Squalius anatolicus* (Cyprinidae). *Bulletin of the European Associatıon of Fısh Pathologists*, *35*(5), 185-191.

Bommakanti, L. (2016). Prevalence of *Gyrodactylus sp*. in *Channa punctatus* (Bloch, 1793) monogenean ectoparasite Family: Gyrodactilidae at Lower Manair Dam. *International Journal of Current Microbiology and Applied Sciences*, *5*(9), 496-507. https://doi.org/10.20546/ijcmas.2016.509.055

Bush, A.O. Lafferty, K.D. Lotz, J.M., & Shostak, W. (1997). Parasitology meets ecology on its own terms: Margolis *et al.* Revisited. *Journal of Parasitology*, *83*, 575-583. https://doi.org/10.2307/3284227

Civáňová, K., Koyun, M., & Koubková, B. (2013). The molecular and morphometrical description of a new diplozoid species from the gills of the *Garra rufa* (Heckel, 1843) (Cyprinidae) from Turkey-including commentary on taxonomic division of Diplozoidae. *Parasitology Research*, *112*, 3053-3062. https://doi.org/10.1007/s00436-013-3480-6

Dos Santos, Q.M., Jansen van Vuuren, B., & Avenant-Oldewage, A. (2015). *Paradiplozoon vaalense* n. sp. (Monogenea: Diplozoidae) from the gills of moggel, *Labeo umbratus* (Smith, 1841), in the Vaal River System, South Africa. *Journal of Helminthology*, *89*, 58-67. https://doi.org/10.1017/S0022149X1300059X

Freyhof, J. (2014). *Pseudophoxinus burduricus*. The IUCN Red List of Threatened Species, 2014: e.T54126285A54128761. http://dx.doi.org/10.2305/IUCN.UK.20141.RLTS.T54126285A54128761.en. Downloaded on 10 July 2018.

Gilbert, B.M., & Avenant-Oldewage, A. (2016a). Effects of altered water quality and trace elements on the infection variables of *Paradiplozoon ichthyoxanthon* (Monogenea: Diplozoidae) from two sites in the Vaal River system, South Africa. *Acta Parasitologica*, *61*(1), 52-62. https://doi.org/10.1515/ap-2016-0005

Gilbert, B.M., & Avenant-Oldewage, A. (2016b). Seasonal occurrence and microhabitat specificity of *Paradiplozoon ichthyoxanthon* Avenant-Oldewage in Avenant-Oldewage *et al.*, 2014 (Monogenea: Diplozoidae) infecting *Labeobarbus aeneus* (Burchell) (Teleostei: Cyprinidae) from the Vaal Dam, South Africa: water quality and host size as determining factors?. *Folia Parasitologica*, *63*, 4-10.

Gülle, İ. Küçük, F., Innal, D., & Güçlü, S.S. (2016). Burdur İli Balıkları: Biyoçeşitlilik Envanteri, Popülasyon ve Habitat Durumları. *Mehmet Akif Ersoy Üniversitesi Fen Bilimleri Enstitüsü Dergisi*, *7*(Ek 1), 232-239.

Gürkan, Ü., & Tekin-Özan, S. (2012). Susurluk Çayı (Bursa-Balıkesir)'ndaki tatlı su kefali (*Squalius cephalus* L.,) 'nin helmint faunası. *Süleyman Demirel University Journal of Science (E-Journal)*, *7*(2), 77-85.

Hodová, I., Sonnek, R., Gelnar, M., & Valigurová, A. (2018). Architecture of *Paradiplozoon homoion:* A diplozoid monogenean exhibiting highly-developed equipment for ectoparasitism. *PLoS ONE*, *13*(2), e0192285. https://doi.org/10.1371/journal.pone.01922855

Ilhan, A., & Gücer, M. (2018). Length-weight relationship of eight endemic *Pseudophoxinus* species to Anatolia. *Ege Journal of Fisheries and Aquatic Sciences*, *35*(1), 73-77. https://doi.org/10.12714/egejfas.2018.35.1.12

Innal, D., Avenant-Oldewage, A., Doğangil, B., Stavrescu-Bedivan, M. M., Özmen, Ö., & Mavruk, S. (2017). Susceptibility of endemic and non-indigenous fish to *Lernaea cyprinacea* (Copepoda: Lernaeidae): a case study from Düger Spring Creek (Burdur-Turkey). *Bulletin of the European Association of Fish Pathologists*, *37*(3), 96-105.

Jirsová, D., Ding, X., Civáňová, K., Jirounková, E., Ilgová, J., Koubková, B., Kašný, M., & Gelnar, M. (2018). Redescription of *Paradiplozoon hemiculteri* (Monogenea, Diplozoidae) from the type host *Hemiculter leucisculus*, with neotype designation. *Parasite*, *25*(4), 1-8. https://doi.org/10.1051/parasite/2018004

Kearn, G.C. (2011). Monogeneans, the ultimate fish parasites. *Biologist*, *58*, 28-32.

Kearn, G.C. (2014). Some aspects of the biology of Monogenean (Platyhelminth) parasites of marine and freshwater fishes. *Oceanography*, *2(1),* 1-8. https://doi.org/10.4172/2332-2632.1000117

Kmentová, N., Gelnar, M., Koblmüller, S., & Vanhove, M.P.M. (2016). First insights into the diversity of gill monogeneans of *Gnathochromis* and *Limnochromis* (Teleostei, Cichlidae) in Burundi: do the parasites mirror host ecology and phylogenetic history*?*. *Journal of Life and Environmental Sciences*, *4*, e1629. https://doi.org/10.7717/peerj.1629

Koyun, M., & Altunel, F.N. (2007). Metazoan parasites of bleak (*Alburnus alburnus*), crucian carp (*Carassius carassius*) and golden carp (*Carassius auratus*) in Enne Dam Lake, Turkey. *International Journal of Zoology Research*, *3*, 94-100. https://doi.org/10.3923/ijzr.2007.94.100

Koyun, M. (2011). Seasonal distribution and ecology of some *Dactylogyrus* species infecting *Alburnus alburnus* and *Carassius carassius* (Osteichthyes: Cyprinidae) from Porsuk River, Turkey. *African Journal of Biotechnology*, *10*(7), 1154-1159.

Konstanzová, V., Koubková, B., Kašný, M., Ilgová, J., Dzika, E., & Gelnar, M. (2017). An ultrastructural study of the surface and attachment structures of *Paradiplozoon homoion* (Bychowsky & Nagibina, 1959) (Monogenea: Diplozoidae). *Parasites and Vectors*, *10*(261), 1-10.

Küçük, F., Atalay, M.A., Güçlü, S.S., & Gülle, İ. (2012). Türkiye'de yayılış gösteren *Pseudophoxinus* (Teleostei: Cyprinidae) türlerinin bazı morfolojik özellikleri ve zoocoğrafik dağılımları. *Eğirdir Su Ürünleri Fakültesi Dergisi*, *8*(2), 1-9.

Küçük, F., Gülle, İ., Güçlü, S.S., Çiftçi, Y., & Erdoğan, Ö. (2013). A new *Pseudophoxinus* (Teleostei, Cyprinidae) species from Southwestern Anatolia, with remarks on the distribution of the genus in western Anatolia. *ZooKeys*, *320*, 29-41. https://doi.org/10.3897/zookeys.320.4447

Lagler, K. F. (1956). Freshwater fishery biology. Wm. C. Brown Company, Dubuque, lowa.

Lesley, R., Aydoğdu, A., & Emre, Y. (2015). *Acanthocephala* from seven species of freshwater fish (Cyprinidae and Cyprinodontidae) from Turkey with the description of a new species of Paralongicollum (Pomphorhynchidae). *Comparative Parasitology*, *82*(1), 94-100. https://doi.org/10.1654/4709.1

Matějusová, I., Koubková, B., D'Amélio, S., & Cunningham, C.O. (2001). Genetic characterization of six species of diplozoids (Monogenea; Diplozoidae). *Parasitology*, *123*(5), 465-474. https://doi.org/10.1017/S0031182001008617

Matějusová, I., Koubková, B., & Cunningham, C. (2004). Identification of European Diplozoids (Monogenea, Diplozoinae) by restriction digestion of the ribosomal RNA internal transcribed spacer. *Journal of Parasitology*, *90*(4), 817-822. https://doi.org/10.1645/GE-138R.

Özer, A., Öztürk, T., & Öztürk, M.O. (2004). Prevalence and intensity of *Gyrodactylus arcuatus* Bychowsky, 1933 (Monogenea) infestations on the three-spined stickleback, *Gasterosteus aculeatus* L., 1758. *Turkish Journal of Veterinary and Animal Sciences*, *28*, 807-812.

Öztürk, M.O., & Altunel, F.N. (2006). Occurrence of *Dactylogyrus* infection linked to seasonal changes and host fish size on four cyprinid fishes in Lake Manyas, Turkey. *Acta Zoologica Academiae Scientiarum Hungaricae*, *52*(4), 407-415.

Öztürk, M.O. (2011). Investigations on *Paradiplozoon homoion* (Monogenea, Diplozoidae) infection of some fishes from Lake Manyas (Balıkesir). *Fırat University Journal of Science*, *23*(1), 57-61 (In Turkish).

Öztürk, T., & Özer, A. (2014). Monogenean fish parasites, their host preferences and seasonal distributions in the lower Kızılırmak Delta (Turkey). *Turkish Journal of Fisheries and Aquatic Sciences*, *14*, 367-378.

Pečínková, M., Matějusová, I., Koubková, B., & Gelnar, M. (2005). Classification and occurrence of abnormally developed *Paradiplozoon homoion* (Monogenea, Diplozoidae) parasitizing gudgeon *Gobio gobio*. *Diseases of Aquatic Organisms*, *64*, 63–68. https://doi.org/10.3354/dao064063

Pečínková, M., Vøllestrad, L.A., Koubková, B., & Gelnar, M. (2007). Asymmetries in the attachment apparatus of a gill parasite. *Journal of Zoology*, *272*, 406-414.

Reed, P., Francis-Floyd, R., & Klinger, R.E. (2009a). Monogenean parasites of fish. University of Florida UF, IFAS Extension FA28, 1-4.

Reed, P., Francis-Floyd, R., Klinger, R.E., & Petty, D. (2009b). Monogenean parasites of fish. Fisheries and Aquatic Sciences. University of Florida UF, IFAS Extension. FA28: 1-10pp.

Sobecka, E., Jurkiewicz, E., & Piasecki, W. (2014). Parasite fauna of Ide, *Leuciscus idus* (L.) in Lake Dnbie, Poland. *Acta Ichthyologica Et Piscatoria*, *34*(1), 33-42. https://doi.org/10.3750/AIP2004.34.1.04.

Soylu, E., & Emre, Y. (2007). Monogenean and cestode parasites of *Pseudophoxinus antalyae*, Bogutskaya 1992 and *Cyprinus carpio* Linnaeus, 1758 from Kepez Antalya, Turkey. *Bulletin of the European Association of Fish Pathologist*, *27*(1), 23-28.

Soylu, E. (2007). Seasonal occurrence and site selection of *Paradiplozoon homoion* (Bychowsk and Nagibina, 1959) on the gills of *Pseudophoxinus antalyae* Bogutskaya, 1992 from Kepez-Antalya, Turkey. *Bulletin of the European Association of Fish Pathologist*, *27*(2), 71-74.

Soylu E. (2009). Monogenean parasites on the gills of some fish species from Lakes Sapanca and Durusu, Turkey. *E.U. Journal of Fisheries and Aquatic Sciences*, *26*(4), 247-251.

Soylu, E. (2012). Monogenean parasites of white bream (*Blicca bjoerkna* Linnaeus, 1758) in Lake Sapanca, Turkey. *Journal of the Faculty of Veterinary Medicine, Kafkas University*, *18*(Suppl-A), A23-A28.

Stavrescu-Bedivan, M.M., & Aioanei, F.T. (2008). Some aspects of branchial parasitism in *Leuciscus cephalus* (Teleostei, Cyprinidae): first record of *Lamproglena compacta* (Cyclopoida, Lernaeidae) in Romania. *Aquaculture, Aquarium, Conservation and Legislation Bioflux*, *1*(2), 111-115.

Stojanovski S., Hristovsk N., Cakic P., Nedeva I., Karaivanova E., & Atanasov G. (2009). Monogenean trematods-parasites of some cyprinid fishes from lakes Ohrid and Prespa (Macedonia). *Biotechnology & Biotechnological Equipment*, *23*(1), 360-364. https://doi.org/10.1080/13102818.2009.10818439

Stojanovski, S., Hristovski, N., Cakic, P., Hristovski, M., Velkova-Jordanoska, L., & Blazekovic D. (2010). Monogenean trematods of chub *Leuciscus cephalus albus* Bonaparte, 1838 from The Lake Ohrid (Macedonia). *Biotechnology and Biotechnological Equipment*, *24* (Special edition), 623-627.

Tombi, J., Akoumba, J.F., & Bilong Bilong, C.F. (2014). The monogenean community on the gills of *Oreochromis niloticus* from Melen fish station in Yaounde, Cameroon. *International Journal of Modern Biological Research*, *2*, 16-23.

Tunç, A.Ö., & Koyun, M. (2018). Seasonal infection of metazoan parasites on mosul bleak (*Alburnus mossulensis*) inhabiting Murat River and its tributaries in Eastern Anatolia, Turkey. *Türk Tarım ve Doğa Bilimleri Dergisi*, *5*(2), 153-162. https://doi.org/10.30910/turkjans.421357

Ünal, M.C., Innal, D., Civáňová, K., Stavrescu –Bedivan, M.M., Koubková, B., Özmen, Ö., & Gelnar, M. (2017). Identification of two gill parasites *Lamproglena compacta* (Copepoda: Lernaeidae) and *Paradiplozoon bliccae* (Monogenea: Diplozoidae) from endemic aegean chub (*Squalius fellowesii*). *Bulletin of the European Association of Fish Pathologist*, *37* (4), 135-147.

Yoğurtçuoğlu, B., Atalay, M.A., & Ekmekçi, F.G. (2016). Length–weight and length–length relationships for three endemic *Pseudophoxinus* species in Turkey. *Journal of Applied Ichthyology, 32*, 495-496. https://doi.org/10.1111/jai.12965