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# Occurrence of Cystacanths of *Pomphorhynchus laevis* (Zoega in Müller, 1776) (Acanthocephala) in its Intermediate Host *Gammarus obnixus* Karaman & Pinkster, 1977 (Amphipoda): A Comparative Study

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**Abstract:** The amphipod *Gammarus obnixus* Karaman & Pinkster, 1977 is an intermediate host for the acanthocephalan parasite *Pomphorhynchus laevis* (Zoega in Müller, 1776). Specimens of *G. obnixus* were collected from two sampling stations: (1) Işıklı Spring (clear, cold water with a fast current and hard substratum with a gravel-covered bottom) and (2) a rainbow trout net-cage area (dense community of macrophytes on a soft substratum due to net-cages residues and high water turbidity). The aim of this study was to determine monthly changes of the larval occurrence of *P. laevis* and to understand the effect of the fish farming on the infection rate with cystacanths of *P. laevis*. A total of 14,027 specimens of *G. obnixus* were collected. Cystacanths of *P. laevis* were found in the hemocoel of the gammarids. At the Işıklı Spring, *P. laevis* infected 832 (16.2%) of the 5149 *G. obnixus* examined over the total sampling period and had a mean intensity of the cystacanths of 1.5 and mean abundance 0.2 per amphipod individual. At the net-cage area, *P. laevis* infected 3480 (39.2%) of the 8878 *G. obnixus*, with a mean intensity of 2.3 and mean abundance 0.9 per amphipod host. Amphipods in all 12 length classes were infected with *P. laevis*. The maximum intensity of the infection was 16 cystacanths of *P. laevis* in a single *G. obnixus* in August. Sex ratio of the cystacanths was approximately 1:1. Males of *G. obnixus* from both stations were more heavily infected than females. The results showed that the population density and infection rates of *G. obnixus* were higher at the net-cage area than at the Işıklı Spring.

**Key words:** Cystacanths, *Pomphorhynchus laevis*, intermediate host, *Gammarus obnixus*.

## Introduction

Members of the phylum Acanthocephala are commonly known as "spiny-headed worms" and there are about 1200 species known (Amin 2013). All known acanthocephalans are endoparasites and adults live in the intestines of vertebrates, including fishes (Golvan 1994). Various species of fish acanthocephalan parasites, which have an indirect life cycle, exploit amphipod crustaceans as intermediate hosts, in which they develop from egg to acanthella and cystacanth (Taraschewski 2000, Kennedy 2006, Perrot-Minnot et al. 2011, Dianne et al. 2012). Larvae of *Polymorphus minutus* were found to co-occur with cystacanths of *Pomphorhynchus laevis* in *Echinogammarus stammeri* (Dezfuli &

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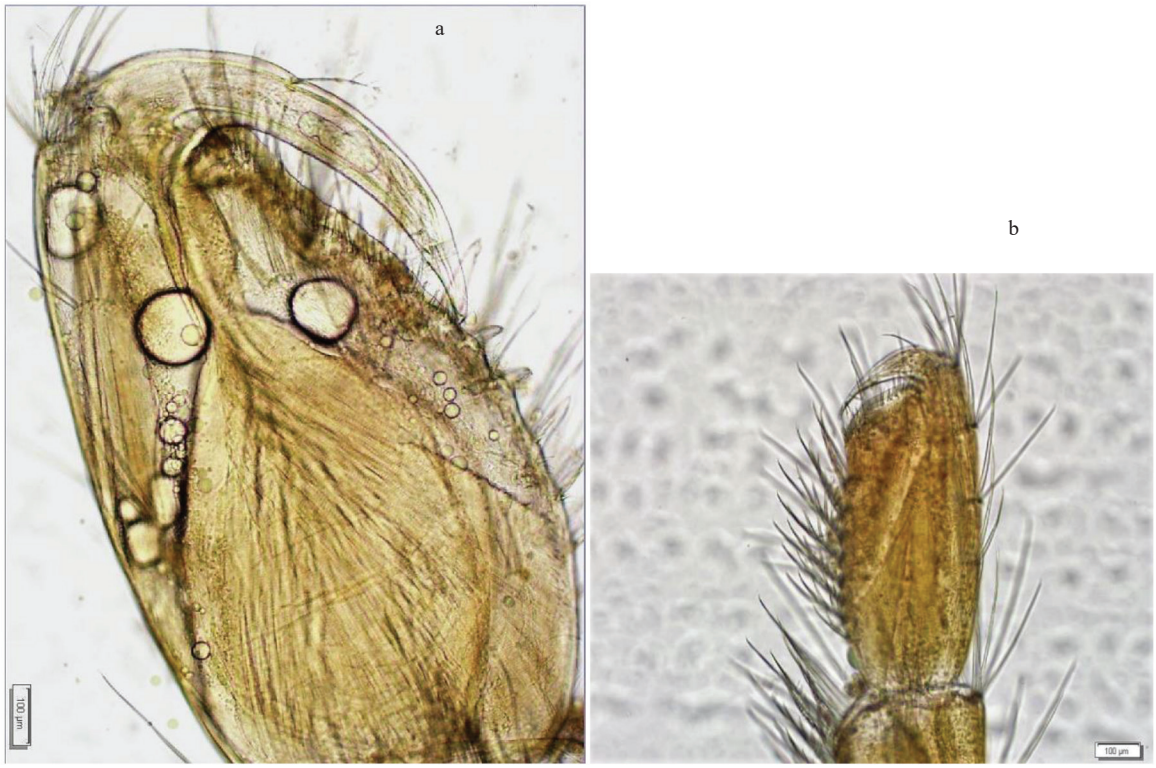



**Fig. 1.** Propodus and nail of dactylus on gnathopod 1 of *Gammarus obnixus* from the Işıklı Spring: a. male; b. female.

Giari 1999). All acanthocephalan fish parasites require trophic transmission to complete their life cycle. The acanthocephalan parasite is transmitted by crustacean gammarids to its paratenic or final hosts, fish (Bakker et al. 1997). *Pomphorhynchus laevis* use some cyprinid and salmonid fish as definitive hosts and several amphipod crustacean species as intermediate hosts (Kennedy 2006). Interactions between acanthocephalan parasites and their amphipod hosts have been widely studied. Some parasite species have evolved the ability to alter the behaviour of their intermediate host that increases the probability of consumption by the definitive host (Taraschewski 2000, Cézilly & Perrot-Minnot 2005, Mormann 2010). *Pomphorhynchus* and *Polymorphus* are known to change the photophobic behaviour of their amphipod intermediate hosts (Bakker et al. 1997). *Pomphorhynchus laevis* manipulates amphipods to increase their susceptibility to fish predation (Dezfuli et al. 2000, Perrot-Minnot et al. 2007).

There is no information available on the intermediate hosts of fish acanthocephalans in Turkey. In the present study, we found cystacanths of *P. laevis* in the hemocoel of *Gammarus obnixus*. Adults of *P. laevis* were previously reported in the intestine of *Oncorhynchus mykiss* (see Çevrimel & Soylu 2017) and *Squalius carinus* (see Soylu et al. 2017) caught from the same study sites. We focused on studying the monthly changes of occurrence of larval *P. laevis* within its intermediate host *G. obnixus,* which was a prevalent amphipod in both Işıklı Spring and rainbow trout net-cage area. In addition, we examined whether there were any differences of infection parameters between the two stations.

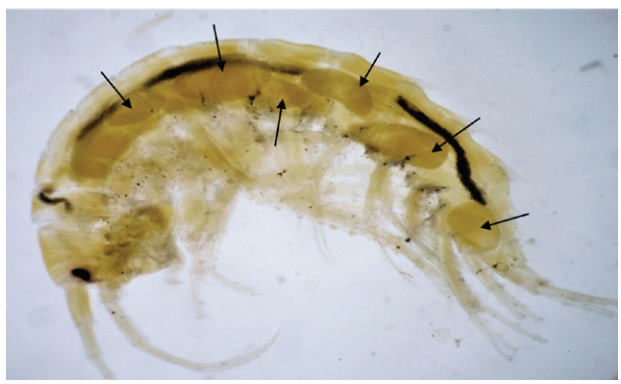


**Fig. 2.** Cystacanths of *Pomphorhynchus laevis* (arrows) in the hemocoel of *Gammarus obnixus* from the Işıklı Spring.

## Materials and Methods

Specimens of *G. obnixus* were taken between January and November 2015 from the Işıklı Spring (38º18′55.67″N, 29º51′38.29″E). The first trout net-cage was located 700 m away from the spring. There

| | |
|---|---|
| ggtctgatgt atgttttggt tggtgtgtga ggggggctaa tgggattttc tataaggcta | 60 |
| ttaattcgat tagagctagg gagaggaggg gtttggatag gaagagaggc tgtgtataat | 120 |
| gttttagtga ctagacatgc tgttataata gtatttttttc tagtaatacc agtatttatg | 180 |
| ggaggatttg gtaattggct catgccagtt atgttaggat tgagggacat ggccctccca | 240 |
| cgactgaata atttgaggct tattctactt atcgctaggt tgggaattat aggagtatcc | 300 |
| ctgcttttag gagggggtgg ggctggttgg acaatgtatc cacccctcat gttgggggat | 360 |
| tacaggtctg gtgtagctgt tgacctaatg atcctgaggt tgcatgtagt aggtctttcc | 420 |
| tctatcctag gctcaatcaa catcctgatt acatgggtag ccgggaggag ggtggtgtat | 480 |
| agagtagaac aggcacctct gtttgtatgg gctttagtaa cgaccgctgg cttagtggtt | 540 |
| ttaacggtcc cagtcttggc ggcagcttta acgatgcttt tgatagaccg taatttgaat | 600 |
| gccagatttt ttga | 614 |

**Fig. 3.** Sequences of mitochondrial partial cytochrome oxidase subunit 1 *COI* gene of the acanthocephalan specimen from the Işıklı Spring.

was a 5 m difference in altitude between the spring pool and the net cage area, which contained 70 cages. The Işıklı Spring had clear, cold water with a fast current and hard substratum with a gravel-covered bottom. In contrast, the trout net-cage area featured dense community of macrophytes on a soft substratum, resulting from net-cage residues and high water turbidity. In total, 14,027 specimens of *Gammarus obnixus* were collected (5149 specimens from the Işıklı Spring and 8878 specimens from the net cage area). Specimens were collected through sweeping over submerged plants with a hand-held net with a two-millimetre mesh. Collected amphipod specimens were fixed in 4% formalin, cleared in lactic acid-glycerine-water and then examined for infection of *Pomphorhynchus laevis*. The total length of specimens of *G. obnixus* was measured to the nearest millimetre, from the tip of the rostrum to the end of the telson. Female and male gammarids were differentiated by the shape and size of propodus (males have large gnathopods, nearly twice the size of those of the females), their hook-like dactylus attached to the distal end of gnathopods 1 and 2 (Fig. 1a, 1b) and the presence of eggs or embryos in the brood pouch (Karaman & Pinkster 1977, Ware & Sandefur 2009). Infected gammarids were separated for counting of cystacanths (Fig. 2). The number of acanthocephalans present, their sex and length were recorded for each individual. The intestines of 21 *Chondrostoma meandrense* were examined for the presence of *P. laevis*. Identification of acanthocephalan specimens was performed as described by Špakulová et al. (2011) using unfixed fresh material. Immediately after collection, some acanthocephalan specimens were washed in saline and then fixed in 90–100% ethanol for mitochondrial and nuclear sequencing.

# Results

Morphological characteristics of the cystacanths collected from the hemocoel of *G. obnixus* and mature specimens of *P. laevis* collected from the intestine of *C. meandrense* inhabiting the study area were compared. This comparison were based on the dimensions and shape of proboscis, length of the proboscis hooks and neck, number of longitudinal rows of proboscis hooks and number of hooks in each row. Consequently, acanthocephalan larvae collected from *G. obnixus* was identified as *P. laevis.* Sequencings of mitochondrial partial cytochrome oxidase subunite 1 *COI* gene of the acanthocephalan specimens confirmed the morphological identification (Fig. 3).

A total of 14,027 specimens of *G. obnixus* were collected from the two sampling stations. Yellow-orange coloured cystacanths of *P. laevis* were seen in the hemocoel of *G. obnixus* on fresh unfixed materials. Some melanised cystacanths were also found within the gammarids.

**Sampling Station I (Işıklı Spring, St-I).** Cystacanths of *P. laevis* infected 832 (16.2%) of the 5149 individuals of *G. obnixus* examined from the Işıklı Spring. Out of them, 3049 (59.2%) were females and 2100 (40.8%) were males. The total number of cystacanths recovered from the infected *G. obnixus* was 1265. Mean intensity and mean abundance of cystacanth for the total sampling period were 1.5 and 0.2, respectively. There were monthly changes in occurrence of cystacanths in *G. obnixus* (Table 1). The prevalence of cystacanths in *G. obnixus* changed from 4.2% in March to 30.6% in June, although the monthly differences were not significant (Mann-Whitney U-test Z=12; P>0.05). The largest number of worms per individual (16 cysta-

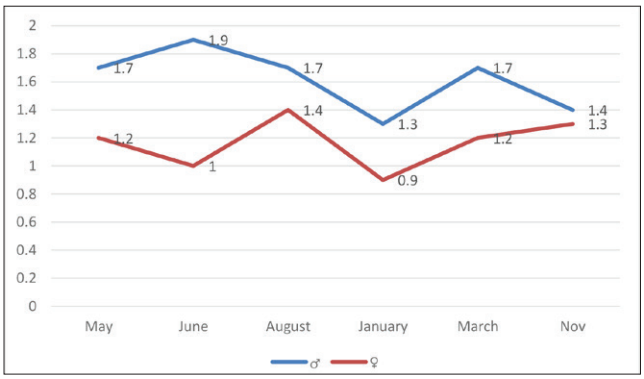



**Fig. 4.** Monthly change in the mean intensity of infection with *Pomphorhynchus laevis* in males and females of *Gammarus obnixus* at the Işıklı Spring (St–I).

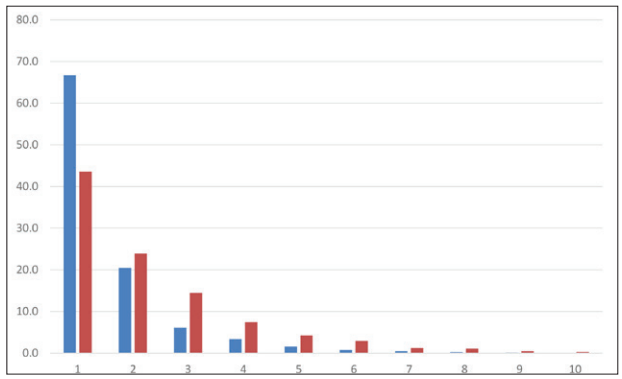



**Fig. 5.** Frequency distribution of *Pompohynchus laevis* cysacanths in *Gammarus obnixus* from Işıklı Spring (St-I) and net-cage area (St-II).

**Table. 1** Monthly changes in the occurrence of cystacanths of *Pomphorhynchus laevis* in *Gammarus obnixus* from the Işıklı Spring (St–I).

| Months | Number of *Gammarus obnixus* examined | Females | Infected females (%) | Collected cystacanth | Males | Infected males (%) | Collected cystacanth | Total prevalence (%) |
|---|---|---|---|---|---|---|---|---|
| January | 244 | 155 | 16 (10.3) | 15 | 89 | 23 (25.8) | 31 | 16.0 |
| March | 1266 | 865 | 26 (3.0) | 31 | 401 | 27 (6.7) | 45 | 4.2 |
| May | 2008 | 1103 | 108 (9.8) | 130 | 905 | 181 (20.0) | 311 | 14.4 |
| June | 754 | 334 | 55 (16.5) | 54 | 420 | 176 (41.9) | 326 | 30.6 |
| August | 636 | 458 | 94 (20.5) | 129 | 178 | 54 (30.3) | 94 | 23.3 |
| November | 241 | 134 | 16 (11.9) | 20 | 107 | 56 (52.3) | 79 | 29.9 |
| Total | 5149 | 3049 | 315 | 379 | 2100 | 517 | 886 | |

**Table 2.** Mean intensity and prevalence of larval infection with *Pomphorhynchus laevis* in *Gammarus obnixus* in relation to length classes from the Işıklı Spring (St–I).

| Length class (mm) | Number of infected amphipods | Number of parasites | Mean number of parasites | Prevalence (%) |
|---|---|---|---|---|
| 6 | 12 | 13 | 1.1 | 1.4 |
| 7 | 32 | 43 | 1.3 | 3.8 |
| 8 | 61 | 72 | 1.2 | 7.3 |
| 9 | 73 | 91 | 1.2 | 8.8 |
| 10 | 103 | 134 | 1.3 | 12.4 |
| 11 | 119 | 153 | 1.3 | 14.3 |
| 12 | 159 | 264 | 1.7 | 19.1 |
| 13 | 145 | 247 | 1.7 | 17.4 |
| 14 | 84 | 162 | 1.9 | 10.2 |
| 15 | 37 | 77 | 2.1 | 4.4 |
| 16 | 7 | 19 | 1.3 | 0.9 |
| Total | 832 | 1265 | | |

canths) was recorded in *G. obnixus* with length of 12 mm. The mean intensity of the cystacanths of *P. laevis* in *G. obnixus* changed from 1.1 in 6 mm to 2.1 in 15 mm size classes. Prevalence of the infection varied from 1.4% in 6 mm to 19.1% in 12 mm size classes (Table 2). The monthly differences of the mean intensity of cystacanths in males and females of *G. obnixus* (Fig. 4) varied significantly ($p=0.009$, $p<0.05$ and $p=0.027$, $p<0.05$, respectively). Overall, 542 (10.5%) of the examined *G. obnixus* had one cystacanth, 171 (3.3%) had two and 53 (1.0%) had three cystacanths. The frequency distribution of cystacanths of *P. laevis* in *G. obnixus* from the two sampling stations is shown in Fig. 5. No significant differences were observed between infections in male and female *G. obnixus*. Mean intensity and mean abundance of the worms were, respectively, 1.2 and 0.1 in female and 1.7 and 0.4 in male *G. obnixus*. The mean percentage of infected egg-carrying *G. obnixus* was 23.8% from those animals collected from the Işıklı Spring.

**Sampling Station II (Net cage area, St-II).** Cystacanths infected 3480 (39.2%) of the examined 8878 individuals of *G. obnixus* in the net-cage area. These were 3973 (44.8%) females and 4905 (55.2%) males. The total number of larvae of *P. laevis* collected from the infected amphipods was 7953 individuals. Mean intensity and mean abundance of cystacanth for the total sampling period were 2.3 and 0.9, respectively. The monthly changes in occurrence of cystacanths in *G. obnixus* are presented in Table 3.

The prevalence of cystacanths in *G. obnixus* changed from 58.7% in August to 18.3% in November and the monthly variation was significant (Mann-Whitney U-test Z=9, p<0.05). *Gammarus obnixus* of 13 mm in length were infected with the largest number of worms. Mean intensity of the cystacanth of *P. laevis* in *G. obnixus* changed from 1.2 in 6 mm to 4.0 in 16 mm size classes. Prevalence of the infection varied from 0.6% in 6 mm to 19.5% in 13 mm size classes (Table 4). The monthly differences of the mean intensity of cystacanths in male and female *G. obnixus* (Fig. 6) varied significantly (p=0.002, p<0.05 and p=0.008, p<0.05, respectively). Overall, 1517 (17.1%) of the examined *G. obnixus* had one cystacanth, 818 (9.2%) had two and 487 (5.5%) had three cystacanths (Fig. 5). Mean intensity and mean abundance of the worms in the females of *G. obnixus* were 1.6 and 0.5, respectively; for the males, they were 2.6 and 1.2, respectively. The differences between the infections in male and female *G. obnixus* were bordering on significance (p=0.048, p<0.05). The mean percentage of the infected individuals carrying eggs was 6.2% in the net-cage area.

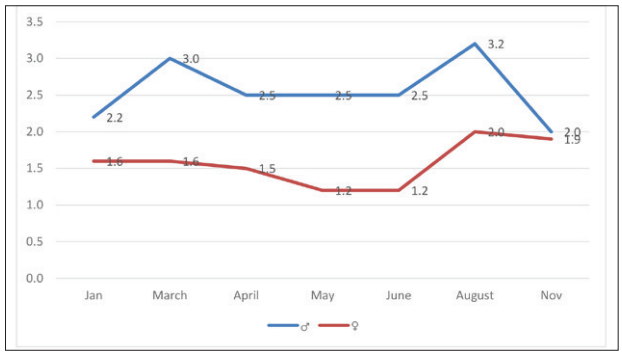



**Fig. 6.** Monthly change in the mean intensity of infection with *Pomphorhynchus laevis* in males and females of *Gammarus obnixus* at the net–cage area (St–II).

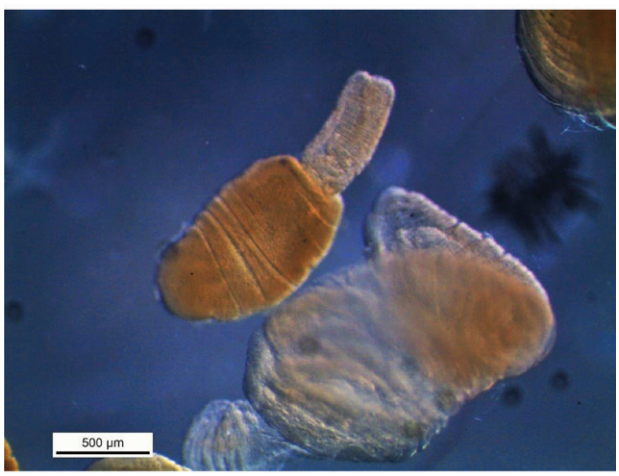



**Fig. 7.** Cystacanth of *Pomphorhynchus laevis* with everted proboscis collected from the hemocoel of *Gammarus obnixus* from the Işıklı Spring.

The mean length of cystacanths for the entire sampling period was 1.6 mm (range 0.8–2.4 mm). The sex ratio of the cystacanths was approximately 1:1. There were no statistically significant differences in the sex ratio of the cystacanths in the males and females of *G. obnixus*. Some cystacanths of *P. laevis* had everted proboscis (Fig. 7). Males of *G. obnixus* were significantly larger than females (♂: mean ± SE = 10.3 ± 0.07 mm, n= 236; ♀: 8.21 ± 0.03 mm, n = 321, Mann-Whitney U-test Z=5.653, p <0.001).

Adults of *P. laevis* were found at the study sites in the intestine of *Chondrostoma meandrense* with an overall prevalence of 18.8% and mean intensity of 2.6.

## Discussion

The main purpose of the current study was to compare the occurrence of cystacanths of *P. laevis* within its intermediate host *G. obnixus* in the spring and net-cage area and to understand the influence of fish

**Table 3.** Monthly changes in occurrence of cystacanths of *Pomphorhynchus laevis* in *Gammarus obnixus* from the net cage area (St–II).

| Months | Number of examined *Gammarus obnixus* | Females | Infected females (%) | Collected cystacanth | Males | Infected males (%) | Collected cystacanth | Total prevalence (%) |
|---|---|---|---|---|---|---|---|---|
| January | 1531 | 613 | 224 (36.5) | 365 | 918 | 333 (36.3) | 739 | 36.4 |
| March | 2201 | 1138 | 292 (25.7) | 465 | 1063 | 511 (48.1) | 1536 | 36.9 |
| April | 1507 | 582 | 189 (32.5) | 276 | 925 | 484 (52.3) | 1213 | 44.7 |
| May | 947 | 352 | 59 (16.8) | 73 | 595 | 301 (50.6) | 759 | 38.0 |
| June | 1288 | 574 | 101 (17.6) | 126 | 714 | 411 (57.6) | 1037 | 39.8 |
| August | 787 | 523 | 287 (54.9) | 572 | 264 | 175 (66.3) | 566 | 58.7 |
| November | 617 | 191 | 39 (20.4) | 76 | 426 | 74 (17.4) | 150 | 18.3 |
| Total | 8878 | 3973 | 1191 | 1953 | 4905 | 2289 | 6000 | |

**Table 4.** Mean intensity and prevalence of larval infection with *Pomphorhynchus laevis* in *Gammarus obnixus* in relation to length classes from St–II.

| Length class (mm) | Number of infected amphipods | Number of parasites | Mean number of parasites | Prevelance (%) |
|---|---|---|---|---|
| 6 | 23 | 27 | 1.2 | 0.6 |
| 7 | 76 | 99 | 1.3 | 2.2 |
| 8 | 156 | 251 | 1.6 | 4.5 |
| 9 | 319 | 529 | 1.7 | 9.2 |
| 10 | 399 | 704 | 1.8 | 11.5 |
| 11 | 436 | 773 | 1.8 | 12.5 |
| 12 | 565 | 1191 | 2.1 | 16.2 |
| 13 | 679 | 1824 | 2.7 | 19.5 |
| 14 | 457 | 1271 | 2.8 | 13.1 |
| 15 | 285 | 956 | 3.4 | 8.2 |
| 16 | 69 | 279 | 4.0 | 2.0 |
| 17 | 16 | 49 | 3.1 | 0.5 |
| Total | 3480 | 7953 | | |

farming on the infection rate of the gammarids by larval acanthocephalans. The results showed that the percentage of infected *G. obnixus,* the mean intensity and abundance of cystacanths were higher at St II. At both stations, the infection rate of male *G. obnixus* was higher than in females. A higher percentage of cystacants were found in the 12 mm size class at St I and in the 13 mm size class at St II. The percentage of infected, eggs-carrying individuals of *G. obnixus* was four times greater at St I.

Several studies concerning acanthocephalan parasites and their intermediate and final hosts have been published. Muzzal (1982) studied *Pomphorhynchus bulbocolli* in *Gammarus pseudolimnaeus*. Dezfuli et al. (1991) collected *Echinogammarus stammeri* (Amphipoda) to study its role as an intermediate host of *P. laevis*. Dezfuli et al. (1999) examined *E. stammeri* as an intermediate host of *P. minitus*. Dudinak & Spakulova (2003) explored the life cycle and the seasonal changes in the occurrence of *P. laevis* in its intermediate host *Gammarus balcanicus* and its final host *Phoxinus phoxinus*. The infection rates and intensity of *P. laevis* were also reported in the intestine of two fish species from our study site Işıklı Spring: *Squalius carinus*, with prevalence 85.2% and mean intensity 12.4 (Soylu et al. 2017) and *Oncorhynchus mykiss*, with prevalence 77.8% and mean intensity 6.7 (Çevrimel & Soylu 2017).

There are no published reports for Turkey of gammarid amphipods serving as intermediate host for acanthocephalans that utilise fish as final hosts. In the present study, we explore the monthly changes of the occurrence of cystacanths of *P. laevis* in a comparative study from two stations. Overall, the prevalence in females and males individuals of *G. obnixus* were 59.2% and 40.8%, respectively, at St-I. However, at St-II, these were 44.8% and 55.2%, respectively. At St-I, the percentage of infected gammarids was 16.2%, whereas at St-II it was 39.2%. There were no significant differences in the monthly percentage of infected *Gammarus obnixus* at St-I, however significant differences were found at St-II. These differences between the infection characteristics at the two stations were likely driven by different environmental factors operating at the two sites. Excessive nutrient load results in intense sedimentation of organic matter and overgrowth of higher plants and algae (Karlson et al. 2002). Cage culture farming has been reported to cause negative effects on the environment, such as eutrophication, which is recognised as a major threat to aquatic ecosystems (Nordvarg 2001). Particulate and dissolved nutrients are discharged directly into the surrounding waters through uneaten waste feed, faecal matter and excretory products (Masser 2008). At St-II, a dense population of *G. obnixus* was observed on the leaves of aquatic macrophytes. Gammarids are one of the organic pollution-facultative and tolerant organisms (Hawkes 1979). The combined effect of abiotic and biotic factors in the habitat of our study site St-II likely triggered an increase in the population density of *G. obnixus* much more rapidly than at St-I. In addition, at St II, mature females of *Pomphorhynchus laevis* in the gut of *Oncorhynchus mykiss* (Çevrimel & Soylu 2017) could produce higher numbers of eggs and serve as a source of year-round infections in gammarids, characterised by higher prevalence, mean intensity and abundance than at St I.

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## References

Amin O.M. 2013. Classification of the Acanthocephala. Folia Parasitologica 60: 273-305.

Bakker T.C.M., Mazzi D. & Zala S. 1997. Parasite-induced changes in behavior and color make *Gammarus pulex* more prone to fish predation. Ecology 78: 1098–1104.

Cézilly F. & Perrot-Minnot M.-J. 2005. Studying adaptive changes in the behaviour of infected hosts: a long and winding road. Behavioural Processes 68: 223–228.

Çevrimel S.D., Soylu E. 2017. The occurrence of *Pomphorhynchus laevis* (Acanthocephala) in cage reared rainbow trout (*Oncorhynchus mykiss*) from Işıklı Spring, Çivril, Turkey. Ege Journal of Fisheries and Aquatic Sciences 34: 255–260.

Dezfuli B.S., Zanini N., Reggiani G. & Rossi R. 1991. *Echinogammarus stammeri* (Amphipoda) as an intermediate host for *Pomphorhynchus laevis* (Acanthocephala) parasite of fishes from the River Brenta. Bollettino di Zoologia 58: 267–271.

Dezfuli B.S., Rossetti E., Bellettato C.M. & Maynard B.J. 1999. *Pomphorhynchus laevis* in its intermediate host *Echinogammarus stammeri* in the River Brenta, Italy. Journal of Helminthology 73: 95–102.

Dezfuli B.S. & Giari L. 1999. Amphipod intermediate host of *Polymorphus minutus* (Acanthocephala), parasite of water birds, with notes on ultrastructure of host-parasite interface. Folıa Parasıtologıca 46: 117–122, 199.

Dezfuli B.S., Giari L. & Poulin R. 2000. Species associations among larval helminths in an amphipod intermediate host. International Journal for Parasitology 30: 1143–1146.

Dianne L., Bollache L., Lagrue C., Franceschi N & Rigaud T. 2012. Larval size in acanthocephalan parasites: Influence of intraspecific competition and effects on intermediate host behavioural changes. Parasites & Vectors 5: 166.

Dudinak V. & Spakulova M. 2003. The life-cycle and seasonal changes in the occurrence of *Pomphorhynchus laevis* (Palaeacanthocephala, Pomphorhynchidae) in a small isolated lake. Parasite 10: 257–262.

Golvan Y. J. 1994. Nomenclature of acanthocephala. Research and Review in Parasitology 54: 135–205.

Hawkes H. A. 1979. Invertebrates as indicators of river water quality. In: James A. & Evison L. (Eds.): Biological indicators of water quality. New York: John Wiley & Sons, 2: 1–45.

Karaman G.S. & Pinkster S. 1977. Freshwater *Gammarus* species from Europe, North Africa and Adjacent Regions of Asia (Crustacea – Amphipoda). Part I. *Gammarus pulex*-group and related species. Bijdragen Tot de Dierkunde 47: 1–97.

Karlson K., Rosenberg R. & Bonsdorff E. 2002. Temporal and spatial largescale effects of eutrophication and oxygen deficiency on benthic fauna in Scandinavian and Baltic waters – a review. Oceanography and Marine Biology: an Annual Review 40: 427–489.

Kennedy C.R. 2006. Ecology of the Acanthocephala. Cambridge: Cambridge University Press. 249 p.

Masser M. 2008. What is cage culture? Southern Regional Aquaculture Center United States Department of Agriculture, Cooperative State Research, Education, and Extension Service (SRAC), Publication No. 160.

Mormann K. 2010. Factors influencing parasite–related suppression of mating behavior in the isopod *Caecidotea intermedius*. College of Liberal Arts & Social Sciences Theses and Dissertations. Paper 48. DePaul University Chicago, IL 72 p.

Muzzal P.M. 1982. Parasites of *Gammarus pseudolimnaeus* and *Hyalella azteca* (Crustacea: Amphipoda) in Three South–central Michigan Localities. Proceedings of the Helminthological Society of Washington 49: 289–294.

Nordvarg L. 2001. Predictive models and eutrophication effects of fish farms. Acta Universitatis Upsaliensis. Comprehensive Summaries of Uppsala Dissertations from the Faculty of Science and Technology 602. 44 p.

Perrot–Minnot M.J., Kaldonski N. & Cézilly F. 2007. Increased susceptibility to predation and altered anti–predatory behaviour in an acanthocephalan–infected amphipod. International Journal for Parasitology 37: 645–651.

Perrot–Minnot M.J., Gaillard M., Dodet R. & Cezilly F. 2011. Interspecific differences in carotenoid content and sensitivity to UVB radiation in three acanthocephalan parasites exploiting a common intermediate host. International Journal for Parasitology 41: 173–181.

Soylu E., Uzmanoğlu S., Çolak Ö.S & Soylu M.P. 2017. Community Structure of the Parasites of the Endemic Chocolate Chub *Squalius carinus* Özuluğ & Freyhof, 2011 (Cyprinidae) from Işıklı Lake, Çivril, Turkey. Acta Zoologica Bulgarica 69: 405–409.

Špakulová M., Perrot-Minnot M.J., & Neuhaus B. 2011. Resurrection of *Pomphorhynchus tereticollis* (Rudolphi, 1809) (Acanthocephala: Pomphorhynchidae) based on new morphological and molecular data. Helminthologia 48: 268–277.

Taraschewski H. 2000. Host-parasite interactions in Acanthocephala: a morphological approach. Advances in Parasitology 46: 1–179.

Ware S.L. & Sandefur K. 2009. Body Length Frequency Distributions among Male and Female *Gammarus* minus. Medical-Lee Speaking.

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