

## Trichodinid fauna of freshwater fishes with infestation indices in the Lower Kızılırmak Delta in Turkey and a checklist of trichodinids (Ciliophora: Trichodinidae) in Turkish waters

Ahmet ÖZER\*, Tükray ÖZTÜRK

Faculty of Fisheries and Aquatic Sciences, Sinop University, Sinop, Turkey

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**Abstract:** This paper provides both the results of a comprehensive research study on trichodinid parasites of several fish species and a review of current trichodinid fauna of fish species revealed during parasitological survey studies in Turkey. The present study yielded 1 *Tripartiella*, 1 *Paratrachodina*, and 8 *Trichodina* identified to the species level and 3 *Trichodina* identified to the generic level in 12 fish species belonging to several families; their host preferences and infestation indices have also been presented. As a result of fish parasite investigations, a total of 33 trichodinid species have been identified on 30 fish species in Turkey. Considering the total number of 850 marine and freshwater fish species present in the Turkish fauna, the present data on the trichodinid fauna of fishes in the Lower Kızılırmak Delta and the literature studies conducted so far clearly point out the necessity of conducting more investigations on unexamined fish species to attain a more complete picture throughout all Turkish waters. The bioindicator potential of trichodinid parasites will also provide clues for the current status of aquatic environments.

**Key words:** Trichodinid parasites, fish, checklist, Turkey

### 1. Introduction

Trichodinids are among the most commonly encountered parasitic ciliates and are widely dispersed and present in many zoogeographical localities (Lom and Dykova, 1992). To date, about 300 nominal trichodinid species have been reported from the skin, fins, gills, and urinary bladders of fishes from different environments in the world (Öztürk and Özer, 2007; Tang and Zhao, 2013). Host specificity in trichodinids appears variable, with species such as *Trichodina acuta* and *T. nigra* in fresh water, *T. rectuncinata* and *T. ovonucleata* infecting a large number of marine host species, and species such as *T. tenuidens* parasitizing only a couple of freshwater host species (Lom, 1970). *T. puytoraci* and *T. lepsi* have only been reported from mugilids, such as the striped mullet, *Mugil cephalus* L., 1758, and the golden grey mullet, *Liza aurata* Risso, 1810 in brackish water (Bykhovskaya-Pavlovskaya et al., 1964; Kinne, 1984; Grupcheva et al., 1989). Moreover, *Trichodina heterodontata* has been reported to be one of the trichodinid species with the widest distributions with low specificity, able to infest a wide range of vertebrate and invertebrate hosts in both marine and freshwater environments (Van As and Basson, 1992; Dove and O'Donoghue, 2005; Dias et al., 2009; Martins et al., 2010).

Protozoan infestations on fish, including trichodinids, are strongly dependent on ecological conditions such as temperature, high organic loads, and deterioration of water quality (Özer and Yılmaz Kırca, 2013). Trichodinid parasites have been recommended as biological indicators for comparing organically polluted and unpolluted areas (Palm and Dobberstein, 1999). Ögüt and Palm (2005) indicated that infestation parameters by trichodinid parasites could be used to indicate levels of organic pollution. Moreover, MacKenzie (1983) proposed trichodinids to be good bioindicators due to having 4 characteristics suitable for assessing the biological integrity of aquatic ecosystems.

In Turkey, there was no detailed information available on trichodinid ectoparasites of fishes until 1998, when Özer and Erdem (1998) reported the occurrence of *T. acuta*, *T. nigra*, *T. mutabilis*, and *Trichodinella subtilis* from wild and cultured common carp, *Cyprinus carpio* L., 1758, in Sinop. In the first decade of the 21st century, research on this important group gained momentum; as a result, several species belonging to the genera *Trichodina* Ehrenberg, 1838; *Paratrachodina* Lom, 1963; *Trichodinella* (Raabe, 1950) Smarek-Husek, 1953; and *Tripartiella* Lom, 1959 have so far been identified to either species or generic

\* Correspondence: aozer@sinop.edu.tr

level and have been reported by many authors (see Table 1 for details).

Turkey has a coastline of 8333 km and is surrounded by 4 seas: the Mediterranean Sea, Aegean Sea, Marmara

sea, and Black Sea. Turkey also has a total river length of 177,114 km, along with 1193 natural and artificial lakes suitable for aquaculture activities (Aksungur and Firidin, 2008). A total of 532 marine and 318 freshwater

**Table 1.** Records of Trichodinid parasites in Turkish waters: a checklist.

| Trichodinid species                                 | Fish host                                  | Locality | Authors (references)         |
|-----------------------------------------------------|--------------------------------------------|----------|------------------------------|
| <i>Trichodina modesta</i> Lom, 1970                 | <i>Aphanius danfordii</i> Boulenger, 1890  | 4        | Özer (2007)                  |
|                                                     | "                                          | 4        | Öztürk and Özer (2007)       |
|                                                     | "                                          | 4        | This study                   |
| <i>Trichodina acuta</i> Lom, 1961                   | <i>Cyprinus carpio</i> L., 1758            | 4        | Özer and Erdem (1998)        |
|                                                     | "                                          | 4        | Özer and Erdem (1999)        |
|                                                     | "                                          | 4        | Özer (2000)                  |
|                                                     | "                                          | 4        | This study                   |
|                                                     | <i>Oreochromis niloticus</i> L., 1758      | 5        | Can and Cengizler (1999)     |
| <i>Trichodina mutabilis</i> Kazubski & Migala, 1968 | <i>Cyprinus carpio</i> L., 1758            | 4        | Özer and Erdem (1998)        |
|                                                     | "                                          | 4        | Özer and Erdem (1999)        |
|                                                     | "                                          | 4        | Özer (2000)                  |
| <i>Trichodina nigra</i> Lom, 1960                   | <i>Cyprinus carpio</i> L., 1758            | 4        | Özer and Erdem (1998)        |
|                                                     | "                                          | 4        | Özer and Erdem (1999)        |
|                                                     | "                                          | 4        | Özer (2000)                  |
|                                                     | "                                          | 5        | Cengizler et al. (2001)      |
|                                                     | "                                          | 3        | Kılınçaslan (2007)           |
|                                                     | <i>Silurus glanis</i> L., 1758             | 3        | Kılınçaslan (2007)           |
|                                                     | <i>Leuciscus cephalus</i> L., 1758         | 3        | Kılınçaslan (2007)           |
|                                                     | <i>Mugil cephalus</i> L., 1758             | 4        | Özer and Öztürk (2004)       |
| <i>Trichodina lepsii</i> Lom, 1962                  | "                                          | 4        | This study                   |
|                                                     | <i>Liza aurata</i> Risso, 1810             | 4        | Özer and Öztürk (2004)       |
|                                                     | "                                          | 4        | Özer and Yılmaz Kırca (2013) |
|                                                     | "                                          | 4        | Öztürk (2013)                |
|                                                     | "                                          | 4        | This study                   |
|                                                     | <i>Mugil cephalus</i> L., 1758             | 4        | Özer and Öztürk (2004)       |
| <i>Trichodina puytoraci</i> Lom, 1962               | <i>Merlangius merlangus</i> L., 1758       | 4        | Öğüt and Palm (2005)         |
|                                                     | <i>Liza aurata</i> Risso, 1810             | 4        | Özer and Öztürk (2004)       |
|                                                     | <i>Liza aurata</i> Risso, 1810             | 4        | Öztürk (2013)                |
|                                                     | "                                          | 4        | This study                   |
|                                                     | <i>Platichthys flesus</i> L., 1758         | 4        | Öztürk and Özer (2007)       |
|                                                     | "                                          | 4        | Öztürk and Özer (2008)       |
| <i>Trichodina domerguei</i> Wallengren, 1897        | <i>Aphanius danfordii</i> Boulenger, 1890  | 4        | Öztürk and Özer (2007)       |
|                                                     | "                                          | 4        | This study                   |
|                                                     | <i>Gambusia holbrooki</i> Girard, 1859     | 4        | This study                   |
|                                                     | <i>Dicentrarchus labrax</i> L., 1758       | 5        | Canlı (2010)                 |
|                                                     | <i>Gasterosteus aculeatus</i> L., 1758     | 4        | Özer (2003a)                 |
|                                                     | "                                          | 4        | This study                   |
|                                                     | <i>Neogobius melanostomus</i> Pallas, 1811 | 4        | Özer (2003b)                 |
|                                                     | <i>Sparus aurata</i> L., 1758              | 5        | Canlı (2010)                 |
|                                                     | <i>Neogobius fluviatilis</i> Pallas, 1814  | 4        | Öztürk and Çam (2013)        |
|                                                     | "                                          | 4        | This study                   |
|                                                     | "                                          | 4        | This study                   |

**Table 1.** (Continued).

| Trichodinid species                                    | Fish host                                    | Locality | Authors (references)                        |
|--------------------------------------------------------|----------------------------------------------|----------|---------------------------------------------|
|                                                        | <i>Pomatoschistus marmoratus</i> Risso, 1810 | 4        | Öztürk and Çam (2013)                       |
|                                                        | "                                            | 4        | This study                                  |
| <i>Trichodina heterodontata</i> Duncan, 1977           | <i>Neogobius fluviatilis</i> Pallas, 1814    | 4        | Öztürk and Çam (2013)                       |
|                                                        | "                                            | 4        | This study                                  |
|                                                        | <i>Pomatoschistus marmoratus</i> Risso, 1810 | 4        | Öztürk and Çam (2013)                       |
|                                                        | "                                            | 4        | This study                                  |
|                                                        | <i>Proterorhinus marmoratus</i> Pallas, 1814 | 4        | Öztürk and Çam (2013)                       |
|                                                        | "                                            | 4        | This study                                  |
|                                                        | <i>Aphanius danfordii</i> Boulenger, 1890    | 4        | This study                                  |
|                                                        | <i>Sander lucioperca</i> L. 1758             | 4        | This study                                  |
| <i>Trichodina jadratica</i> Raabe, 1958                | <i>Platichthys flesus</i> L., 1758           | 4        | Öztürk and Özer (2007)                      |
|                                                        | "                                            | 4        | Öztürk and Özer (2008)                      |
| <i>Trichodina tenuidens</i> Faure-Fremiet, 1944        | <i>Gasterosteus aculeatus</i> L., 1758       | 4        | Özer (2003a)                                |
|                                                        | "                                            | 4        | This study                                  |
| <i>Trichodina luciopercae</i> Lom, 1970                | <i>Sander lucioperca</i> L., 1758            | 4        | This study                                  |
| <i>Trichodina claviformis</i> Dobberstein & Palm, 2000 | <i>Merlangius merlangus</i> L., 1758         | 4        | Öğüt and Palm (2005)                        |
| <i>Trichodinella subtilis</i> Lom, 1959                | <i>Cyprinus carpio</i> L., 1758              | 4        | Özer and Erdem (1998)                       |
|                                                        | "                                            | 4        | Özer and Erdem (1999)                       |
| <i>Tripartiella macrosoma</i> Basson & Van As, 1987    | <i>Aphanius danfordii</i> Boulenger, 1890    | 4        | Öztürk and Özer (2007)                      |
|                                                        | "                                            | 4        | This study                                  |
| <i>Paratrachodina corlissi</i> Lom & Haldar, 1977      | <i>Neogobius fluviatilis</i> Pallas, 1814    | 4        | Öztürk and Çam (2013)                       |
|                                                        | "                                            | 4        | This study                                  |
|                                                        | <i>Pomatoschistus marmoratus</i> Risso, 1810 | 4        | Öztürk and Çam (2013)                       |
|                                                        | "                                            | 4        | This study                                  |
| <i>Trichodina cobitis</i> Lom, 1960                    | <i>Cobitis taenia</i> L., 1758               | 4        | This study                                  |
| <i>Tripartiella</i> sp.                                | <i>Oncorhynchus mykiss</i> Walbaum, 1792     | 3        | Altunay and Yavuzcan Yıldız (2008)          |
| <i>Trichodina</i> sp.                                  | <i>Belone belone</i> L., 1761                | 4        | Özer and Yurakhno (2013)                    |
| <i>Trichodina</i> sp.                                  | <i>Carassius auratus</i> L., 1761            | 5        | Bulguroğlu and Korun (2013)                 |
| <i>Trichodina</i> sp.                                  | <i>Cyprinus carpio</i> L., 1758              | 7        | Pişkin and Ütük (2008)                      |
| <i>Trichodina</i> sp.                                  | <i>Oncorhynchus mykiss</i> Walbaum, 1792     | 3        | Burgu et al. (1998)                         |
| <i>Trichodina</i> sp.                                  | <i>Oncorhynchus mykiss</i> Walbaum, 1792     | 3        | Altunay and Yavuzcan Yıldız (2008)          |
| <i>Trichodina</i> sp.                                  | <i>Oncorhynchus mykiss</i> Walbaum, 1792     | 5        | Özer et al. (2010)                          |
| <i>Trichodina</i> sp.                                  | <i>Psetta maximus</i> L., 1758               | 4        | Aksungur (2003)                             |
| <i>Trichodina</i> sp.                                  | <i>Psetta maximus</i> L., 1758               | 5        | Emre et al. (2011)                          |
| <i>Trichodina</i> sp.                                  | <i>Poecilia reticulata</i> Peters, 1859      | 5        | Koyuncu and Cengizler (2002)                |
| "                                                      | <i>Poecilia latipinna</i> Lesueur, 1821      | 5        | Koyuncu and Cengizler (2002)                |
| "                                                      | <i>Xiphophorus helleri</i> Heckel, 1848      | 5        | Koyuncu and Cengizler (2002)                |
| "                                                      | <i>Xiphophorus maculatus</i> Günther, 1866   | 5        | Koyuncu and Cengizler (2002)                |
| <i>Trichodina</i> sp.                                  | <i>Carassius auratus</i> L., 1761            | 4        | Kayış et al. (2013)                         |
| "                                                      | <i>Heros efasciatus</i> Heckel, 1840         | 4        | Kayış et al. (2013)                         |
| "                                                      | <i>Labidochromis caeruleus</i> Fryer, 1956   | 4        | Kayış et al. (2013)                         |
| <i>Trichodina</i> sp.                                  | <i>Ctenopharingedon idella</i> Val. 1844     | 3        | Kırkağaç-Uzbilek and Yavuzcan Yıldız (2002) |
| <i>Trichodina</i> sp.                                  | <i>Sparus aurata</i> L., 1758                | 2        | Tokşen (2004)                               |
| <i>Trichodina</i> sp.                                  | <i>Merlangius merlangus</i> L., 1758         | 4        | Öğüt and Palm (2005)                        |
| "                                                      | "                                            | 4        | Öğüt and Altuntaş (2011)                    |
| <i>Trichodina</i> sp1                                  | <i>Gasterosteus aculeatus</i> L., 1758       | 4        | This study                                  |
| <i>Trichodina</i> sp2                                  | <i>Cobitis taenia</i> L., 1758               | 4        | This study                                  |
| <i>Trichodina</i> sp3                                  | <i>Syngnathus acus</i> L., 1758              | 4        | This study                                  |

fish species have been reported in Turkish waters (www.fishbase.org), but only 204 fish species have so far been investigated in parasitological studies. The present paper deals with the occurrence of 13 ectoparasitic trichodinid species belonging to the genera *Trichodina* Ehrenberg, 1830; *Tripartiella* Lom, 1959; and *Paratrichodina* Lom, 1963 based on the silver nitrate impregnation technique on 12 fish species collected from the Lower Kızılırmak Delta in Samsun, Turkey.

In this study, our aims were: 1) to contribute to the parasite fauna of fish hosts, 2) to establish a background for further studies on trichodinids, and 3) to expand knowledge on the distribution of several identified trichodinid species in the Lower Kızılırmak Delta located on the Black Sea coast at Samsun, along with a checklist on current trichodinid fauna in Turkey.

## 2. Materials and methods

Host fishes were collected monthly by fishing nets and electrofishing devices in the period between December 2011 and November 2012 in the Lower Kızılırmak Delta in Samsun, Turkey (Figure 1). Efforts were performed to collect seasonal fish samples at each sampling locality in the delta, which included 7 lakes and lagoons of sizes varying between 52 ha and 1389 ha and depths of 1.5–5 m, two

of which have direct connections with the Black Sea from time to time over the course of the year. For parasitological examination, fish were transported either alive in local water or in boxes of dry ice directly to the Sinop Fisheries Faculty Laboratory immediately after capture. Skin, fins, and gills were examined under a light microscope, and scrapings of whole mucus from these parts of the fish were placed on several slides. Air-dried smears were stained in accordance with Klein's silver nitrate ( $\text{AgNO}_3$ ) method (Lom and Dykova, 1992) in order to study details of the adhesive disk. All morphological measurements were carried out by oil-immersion light microscope (Olympus BX53). All measurements are in micrometers and follow the uniform specific characteristics proposed by Lom (1958). In the description of denticle elements, the format recommended by Van As and Basson (1989) and Lom and Dykova (1992) was followed. Appropriate identification keys were used for determination of parasite fauna representatives to the lowest possible taxonomic level (Bykhovskaya-Pavlovskaya et al., 1964; Lom and Dykova, 1992; Özer and Erdem, 1998; Özer and Öztürk, 2004). Infestation indices of prevalence (%), mean intensity, and abundance follow the recommendations of Bush et al. (1997). These indices of trichodinids on each respective fish species were calculated as pooled data rather than by



Figure 1. Sampling area and all geographical regions of Turkey.

species when more than one parasite species occurred. It is important to note that when trichodinids are alive, they are morphologically similar and difficult to discriminate from one another. Therefore, they are considered together in terms of the number of live parasites observed on the fish, but their identities were confirmed by the methods given above. A Kruskal–Wallis test (nonparametric ANOVA) was performed to find significant differences in seasonal mean intensity values of the trichodinids. All statistical analyses were performed at the significance level of 5% using the statistical program GraphPad InStat 3.00. Some physicochemical parameters, including temperature (°C), dissolved oxygen (mg/L), salinity (ppt), and nitrate (mg/L), were measured monthly in the sampling localities using a YSI Professional Plus water-quality instrument; obtained data were pooled seasonally for each environmental parameter and mean values reflecting the values for the delta were then calculated.

This review also includes information on trichodinid species reported from inland, marine, and aquarium environments during long-term investigations throughout Turkish waters in Figure 1. Turkey is divided into 7 geographical areas, which are indicated by the numbers 1 to 7 to illustrate regional distributions of trichodinids in Turkey.

### 3. Results

In the present study, a total of 13 trichodinid species were identified (Figure 2) and found to be infesting 12 fish species belonging to 9 families (Table 2). *Trichodina domerguei*, the most widespread trichodinid, infested 5 different fish species belonging to 4 families, followed by *Trichodina heterodontata* infesting 5 fish species belonging to 3 families. On the other hand, some trichodinid species were host fish-specific: *T. lepsii* and *T. puytoraci* on mugilids *Mugil cephalus* and *Liza aurata*, *T. acuta* on cyprinid *Cyprinus carpio*, *T. luciopercae* on percid *Sander lucioperca*, *T. tenuidens* on gasterosteid *Gasterosteus aculeatus*, and *T. cobitis* on cobitid *Cobitis taenia* fishes. Overall and seasonal infestation prevalence (%), mean intensity, and abundance values of identified trichodinids on their respective fish hosts are presented in Tables 2 and 3. Statistically significant differences were determined in seasonal infestation values of some species where applicable (Table 3).

Water parameters temperature (°C), dissolved oxygen (mg/L), salinity (ppt), and nitrate (mg/L) values measured from the Lower Kızılırmak Delta are presented in Table 4.

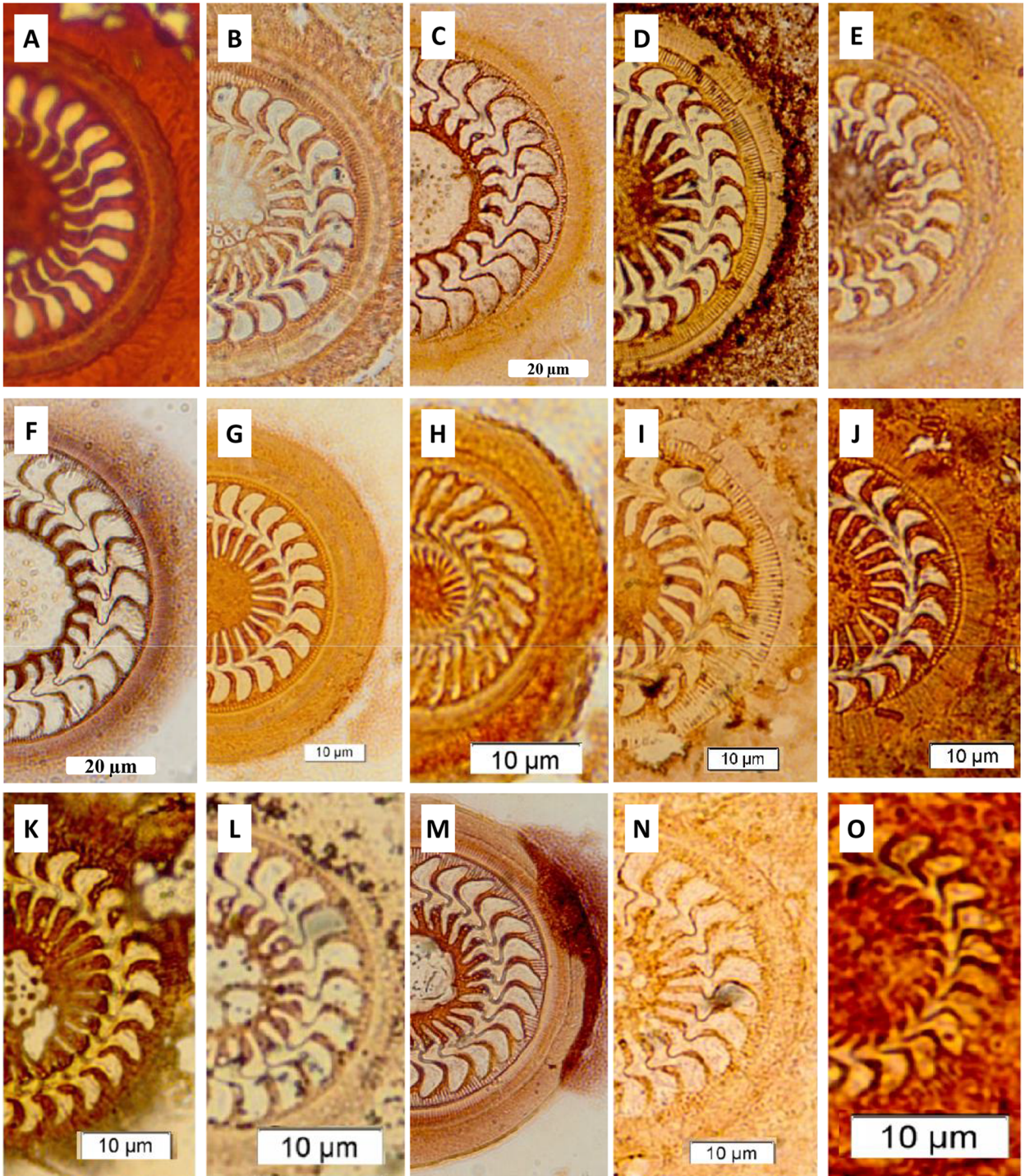
Results of over 50 years long-term ichthyoparasitological investigations in Turkish waters have identified 33 trichodinid species from *Trichodina* (29), *Tripathiella* (2), *Trichodinella* (1), and *Paratrachodina* (1) from 31 freshwater, marine, and aquarium fishes in Turkey in the

last 15 years (see Table 1 for details). In the present study, a checklist of fish hosts and a list of their parasites are also presented in Table 5.

### 4. Discussion

The present study is the first in Turkey for trichodinid fauna in terms of the number of trichodinid species identified and host fish species examined in a delta inhabited by 23 fish species in 7 lakes and lagoons. In the present study, of the 13 trichodinid species identified on 12 fish species, *T. lucioperca* on *Sander lucioperca* and *T. cobitis* on *Cobitis taenia* are new records for Turkish trichodinid fauna, and the presences of *Trichodina* sp1 on *Gasterosteus aculeatus*, *Trichodina* sp2 on *Cobitis taenia*, and *Trichodina* sp3 on *Syngnatus acus* have the potential to be further contributions to the Turkish fauna when they are identified to the species level. Moreover, *T. heterodontata* was found on endemic *Aphanius danfordii* for the first time, while the finding of other species recovered in the present study confirmed some previously reported trichodinid species and their host ranges. *Trichodina acuta* on *Cyprinus carpio*, *T. macrosoma* on *Aphanius danfordii*, *T. lepsii* and *T. puytoraci* on both *Mugil cephalus* and *Liza aurata*, and *T. tenuidens* on *Gasterosteus aculeatus* showed strict host specificity to only one host species or genus, while *T. heterodontata* and *T. domerguei* exhibited a wide host range, as has been previously reported by several authors (Özer, 2000, 2003a, 2007; Özer and Öztürk, 2004; Dove and O'Donoghue, 2005; Öztürk and Özer, 2007, 2008; Martins et al., 2010; Öztürk, 2013; Öztürk and Çam, 2013).

Trichodinids infest many fish species with varying intensities dictated by ecological conditions and host factors. Most of the fish species examined here were found to be infested by several trichodinid species at different infestation values. Trichodinid infestations on gobiid fishes and *L. aurata* in the same sampling data have been the subject of other publications (Özer and Yılmaz Kırca, 2013; Öztürk and Çam, 2013); thus, they were excluded from discussion here. As can be seen in Table 1, it is obvious that most of the studies on trichodinids have been conducted in the same geographical region (4) where this study was carried out (see Figure 1 for details), and all comparable data on the fish–trichodinid relationships, including data from this study, have been produced by the authors of this study (see Table 1 for details). Özer (2007) reported a higher trichodinid prevalence along with lower intensity values than those of our results on *Aphanius danfordii* by *T. modesta* in another locality in the same region (4). On the other hand, Özer (2003a) found similar prevalence but higher infestation intensity on *Gasterosteus aculeatus* by *T. tenuidens* and *T. domerguei* at a different locality in the same region. *Sander lucioperca* was infested by *T. lucioperca* and *T. heterodontata* with low prevalence



**Figure 2.** Trichodinid parasites identified on Lower Kızılırmak Delta fishes: **A)** *T. lepsi*, **B)** *T. puytoraci*, **C)** *T. domerguei*, **D)** *T. heterodentata*, **E)** *Paratrachodina corlissi*, **F)** *T. domerguei*, **G)** *T. modesta*, **H)** *Tripartiella macrosoma*, **I)** *T. acuta*, **J)** *T. lucioperca*, **K)** *T. tenuidens*, **L)** *Trichodina* sp1, **M)** *T. cobitis*, **N)** *Trichodina* sp2, **O)** *Trichodina* sp3.

**Table 2.** Overall infestation prevalence (%), mean intensity, and abundance values of trichodinid species of fishes in the Lower Kızılırmak Delta. (N = number of examined fish, S.E. = standard error).

| Trichodinid species             | Host fish                        | N   | Prevalence (%) | Mean intensity $\pm$ S.E. | Abundance $\pm$ S.E. |
|---------------------------------|----------------------------------|-----|----------------|---------------------------|----------------------|
| <i>Trichodina lepsi</i>         | <i>Mugil cephalus</i>            | 254 | 33.5           | 257.7 $\pm$ 91.4          | 86.2 $\pm$ 31.4      |
| <i>Trichodina puytoraci</i>     |                                  |     |                |                           |                      |
| <i>Trichodina lepsi</i>         | <i>Liza aurata</i>               | 46  | 56.5           | 81.1 $\pm$ 36.6           | 45.8 $\pm$ 21.3      |
| <i>Trichodina puytoraci</i>     |                                  |     |                |                           |                      |
| <i>Trichodina heterodontata</i> | <i>Proterorhinus marmoratus</i>  | 45  | 40.0           | 7.8 $\pm$ 1.7             | 3.1 $\pm$ 0.9        |
| <i>Trichodina domerguei</i>     | <i>Neogobius fluviatilis</i>     | 161 | 23.0           | 188.1 $\pm$ 175.2         | 43.2 $\pm$ 40.3      |
| <i>Trichodina heterodontata</i> |                                  |     |                |                           |                      |
| <i>Paratrachodina corlissi</i>  | <i>Pomatoschistus marmoratus</i> | 16  | 81.3           | 1003.8 $\pm$ 972.3        | 815.6 $\pm$ 790.4    |
| <i>Trichodina domerguei</i>     | <i>Aphanius danfordii</i>        | 125 | 52.8           | 372.3 $\pm$ 98.5          | 196.6 $\pm$ 54.4     |
| <i>Trichodina modesta</i>       |                                  |     |                |                           |                      |
| <i>Trichodina heterodontata</i> |                                  |     |                |                           |                      |
| <i>Tripartiella macrosoma</i>   |                                  |     |                |                           |                      |
| <i>Trichodina acuta</i>         | <i>Cyprinus carpio</i>           | 232 | 0.9            | 4.5 $\pm$ 1.5             | 0.04 $\pm$ 0.03      |
| <i>Trichodina domerguei</i>     | <i>Gambusia holbrooki</i>        | 227 | 7.5            | 8.2 $\pm$ 4.4             | 0.6 $\pm$ 0.4        |
| <i>Trichodina heterodontata</i> | <i>Sander lucioperca</i>         | 73  | 9.6            | 10,188.3 $\pm$ 9442.7     | 976.9 $\pm$ 915.1    |
| <i>Trichodina luciopercae</i>   |                                  |     |                |                           |                      |
| <i>Trichodina domerguei</i>     | <i>Gasterosteus aculeatus</i>    | 29  | 62.1           | 12.8 $\pm$ 3.9            | 7.9 $\pm$ 2.7        |
| <i>Trichodina tenuidens</i>     |                                  |     |                |                           |                      |
| <i>Trichodina sp1</i>           |                                  |     |                |                           |                      |
| <i>Trichodina cobitis</i>       | <i>Cobitis taenia</i>            | 3   | 33.3           | 169.0 $\pm$ 0.0           | 56.3 $\pm$ 56.3      |
| <i>Trichodina sp2</i>           |                                  |     |                |                           |                      |
| <i>Trichodina sp3</i>           | <i>Syngnathus acus</i>           | 10  | 40.0           | 255.5 $\pm$ 4.4           | 102.2 $\pm$ 45.9     |

**Table 3.** Seasonal infestation prevalence (%), mean intensity, and abundance values of trichodinid species of fishes in the Lower Kızılırmak Delta (M.I. = mean intensity, Ab = abundance, S.E. = standard error, n = number of examined fish).

| Trichodinid species                                                                                                          | Host fish                        | Infestation indices              | Season                                               |                                                           |                                                           |                                                            |
|------------------------------------------------------------------------------------------------------------------------------|----------------------------------|----------------------------------|------------------------------------------------------|-----------------------------------------------------------|-----------------------------------------------------------|------------------------------------------------------------|
|                                                                                                                              |                                  |                                  | Winter                                               | Spring                                                    | Summer                                                    | Autumn                                                     |
| <i>Trichodina lepsii</i><br><i>Trichodina puytoraci</i>                                                                      | <i>Mugil cephalus</i>            | P (%)<br>MI ± SE<br>Ab ± SE<br>n | 6.7<br>8.0 ± 4.9 <sup>ab</sup><br>0.6 ± 0.4<br>75    | 31.6<br>16.7 ± 5.9 <sup>a</sup><br>5.3 ± 2.0<br>79        | 27.0<br>81.3 ± 50.3 <sup>ab</sup><br>22.0 ± 14.4<br>37    | 71.4<br>458.4 ± 167.5 <sup>b</sup><br>327.5 ± 122.1<br>63  |
| <i>Trichodina lepsii</i><br><i>Trichodina puytoraci</i>                                                                      | <i>Liza aurata</i>               | P (%)<br>MI ± SE<br>Ab ± SE<br>n | -<br>-<br>-<br>0                                     | -<br>-<br>-<br>0                                          | 71.0<br>46.3 ± 19.1 <sup>a</sup><br>32.8 ± 14.0<br>31     | 26.6<br>272.8 ± 209.7 <sup>b</sup><br>72.7 ± 59.6<br>15    |
| <i>Trichodina heterodontata</i>                                                                                              | <i>Proterorhinus marmoratus</i>  | P (%)<br>MI ± SE<br>Ab ± SE<br>n | 5.3<br>2.0 ± 0.0*<br>0.1 ± 0.1<br>19                 | -<br>-<br>0                                               | 100<br>4.0 ± 0.0*<br>4.0 ± 0.0<br>2                       | 62.5<br>8.7 ± 2.0*<br>5.5 ± 1.5<br>24                      |
| <i>Trichodina domerguei</i><br><i>Trichodina heterodontata</i><br><i>Paratrachodina corlissi</i>                             | <i>Neogobius fluviatilis</i>     | P (%)<br>MI ± SE<br>Ab ± SE<br>n | -<br>-<br>-<br>0                                     | 17.6<br>745.3 ± 718.5 <sup>a</sup><br>131.5 ± 127.3<br>51 | 16.1<br>9.4 ± 6.4 <sup>a</sup><br>1.5 ± 1.1<br>62         | 37.5<br>8.8 ± 4.2 <sup>a</sup><br>3.3 ± 1.7<br>48          |
| <i>Trichodina domerguei</i><br><i>Trichodina modesta</i><br><i>Trichodina heterodontata</i><br><i>Tripartiella macrosoma</i> | <i>Pomatoschistus marmoratus</i> | P (%)<br>MI ± SE<br>Ab ± SE<br>n | -<br>-<br>-<br>0                                     | 100.0<br>1154.8 ± 1151.4*<br>1154.8 ± 1151.4<br>11        | -<br>-<br>-<br>0                                          | 40.0<br>173.5 ± 31.5*<br>69.4 ± 43.7<br>5                  |
| <i>Trichodina domerguei</i><br><i>Trichodina modesta</i><br><i>Trichodina heterodontata</i><br><i>Tripartiella macrosoma</i> | <i>Aphanius danfordii</i>        | P (%)<br>MI ± SE<br>Ab ± SE<br>n | 34.1<br>35.4 ± 20.6 <sup>a</sup><br>12.1 ± 7.4<br>41 | 44.1<br>164.5 ± 83.0 <sup>ab</sup><br>72.5 ± 38.6<br>34   | 80.6<br>636.3 ± 202.6 <sup>b</sup><br>512.6 ± 168.2<br>36 | 57.1<br>394.4 ± 210.2 <sup>ab</sup><br>225.4 ± 128.6<br>14 |
| <i>Trichodina acuta</i>                                                                                                      | <i>Cyprinus carpio</i>           | P (%)<br>MI ± SE<br>Ab ± SE<br>n | 2.3<br>3.0 ± 0.0*<br>0.1 ± 0.1<br>43                 | 0<br>-<br>-<br>66                                         | 1.6<br>6.0 ± 0.0*<br>0.1 ± 0.1<br>63                      | 0<br>-<br>-<br>60                                          |
| <i>Trichodina domerguei</i>                                                                                                  | <i>Gambusia holbrooki</i>        | P (%)<br>MI ± SE<br>Ab ± SE<br>n | 12.2<br>7.2 ± 5.6*<br>0.9 ± 0.7<br>106               | 22.2<br>13.5 ± 11.5*<br>3.0 ± 2.8<br>9                    | 7.7<br>1.0 ± 0.0*<br>0.1 ± 0.1<br>13                      | 1.0<br>18.0 ± 0.0*<br>0.2 ± 0.2<br>99                      |
| <i>Trichodina heterodontata</i><br><i>Trichodina luciopercae</i>                                                             | <i>Sander lucioperca</i>         | P (%)<br>MI ± SE<br>Ab ± SE<br>n | 25<br>709.5 ± 456.5*<br>177.4 ± 144.7<br>8           | 14.3<br>33,500.5 ± 33,300.5*<br>4785.8 ± 4770.4<br>14     | 8.0<br>68.5 ± 62.5*<br>5.5 ± 5.2<br>25                    | 3.8<br>2761.0 ± 0.0*<br>106.2 ± 106.2<br>26                |
| <i>Trichodina domerguei</i><br><i>Trichodina tenuidens</i><br><i>Trichodina sp1</i>                                          | <i>Gasterosteus aculeatus</i>    | P (%)<br>MI ± SE<br>Ab ± SE<br>n | -<br>-<br>-<br>0                                     | -<br>-<br>-<br>0                                          | 62.1<br>12.8 ± 3.9<br>7.9 ± 2.7<br>29                     | -<br>-<br>-<br>0                                           |
| <i>Trichodina cobitis</i><br><i>Trichodina sp2</i>                                                                           | <i>Cobitis taenia</i>            | P (%)<br>MI ± SE<br>Ab ± SE<br>n | -<br>-<br>-<br>0                                     | -<br>-<br>-<br>0                                          | -<br>-<br>-<br>0                                          | 33.3<br>169.0 ± 0.0<br>56.3 ± 56.3<br>3                    |
| <i>Trichodina sp3</i>                                                                                                        | <i>Syngnathus acus</i>           | P (%)<br>MI ± SE<br>Ab ± SE<br>n | -<br>-<br>-<br>4                                     | -<br>-<br>-<br>1                                          | 100.0<br>259.5 ± 52.2<br>259.5 ± 52.2<br>4                | -<br>-<br>-<br>1                                           |

Values followed by the same superscript letter are not significantly different. \*Too few values for statistical analysis.

**Table 4.** Seasonal water temperature (°C), dissolved oxygen (mg/L), salinity (ppt), and nitrate (mg/L) values in the Lower Kızılırmak Delta.

| Season/water parameters    | Temperature (°C) | Dissolved oxygen (mg/L) | Salinity (ppt) | Nitrate (mg/L) |
|----------------------------|------------------|-------------------------|----------------|----------------|
| Winter (December–February) | 8.68             | 10.38                   | 1.10           | 1.30           |
| Spring (March–May)         | 20.56            | 8.44                    | 1.57           | 1.68           |
| Summer (June–August)       | 27.22            | 7.64                    | 1.35           | 1.80           |
| Autumn (September–October) | 12.76            | 9.64                    | 1.07           | 0.25           |

**Table 5.** Fish species and their trichodinid parasites in Turkey: a checklist.

| Fish host                                 | Trichodinid species                                    | Locality | Authors (references)                        |
|-------------------------------------------|--------------------------------------------------------|----------|---------------------------------------------|
| <i>Aphanius danfordii</i> Boulenger, 1890 | <i>Trichodina modesta</i> Lom, 1970                    | 4        | Özer (2007)                                 |
|                                           | "                                                      | 4        | Öztürk and Özer (2007)                      |
|                                           | "                                                      | 4        | This study                                  |
|                                           | <i>Trichodina domerguei</i> Wallengren, 1897           | 4        | Öztürk and Özer (2007)                      |
|                                           | "                                                      | 4        | This study                                  |
|                                           | <i>Tripartiella macrosoma</i> Basson and Van As, 1987  | 4        | Öztürk and Özer (2007)                      |
|                                           | "                                                      | 4        | This study                                  |
| <i>Cyprinus carpio</i> L., 1758           | <i>Trichodina heterodentata</i> Duncan, 1977           | 4        | This study                                  |
|                                           | <i>Trichodina acuta</i> Lom, 1961                      | 4        | Özer and Erdem (1998)                       |
|                                           | "                                                      | 4        | Özer and Erdem (1999)                       |
|                                           | "                                                      | 4        | Özer (2000)                                 |
|                                           | "                                                      | 4        | This study                                  |
|                                           | <i>Trichodina mutabilis</i> Kazubski and Migala, 1968  | 4        | Özer and Erdem (1998)                       |
|                                           | "                                                      | 4        | Özer and Erdem (1999)                       |
|                                           | "                                                      | 4        | Özer (2000)                                 |
|                                           | <i>Trichodina nigra</i> Lom, 1960                      | 4        | Özer and Erdem (1998)                       |
|                                           | "                                                      | 4        | Özer and Erdem (1999)                       |
|                                           | "                                                      | 4        | Özer (2000)                                 |
|                                           | "                                                      | 5        | Cengizler et al. (2001)                     |
|                                           | "                                                      | 3        | Kılınçaslan (2007)                          |
|                                           | <i>Trichodinella subtilis</i> Lom, 1959                | 4        | Özer and Erdem (1998)                       |
| <i>Carassius auratus</i> L., 1761         | "                                                      | 4        | Özer and Erdem (1999)                       |
|                                           | <i>Trichodina</i> sp.                                  | 7        | Pişkin and Ütük (2008)                      |
| <i>Ctenopharingedon idella</i> Val. 1844  | <i>Trichodina</i> sp.                                  | 5        | Bulguroğlu and Korun (2013)                 |
|                                           | <i>Trichodina</i> sp.                                  | 4        | Kayış et al. (2013)                         |
| <i>Oreochromis niloticus</i> L., 1758     | <i>Trichodina</i> sp.                                  | 3        | Kırkağaç Uzbilek and Yavuzcan Yıldız (2002) |
| <i>Oreochromis niloticus</i> L., 1758     | <i>Trichodina acuta</i> Lom, 1961                      | 5        | Can and Cengizler (1999)                    |
| <i>Silurus glanis</i> L., 1758            | <i>Trichodina nigra</i> Lom, 1960                      | 3        | Kılınçaslan (2007)                          |
| <i>Leuciscus cephalus</i> L., 1758        | <i>Trichodina nigra</i> Lom, 1960                      | 3        | Kılınçaslan (2007)                          |
| <i>Mugil cephalus</i> L., 1758            | <i>Trichodina lepsi</i> Lom, 1962                      | 4        | Özer and Öztürk (2004)                      |
|                                           | "                                                      | 4        | This study                                  |
|                                           | <i>Trichodina puytoraci</i> Lom, 1962                  | 4        | Özer and Öztürk (2004)                      |
|                                           | "                                                      | 4        | This study                                  |
|                                           | "                                                      | 4        | This study                                  |
| <i>Liza aurata</i> Risso, 1810            | <i>Trichodina puytoraci</i> Lom, 1962                  | 4        | Özer and Öztürk (2004)                      |
|                                           | "                                                      | 4        | Öztürk (2013)                               |
|                                           | "                                                      | 4        | Özer and Yılmaz Kırca (2013)                |
|                                           | "                                                      | 4        | This study                                  |
|                                           | <i>Trichodina lepsi</i> Lom, 1962                      | 4        | Özer and Öztürk (2004)                      |
|                                           | "                                                      | 4        | Özer and Yılmaz Kırca (2013)                |
| <i>Merlangius merlangus</i> L., 1758      | "                                                      | 4        | This study                                  |
|                                           | <i>Trichodina puytoraci</i> Lom, 1962                  | 4        | Öğüt and Palm (2005)                        |
|                                           | <i>Trichodina claviformis</i> Dobberstein & Palm, 2000 | 4        | Öğüt and Palm (2005)                        |
|                                           | <i>Trichodina</i> sp.                                  | 4        | Öğüt and Palm (2005)                        |
|                                           | "                                                      | 4        | Öğüt and Altuntaş (2011)                    |

**Table 5.** (Continued).

| Fish host                                    | Trichodinid species                               | Locality | Authors (references)               |
|----------------------------------------------|---------------------------------------------------|----------|------------------------------------|
| <i>Platichthys flesus</i> L., 1758           | <i>Trichodina domerguei</i> Wallengren, 1897      | 4        | Öztürk and Özer (2007)             |
|                                              | "                                                 | 4        | Öztürk and Özer (2008)             |
|                                              | <i>Trichodina jadranica</i> Raabe, 1958           | 4        | Öztürk and Özer (2007)             |
|                                              | "                                                 | 4        | Öztürk and Özer (2008)             |
| <i>Dicentrarchus labrax</i> L., 1758         | <i>Trichodina domerguei</i> Wallengren, 1897      | 5        | Canlı (2010)                       |
| <i>Gasterosteus aculeatus</i> L., 1758       | <i>Trichodina domerguei</i> Wallengren, 1897      | 4        | Özer (2003a)                       |
|                                              | "                                                 | 4        | This study                         |
|                                              | <i>Trichodina tenuidens</i> Faure-Fremiet, 1944   | 4        | Özer (2003a)                       |
|                                              | "                                                 | 4        | This study                         |
|                                              | <i>Trichodina</i> sp1                             | 4        | This study                         |
| <i>Neogobius melanostomus</i> Pallas, 1811   | <i>Trichodina domerguei</i> Wallengren, 1897      | 4        | Özer (2003b)                       |
| <i>Neogobius fluviatilis</i> Pallas, 1814    | <i>Trichodina domerguei</i> Wallengren, 1897      | 4        | Öztürk and Çam (2013)              |
|                                              | "                                                 | 4        | This study                         |
|                                              | <i>Trichodina heterodontata</i> Duncan, 1977      | 4        | Öztürk and Çam (2013)              |
|                                              | "                                                 | 4        | This study                         |
|                                              | <i>Paratrachodina corlissi</i> Lom & Haldar, 1977 | 4        | Öztürk and Çam (2013)              |
|                                              | "                                                 | 4        | This study                         |
| <i>Pomatoschistus marmoratus</i> Risso, 1810 | <i>Trichodina domerguei</i> Wallengren, 1897      | 4        | Öztürk and Çam (2013)              |
|                                              | "                                                 | 4        | This study                         |
|                                              | <i>Trichodina luciopercae</i> Lom, 1970           | 4        | Öztürk and Çam (2013)              |
|                                              | "                                                 | 4        | This study                         |
| <i>Proterorhinus marmoratus</i> Pallas, 1814 | <i>Trichodina domerguei</i> Wallengren, 1897      | 4        | Öztürk and Çam (2013)              |
| <i>Sparus aurata</i> L., 1758                | <i>Trichodina domerguei</i> Wallengren, 1897      | 5        | Canlı (2010)                       |
|                                              | <i>Trichodina</i> sp.                             | 2        | Tokşen (2004)                      |
| <i>Sander lucioperca</i> L. 1758             | <i>Trichodina domerguei</i> Wallengren, 1897      | 4        | This study                         |
|                                              | <i>Trichodina luciopercae</i> Lom, 1970           | 4        | This study                         |
| <i>Gambusia holbrooki</i> Girard, 1859       | <i>Trichodina domerguei</i> Wallengren, 1897      | 4        | This study                         |
| <i>Cobitis taenia</i> L., 1758               | <i>Trichodina cobitis</i> Lom, 1960               | 4        | This study                         |
|                                              | <i>Trichodina</i> sp2                             | 4        | This study                         |
| <i>Oncorhynchus mykiss</i> Walbaum, 1792     | <i>Trichodina</i> sp.                             | 3        | Burgu et al. (1998)                |
|                                              | <i>Trichodina</i> sp.                             | 4        | Özer et al. (2010)                 |
|                                              | <i>Tripartiella</i> sp.                           | 3        | Altunay and Yavuzcan Yıldız (2008) |
| <i>Belone belone</i> L., 1761                | <i>Trichodina</i> sp.                             | 4        | Özer and Yurakhno (2013)           |
| <i>Psetta maximus</i> L., 1758               | <i>Trichodina</i> sp.                             | 4        | Aksungur (2003)                    |
|                                              | <i>Trichodina</i> sp.                             | 5        | Emre et al. (2011)                 |
| <i>Syngnathus acus</i> L., 1758              | <i>Trichodina</i> sp3                             | 4        | This study                         |
| <i>Poecilia reticulata</i> Peters, 1859      | <i>Trichodina</i> sp.                             | 5        | Koyuncu and Cengizler (2002)       |
| <i>Poecilia latipinna</i> Lesueur, 1821      | <i>Trichodina</i> sp.                             | 5        | Koyuncu and Cengizler (2002)       |
| <i>Xiphophorus helleri</i> Heckel, 1848      | <i>Trichodina</i> sp.                             | 5        | Koyuncu and Cengizler (2002)       |
| <i>Xiphophorus maculatus</i> Günther, 1866   | <i>Trichodina</i> sp.                             | 5        | Koyuncu and Cengizler (2002)       |
| <i>Heros efasciatus</i> Heckel, 1840         | <i>Trichodina</i> sp.                             | 4        | Kayış et al. (2013)                |
| <i>Labidochromis caeruleus</i> Fryer, 1956   | <i>Trichodina</i> sp.                             | 4        | Kayış et al. (2013)                |

but quite high intensity values, similar to data obtained for *Mugil cephalus* by *T. lepsi* and *T. puytoraci*, *Sygnatus acus* by *Trichodina* sp3, and *Cobitis taenia* by *T. cobitis*. On the other hand, *Gasterosteus aculeatus* was infested by *T. domerguei* and *T. tenuidens* with similar prevalence but lower intensities than those found by Özer (2003) in another locality in region 4. Özer and Yılmaz Kırca (2013) indicated that environmental factors in different levels at sampling sites might have an effect in favor of one species over another, and higher level of intensity values recorded for some species in the Kızılırmak Delta might reflect the promoting potential of this sampling area for trichodinid infections.

Protozoan infestations on fish, including trichodinids, are strongly dependent on ecological conditions such as temperature, high organic loads, and deterioration of water quality (Özer and Yılmaz Kırca, 2013). In the present study, the Lower Kızılırmak Delta showed seasonal differences in water temperatures, while dissolved oxygen, salinity, and nitrate were more constant throughout the seasons (see Table 4). Trichodinids on *Mugil cephalus* occurred more frequently in autumn, when there were low levels of temperature, salinity, and nitrate, while trichodinids on *Aphanius danfordii* occurred more frequently in summer, when the highest temperature and nitrate values were recorded in the delta. Trichodinids on *Neogobius fluviatilis* are similar to those of *Aphanius danfordii*, but they occurred more frequently in spring, when moderate water temperature and nitrate values were recorded. It must be noted that *Trichodina heterodontata* on *Neogobius fluviatilis* and *T. modesta* on *Aphanius danfordii* were dominant species. Thus, we think that these differences resulted from different needs of different trichodinid species, considering the differences in trichodinid fauna on both fish species (see Table 3 for details), as was reported by Özer and Yılmaz Kırca (2013). On the other hand, statistical comparisons could not be performed for most of the trichodinid species on their respective hosts due to most of the fish species being obtained only in some seasons. This possibly occurred as a result of their year-round ecological and physiological peculiarities and the

large mesh sizes of our fish nets, despite increased efforts to collect more fish for parasitological investigation in all seasons. However, the data obtained throughout this comprehensive research study still provide important findings for the trichodinid fauna of the Lower Kızılırmak Delta and make valuable contributions to the knowledge of their infestations on fishes of Turkish waters.

According to the results of our parasitological investigation in the Lower Kızılırmak Delta and the review provided in this work, it can be said that many, but still insufficient, studies on fish trichodinids have been conducted in Turkey. Considering all current data on investigated fish species and their trichodinids in Turkey, the first reports go back to 1998; since then, an increasing trend in research studies reporting trichodinids is obvious from different geographical parts of Turkey, especially region 4 (see Table 1 for details). A total of 204 fish species out of 850 in Turkey have been reported to be infected by several parasite species, and only 31 fish species were found infested by 33 trichodinid parasites. Considering the total number of fish species in the Turkish fauna and the number of identified trichodinids, it is necessary to conduct more comprehensive research studies on unexamined fish species to attain a more complete picture throughout all Turkish waters. As was recommended by Palm and Dobberstein (1999) and Ögüt and Palm (2005), the data on trichodinid parasites can be used for evaluation of health conditions and the general influence of the level of parasitism on the community structure, as well as ecological and biological conditions of aquatic systems. Both our results in the present study and the available literature data clearly indicate that more studies will yield more trichodinid species on fish populations, and those studies will also provide information on the current status of Turkish aquatic environments.

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