PARASITIC NEMATODES INFECTING COMMERCIAL FISHES OFF THE COAST OF ALGERIA

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Abstract. A total of 1229 specimens representing 11 commercial fish species caught off the coast of Algeria were examined for parasitic nematodes (larvae) from November 2015 to April 2017. Four nematode species belonging to Anisakis (1 species) and Hysterothylacium (3 species) genera were identified. The presence of A. simplex parasitism in Trachurus trachurus was significantly related to the length (p < 0.05) of the fish and the season of its capture (p < 0.05), but not to its sex (p = 0.61%). Large benthic species and some pelagic species show high rates of infection with parasitic nematodes and therefore pose considerable health risk (anisakiasis) thereby compromising food safety. An up-to-date reference checklist of nematode species collected from the North African fish species was compiled with specific relationships between parasitic nematodes and their hosts and/or their collecting location indicated.

INTRODUCTION

Anisakids (Nematoda: Anisakidae) are parasitic nematodes whose life cycles involve crustaceans, cephalopods, fish and marine mammals (Angelucci et al. 2011). Anisakidae, especially those of the genera Anisakis Dujardin, 1845, Pseudoterranova Mozgovoi, 1951 and Contracaecum Railliet and Henry, 1912, are transmissible to humans. They can cause significant clinical diseases in fish consumers (Yagi et al. 1996; Valero et al. 2003; Martin-Sanchez et al. 2005; Petithory 2008; González et al. 2015 and Baptista-Fernandes et al. 2017) and serious negative impact on the economic prosperity of the fishing industry (Eissa et al. 2018).

Inadvertent ingestion of L3 larvae of parasitic nematodes of the genus Anisakis (Baptista-Fernandes et al. 2017) when consuming raw or undercooked seafood causes the zoonotic disease anisakiasis, which is becoming more prevalent among marine mammals and humans (Adams 1997; Audicana and Kennedy 2008; Colombo et al. 2016).

Worldwide, 14000 cases of anisakiasis, were reported from 1976 to 2002 (Audicana et al. 2002). In Japan, 2000 cases were reported per year, in the United States 50 and in Europe 500, more than 95% of which were reported in the Netherlands, Germany and Spain (Yu- walee 2015).

Larizza and Vovlas (1995) reported risks to public health associated with the appearance of larvae of the parasitic nematodes belonging to Anisakis spp. in the peritoneal cavity of Merluccius (L.) and Sardina pilchardus (Walbaum 1792), common fish species in the southern Adriatic and Ionian Seas. In Algeria, fisheries production in 2017 reached 108000 tons compared to 120000 tons in 2018. This increase in the volume of fisheries production is expected to affect the rate of fish consumption, which is currently estimated at 5 kg/capita/year (MDRP 2018), accordingly. In the Algerian fishing sector, little attention is given to the pathogenic fish parasites. The control of health risks associated with fishery products requires considerable effort. The quality of sea food products is very important considering the risks they may pose to consumers and the exigencies of international commerce. However, regulations defining the measures to be considered in order to mitigate the health risks related to the consumption of parasitized fish are scant. In 1996, the European Union excluded the importation of Mauritanian fish for food security reasons (Khlifa et al. 2013), which has led to major economic losses in Mauritania. In Algeria, the risks related to the presence of parasitic nematodes in fishery products are poorly known by professionals and consumers, which can be explained by the lack of taxonomic and epidemiological studies on these pathogenic parasites. The aims of the current study were: 1) to study the epidemiology of parasitic nematodes in commercial fish species from off the coast of Algeria, 2) to compile an up-to-date checklist of parasitic nematode species reported per fish host in North African waters, and 3) to provide scientific data on these parasites, which may help decision makers (risk managers) to set up a pathogen control system in our fisheries.
MATERIALS AND METHODS

Study area and fish sampling
A total of 1229 specimens belonging to 11 teleost fish species (Pagellus erythrinus (Linnaeus 1758), Pagellus acarne (Risso 1827), Trachurus (Linnaeus 1758), Trachurus mediterraneus (Steindachner 1868), Boops boops (Linnaeus 1758), Mullus surmuletus Linnaeus 1758, Mullus barbatus barbatus Linnaeus 1758, Engraulis encrasicolus (Linnaeus 1758), Merluccius merluccius (Linnaeus 1758), Sardinella aurita Valenciennes 1847 and Sardina pilchardus (Walbaum 1792)) and T. trachurus, P. acarne and P. erythrinus were regularly sampled from a fishing port in the Gulf of Bejaia (eastern coast of Algeria) (Figure 1) between November 2015 and April 2017. The captured fish were transferred to the laboratory, where the length and total weight of each specimen were measured to the nearest 0.1 cm and the nearest (0.1 g), respectively.

Parasitological study
After dissection of the fish, internal organs (abdominal cavities, intestines, stomachs, livers and gonads) of each specimen were examined using a stereomicroscope. The collected parasites were preserved in alcohol 70%, and their morpho-anatomy was identified using the keys available and original descriptions (Petter and Maillard 1987, 1988; Moravec 1994). The parasitological indexes were calculated according to Margolis et al. (1982) and Bush et al. (1997).

Statistical analyses
The comparison of the mean intensity (IM = number of parasites/number of infected fishes) according to the fish sex, size and seasons was tested for significance using the Student’s t-test, non-parametrical Kruskal-Wallis and parametrical ANOVA tests. Infection rates (P% = number of infected fish/number of examined fish × 100) (sex, size and seasons) were compared by Chi-square test. The statistical study was performed with R software (R Development Core Team 2005).

RESULTS
Among the 11 host fish species examined, 8 species were found to be infected with parasitic nematodes. Trachurus trachurus, T. mediterraneus, Mullus surmuletus, M. barbatus barbatus and Merluccius merluccius were infected with the highest number of Nematoda species (four nematode species), whereas Engraulis encrasicolus, Sardinella aurita and Sardina pilchardus were not infected with parasitic nematodes at all. The remaining fish species were found to be infected with three parasitic nematodes species (Table 1), which were mainly collected from the abdominal cavity, gonads, liver and the intestine (Figure 2; Table 1). According to our findings, Hysterothylacium aduncum (Rudolphi 1809) parasitized all infected fishes (8 species), Hysterothylacium fabri (Rudolphi 1819) and Anisakis simplex (Rudolphi 1809) infected seven and six host species, respectively (Table 1). One parasitic
### Table 1. Parasitological indexes of the collected Nematodes.

| Host/parasites                                      | Total |  |  |  |  |  |  |  |  |  |
|----------------------------------------------------|-------|---|---|---|---|---|---|---|---|---|
|                                                    | P%    | MI | P% | MI | P% | MI | Attachment sites | Statistic test P (MI) | Statistic test P (P%) |
| *Pagellus acarne* (n = 280)                        |       |    |    |    |    |    |                   |                         |                        |
| *Hysterothylacium aduncum**                        | 30.35 | 1  | 19.62 | 1.7 | 15.94 | 1.63 | Ac, go, In | P = 0.836 | P = 0.358 |
| *Hysterothylacium fabri**                          | 39.2  | 1.09 | 6.54 | 1.14 | 1.44 | 1.44 | In, Ac | P = 0.693 | P = 0.63 |
| *Hysterothylacium sp.*                             | 89.64 | 1.02 | 40.18 | 2.06 | 23.18 | 2.5 | Ac, In | P = 0.130 | P = 0.814 |
| **Total**                                          | 58.21 | 3.42 | 68.22 | 2.5 | 53.62 | 3.2 |           |                         |                        |
| *Pagellus erythrinus* (n = 335)                     |       |    |    |    |    |    |                   |                         |                        |
| *Hysterothylacium aduncum**                        | 30.44 | 3.68 | 31.72 | 3.48 | 3.89 | 2.21 | Ac, go, In, L | P = 0.008* | P = 0.35 |
| *Hysterothylacium fabri**                          | 34.32 | 3.26 | 35.74 | 2.78 | 33.3 | 3.3 | In, Ac, go | P = 0.78 | P = 0.88 |
| *Hysterothylacium sp.*                             | 33.73 | 3.59 | 34.13 | 3.51 | 2.78 | 4.7 | Ac, In | P = 0.74 | P = 0.42 |
| **Total**                                          | 68.95 | 7.38 | 68.67 | 7.77 | 97.22 | 5 |           |                         |                        |
| *Trachurus trachurus* (n = 317)                     |       |    |    |    |    |    |                   |                         |                        |
| *Hysterothylacium aduncum**                        | 8.23  | 1.7 | 6.17 | 1.81 | 9.45 | 1.28 | Ac, go, In, L | P = 0.352 | P = 0.663 |
| *Hysterothylacium fabri**                          | 2.43  | 1.37 | 2.80 | 1.4 | 2.70 | 1.5 | In, Ac | P = 0.270 | P = 0.628 |
| *Hysterothylacium sp.*                             | 10.06 | 2.36 | 18.53 | 2.36 | 10.81 | 2.75 | Ac, In | P = 0.923 | P = 0.770 |
| *Anisakis simplex**                                | 6.30  | 1.37 | 5.61 | 1.2 | 8.10 | 1.5 | Ac, In | P = 0.611 | P = 0.208 |
| **Total**                                          | 30.91 | 7.38 | 68.22 | 2.5 | 53.62 | 3.2 |           |                         |                        |
| *Trachurus mediterraneus* (n = 23)                  |       |    |    |    |    |    |                   |                         |                        |
| *Hysterothylacium aduncum**                        | 65.21 | 5.33 | 65 | 5.33 | 66.66 | 4 | Ac, go, In | P = 0.695 | P = 0.361 |
| *Hysterothylacium fabri**                          | 4.34  | 2 | 0 | 0 | 33.3 | 2 | In, Ac | P = 0.016* | P = 0.62 |
| *Anisakis simplex**                                | 13.04 | 2.33 | 15 | 2.33 | 0 | 0 | Ac, In | P = 0.072 | P = 0.082 |
| *Hysterothylacium sp.*                             | 34.78 | 1.37 | 40 | 1.37 | 0 | 0 | Ac, In | P = 0.001* | P = 0.002* |
| **Total**                                          | 82.60 | 5.52 | 80 | 5.62 | 100 | 5 |           |                         |                        |
| *Mullus surmuletus* (n = 40)                        |       |    |    |    |    |    |                   |                         |                        |
| *Hysterothylacium aduncum**                        | 20 | 4.37 | 22.22 | 4.5 | 0 | 0 | Ac, go, In | P = 0.002* | P = 0.003* |
| *Hysterothylacium fabri**                          | 3.75 | 3.06 | 33.33 | 3.08 | 50 | 1.5 | In, Ac | P = 0.13 | P = 0.645 |
| *Hysterothylacium sp.*                             | 60 | 3.45 | 61.11 | 4.13 | 50 | 1.5 | Ac, In | P = 0.0007* | P = 0.656 |
| *Anisakis simplex**                                | 2.25 | 1.11 | 22.22 | 1 | 25 | 1 | Ac, In, go | P = 1 | P = 0.920 |
| **Total**                                          | 70 | 6.28 | 69.44 | 6.8 | 75 | 2 |           |                         |                        |
| *Mullus barbatus barbatus* (n = 47)                 |       |    |    |    |    |    |                   |                         |                        |
| *Hysterothylacium aduncum**                        | 14.89 | 1.42 | 13.88 | 1 | 18.18 | 2.5 | In, Ac, L | P = 0.602 | P = 0.772 |
| *Hysterothylacium fabri**                          | 19.14 | 1.55 | 13.88 | 1.2 | 36.36 | 2 | In, Ac | P = 0.146 | P = 0.191 |
| *Hysterothylacium sp.*                             | 21.27 | 1.3 | 13.8 | 1.2 | 45.45 | 1.4 | Ac, In | P = 0.681 | P = 0.083 |
| *Anisakis simplex**                                | 2.12 | 1 | 0 | 0 | 9.09 | 1 | Ac | P = 0.034* | P = 0.340 |
| **Total**                                          | 51.06 | 2.12 | 41.66 | 1.66 | 81.81 | 2.88 |           |                         |                        |
| *Boops boops* (n = 55)                             |       |    |    |    |    |    |                   |                         |                        |
| *Hysterothylacium aduncum**                        | 1.81 | 2 | 0 | 2.63 | 2 | Ac | P = 0.5 | P = 0.323 |
| *Hysterothylacium sp.*                             | 7.27 | 1.25 | 5.88 | 2 | 7.89 | 1 | In, Ac | P = 0.786 | P = 0.422 |
| *Anisakis simplex**                                | 3.63 | 1 | 5.88 | 7 | 2.63 | 1 | Ac, In | P = 1 | P = 0.618 |
| **Total**                                          | 12.72 | 1 | 35.29 | 1 | 13.15 | 1.2 |           |                         |                        |
| *Merluccius merluccius* (n = 12)                    |       |    |    |    |    |    |                   |                         |                        |
| *Hysterothylacium aduncum**                        | 16.66 | 1 | 0 | 0 | 28.57 | 1 | In, Ac | P = 0.091 | P = 0.172 |
| *Hysterothylacium fabri**                          | 10 | 1 | 0 | 0 | 14.28 | 1 | In, Ac | P = 0.003* | P = 0.355 |
| *Hysterothylacium sp.*                             | 16.66 | 1.5 | 0 | 0 | 28.57 | 1.7 | Ac, In | P = 0.204 | P = 0.172 |
| *Anisakis simplex**                                | 33.33 | 1.25 | 20 | 1 | 42.85 | 1.16 | In, go, L | P = 0.183 | P = 0.440 |
| **Total**                                          | 75 | 1 | 20 | 1 | 85.71 | 1.5 |           |                         |                        |
| *Engraulis encrasicolus*                           | 40 | 0 | 0 | 0 | 0 | 0 |           |                         |                        |
| *Sardinella aurita*                                | 40 | 0 | 0 | 0 | 0 | 0 |           |                         |                        |
| *Sardina pilchardus*                               | 40 | 0 | 0 | 0 | 0 | 0 |           |                         |                        |

Ac: Abdominal cavity; go: Gonads; In: intestine; L: Liver; AS: Attachment site; *, Uninfected fish specimen; **: New host for *A. simplex* and *H. aduncum*; M: Mean; SD: Standard deviation; P%: Prevalence; IM: Mean intensity; P: Probability.
nematode species *H. fabri* was newly collected from the study region and 4 new host species (*T. mediterraneus*, *M. surmuletus*, *M. barbatus barbatus* and *M. merluccius*) were recorded for the pathogenic worm *A. simplex*. The majority of the collected parasitic nematodes species had been already reported by several researchers from different localities of the Mediterranean Sea (Table 2). However, only 8 of these worms were reported from Algeria (Table 2). Our results show the highest infection rates in the most consumed pelagic host species, especially in *T. mediterraneus* (P = 82.60%).

This small pelagic species could pose a risk to consumers if no prophylactic measures are taken. The highest total infection rates were also recorded in *M. merluccius* (P = 75%), *M. surmuletus* (P = 70%), *P. erythrinus* (P = 68.95%) and *P. acarne* (P = 58.21%) (Table 1 and Figure 3).

*Hysterothylacium* (Raphidascarididae) was found to exhibit higher infections rates than *Anisakis* (Anisakidae). Their infection rates, presented in descending order, are as follows: *H. aduncum* in *T. mediterraneus*, *Hysterothylacium* sp. in *M. surmuletus* and *H. fabri* in *M. surmuletus*. However, the lowest infection rates were recorded in *Boops boops* and *T. trachurus*. In the study area, small pelagic fish species such as *E. encrasicolus*, *S. aurita* and *S. pilchardus* were found to be uninfected (Table 1 and Figure 3).

There were no significant differences recorded in infection rates between males and females of *P. acarne* and *B. boops* (Table 1). However, significant differences in infection prevalence and/or intensity were observed between the two sexes (Table 1) in *P. erythrinus*, where female specimens were found to be more infected with *H. aduncum* (Table 1) than males (p < 0.05); in *M. surmuletus*, whose female specimens were more infected with *H. aduncum* and *H. sp.* respectively, than males (p < 0.05); in *T. mediterraneus*, whose female specimens were more infected with *H. sp.* and *H. fabri*, whose male specimens were more infected than females (p < 0.05); in *T. trachurus*, where male specimens were found to be more infected with *A. simplex* than females (p < 0.05); in *M. barbatus barbatus*, where male specimens were more infected with *A. simplex* and *H. sp.* respectively (p < 0.05) than females; in *M. merluccius*, where male specimens were more infected with *H. fabri* than females (p < 0.05) (Table 1). Our results show size-dependent variation in infection rates in different fish species (*T. trachurus*, *P. acarne* and *P. erythrinus*) (Figure 4 a, c, e). The highest infection rates were recorded in larger specimens of these three fish species.

As to specimens of *T. trachurus*, the highest infection rates and mean intensity (P = 70%, IM = 5.57) were
### Table 2. Check-list of parasite nematodes collected in the North African Coast.

| Parasites species | Hôtes species | Area study | References |
|-------------------|---------------|------------|------------|
| *Anisakis simplex* | *Merluccius merluccius* | Algeria | Petter and Maillard 1988; Present study |
| | | Mauritania | Farjallah et al. 2008 |
| | | Morocco | Farjallah et al. 2008 |
| *Scorpaena scrofa* | | Algeria | Petter and Maillard 1988 |
| *Trachurus trachurus* | | Algeria | Ichalal et al. 2015; Present study |
| | | Morocco | Farjallah et al. 2008; Kijewska et al. 2009; Azbaid et al. 2016; Shawket et al. 2017 |
| | | Libya | Eissa et al. 2018 |
| *Boops boops* | | Algeria | Ichalal et al. 2015; Ider et al. 2018; Present study |
| *Phycis blennoides* | | Algeria | Hassani 2015 |
| *Phycis phycis* | | Algeria | Hassani 2015 |
| *Xiphias gladius* | | Tunisia | Petter and Maillard 1988 |
| *Sarda sarda* | | Tunisia | Petter and Maillard 1988 |
| *Trachurus mediterraneus* | | Morocco | Farjallah et al. 2008 |
| | | Algeria | Present study |
| | | Morocco | Farjallah et al. 2008 |
| *Scomber scombrus* | | Morocco | Farjallah et al. 2008; Abattouy et al. 2011 |
| *Scomber japonicus* | | Algeria | Petter and Maillard 1988 |
| | | Morocco | Shukhgalter 2004; Farjallah et al. 2008; Kijewska et al. 2009; Abbatouy et al. 2011 |
| *Mullus surmuletus* | | Algeria | Present study |
| *Mullus barbatus barbatus* | | Algeria | Present study |
| *Sardina pilchardus* | | Algeria | Petter and Maillard 1988 |
| *Micromesistius poutassou* | | Algeria | Petter and Maillard 1988 |
| *Anisakis pegreffii* | *Merluccius merluccius* | Mauritania | Farjallah et al. 2008 |
| | | Morocco | Farjallah et al. 2008 |
| *Euthynnus alletteratus* | | Morocco | Farjallah et al. 2008 |
| *Trachurus trachurus* | | Morocco | Farjallah et al. 2008; Abattouy et al. 2014; Shawkat et al. 2017 |
| | | Libya | Eissa et al. 2015, 2018 |
| *Trachurus mediterraneus* | | Morocco | Farjallah et al. 2008 |
| *Scomber scombrus* | | Morocco | Farjallah et al. 2008 |
| *Scomber japonicus* | | Morocco | Farjallah et al. 2008; Abattouy et al. 2011 |
| *Trachyrincus scabrus* | | Morocco | Kijewska et al. 2009 |
| *Merluccius polli* | | Morocco | Kijewska et al. 2009 |
| *Anisakis typica* | *Scomber scombrus* | Morocco | Farjallah et al. 2008 |
| | *Scomber japonicus* | Morocco | Farjallah et al. 2008 |
| | *Merluccius merluccius* | Morocco | Farjallah et al. 2008 |
| | *Merluccius polli* | Morocco | Farjallah et al. 2008 |
| | *Hoplostethus cadenati* | Morocco | Kijewska et al. 2009 |
| *A. pegreffii / A. simplex s.s* | *Scomber japonicus* | Morocco | Abattouy et al. 2011 |
| *Anisakis physeteris* | *Scorpaena scrofa* | Algeria | Petter and Maillard 1988 |
| *Trachipterus trachypterus* | | Algeria | Petter and Maillard 1988 |
| *Phycis blennoides* | | Algeria | Hassani and Kerfouf 2014; Farjallah et al. 2006 |
| *Phycis phycis* | | Tunisia | Farjallah et al. 2006 |
| *Merluccius merluccius* | | Morocco | Mattiucci et al. 2001 |
| *Trachyrincus scabrus* | | Morocco | Kijewska et al. 2009 |
| Parasites species | Hôtés species | Area study | References |
|-------------------|---------------|------------|------------|
| Merluccius polli  | Morocco       | Kijewska et al. 2009 |
| Hoplostethus cadenati | Morocco   | Kijewska et al. 2009 |
| Anisakis brevispiculata | Merluccius merluccius | Morocco | Mattucci et al. 2001 |
| Anisakis brevispiculata | Hoplostethus cadenati | Morocco | Kijewska et al. 2009 |
| Anisakis ziphidarum | Scomber scombrus | Morocco | Farjallah et al.2008 |
| Anisakis ziphidarum | Merluccius merluccius | Morocco | Farjallah et al.2008 |
| Anisakis ziphidarum | Hoplostethus cadenati | Morocco | Kijewska et al. 2009 |
| Anisakis type I    | Boops boops   | Algeria    | Benhamou et al. 2017 |
| Anisakis type II   | Boops boops   | Algeria    | Benhamou et al. 2017 |
| Hysterothylacium aduncum | Phycis blennoides | Algeria | Hassani and Kerfouf 2014 |
|                    | Phycis phyris | Tunisia    | Farjallah et al. 2006 |
|                    | Boops boops   | Algeria    | Merzoug et al. 2012; Ichalal et al. 2015; Benhamou et al. 2017; Ider et al. 2018; Present study |
|                    | Trachurus trachurus | Algeria    | Ichalal et al. 2015; Present study |
|                    | Spicara maena | Algeria    | Benhamou et al. 2017 |
|                    | Merluccius merluccius | Tunisia   | Amor et al. 2011 |
|                    |                | Algeria    | Present study |
|                    | Trachurus mediterraneus | Tunisia | Amor et al. 2011 |
|                    | Pagellus erythinus | Tunisia | Amor et al. 2011 |
|                    |                | Algeria    | Present study |
|                    | Scorpaena notata | Algeria | Petter and Maillard 1988 |
|                    | Scorpaena elongata | Algeria | Petter and Maillard 1988 |
|                    | Phycis blennoides | Algeria    | Hassani and Kerfouf 2014 |
|                    |                | Tunisia    | Farjallah et al. 2006 |
|                    | Phycis phyris | Algeria    | Hassani 2015 |
|                    |                | Tunisia    | Farjallah et al. 2006 |
|                    | Mullus barbatus barbatus | Algeria  | Present study |
|                    | Alosa finta    | Tunisia    | Petter and Maillard 1988 |
|                    | Alosa fallax   | Tunisia    | Petter and Maillard 1988 |
| Hysterothylacium fabri | Scorpaena notata | Algeria | Petter and Maillard 1988 |
|                    | Scorpaena elongata | Algeria | Petter and Maillard 1988 |
|                    | Phycis blennoides | Algeria    | Hassani and Kerfouf 2014 |
|                    |                | Tunisia    | Farjallah et al. 2006 |
|                    | Phycis phyris | Algeria    | Hassani 2015 |
|                    |                | Tunisia    | Farjallah et al. 2006 |
|                    | Mullus surmuletus | Algeria  | Hassani et al. 2015; Present study |
|                    | Trachinus draco | Tunisia    | Azizi et al. 2017 |
|                    | Trachinus radiatus | Tunisia  | Azizi et al. 2017 |
|                    | Trachinus trachurus | Algeria  | Present study |
|                    | Pagellus acarne | Algeria    | Present study |
|                    | Pagellus erythinus | Algeria  | Present study |
|                    | Mullus barbatus barbatus | Algeria  | Present study |
|                    | Merluccius merluccius | Algeria  | Present study |
|                    | Uranoscopus scaber | Tunisia  | Petter and Maillard 1988 |
|                    | Spicara maena flexuosa | Tunisia | Petter and Maillard 1988 |
|                    | Boops boops    | Algeria    | Benhamou et al. 2017 |
| Hysterothylacium sp. | Trachinus draco | Tunisia    | Azizi et al. 2017 |
|                    | Trachinus radiatus | Tunisia  | Azizi et al. 2017 |
| Anisakis sp.        | Trachinus draco | Tunisia    | Azizi et al. 2017 |
|                    | Trachinus radiatus | Tunisia  | Azizi et al. 2017 |
| Hysterothylacium incurvum | Xiphius gladius | Algeria | Petter and Maillard 1987 |
|                    |                | Tunisia    | Petter and Maillard 1987 |
| Hysterothylacium bifidatum | Epinephelus aeneus | Algeria | Petter and Maillard 1987 |
|                    | Epinephelus guaza | Algeria    | Petter and Maillard 1987 |
observed in the largest specimens (18.5–19.9 cm in length) (Figure 4a).

In *P. erythrinus*, the highest infection rates were also observed in the largest specimens (18.2–18.9 cm in length) (P = 84.21%, IM = 5.37 (Figure 4c). Specimens of *P. acarne* also exhibited the highest infection rate (P = 89.47%, IM = 3.85) in the largest specimens, whose length ranged from 15.4 to 16.4 cm (Figure 4e).

Significant differences in infection rates and mean intensities between size classes were noted in *T. trachurus* (p < 0.0001 and p = 0.0115 respectively), in *P. acarne* (p < 0.0001 and p < 0.0001 respectively) and in *P. erythrinus* (in mean intensity, p = 0.0230).

The highest infection rates in *P. erythrinus* and *T. trachurus* were observed in summer (P = 90% and P = 55.55% respectively). However in *P. acarne*, the

![Parasitological indexes](image)

Figure 4. Variation in parasitological indexes by: a: size classes of *T. trachurus*; b: season of *T. trachurus* capture; c: size classes of *P. erythrinus*; d: season of *P. erythrinus* capture; e: size classes of *P. acarne*; f: season of *P. acarne* capture. P%: Prevalence; IM: Mean intensity; AM: Mean abundance.
highest infestation rates ($P = 63.76\%$) were recorded in
the fish caught in autumn (Figure 4b, d and f). Significant differences in infection rates between seasons were noted in *P. erythrinus* and *T. trachurus* ($p = 0.0035$ and $p = 0.00007$ respectively).

The specimens of *T. trachurus*, whose length ranged from 18 to 19.9 cm, were the most infected with *A. simplex* ($P = 20\%$, $MI = 3$), the highest infection rate ($P = 12.19\%$) being observed in summer. The presence of *A. simplex* in *T. trachurus* was found to be not sex-dependent ($p = 0.61$), but slightly significantly related to their body length ($p = 0.02$), and the season of their capture ($p = 0.04$).

**DISCUSSION**

Four parasitic nematodes species were identified based on their morph-anatomical details: *Hysterothylacium aduncum*, *Hysterothylacium fabri*, *Hysterothylacium sp*.

and *Anisakis simplex*. In our study, the most parasitized fish species were *Trachurus trachurus*, *T. mediterraneus*, *Mullus surmuletus*, *M. barbatus barbatus* and *Merluccius merluccius*. One parasitic nematode, *H. fabri*, was collected from the study area for the first time. We found four new hosts to *A. simplex* in our study area (*T. mediterraneus*, *M. surmuletus*, *M. barbatus barbatus* and *M. merluccius*). Previously, this parasitic nematode was known to infect six teleost fish species in our study region.

The fish species that were found to be most infected with parasitic nematode larvae in our study included *T. mediterraneus*, *M. merluccius*, *M. surmuletus*, *P. erythrinus*, and *P. acarne*. It is possible that it is the trophic behavior of these demersal fishes (excepting *T. mediterraneus*) that enhances their infection with parasitic nematodes (Ichalal et al. 2015; Ider et al. 2018). Crustacean and mollusc species are generally potential prey for these fish species (Froese and Pauly 2019). Also, some fishes exhibiting pelagic behavior, such as species of the genus *Trachurus*, become infected with *Anisakis* and *Hysterothylacium* larvae through ingestion of their intermediate hosts such as euphausiids, copepods, and planktivorous fish (Bacha and Amara 2009; Ichalal et al. 2015; Smith 1983).

Except for *P. acarne*, *B. boops* and *T. trachurus*, our results showed statistical differences in infection rates between both sexes in *M. barbatus barbatus* and *M. merluccius*, where males were more infected than females, and in *M. surmuletus*, *P. erythrinus* and *T. mediterraneus*, where females more infected than males. Differences in infection rates of the two sexes maybe related to differences in their trophic behavior. However, Ichalal et al. (2015) reported that off the coast of Algeria, rates of fish infection with parasitic nematodes did not vary depending on the host fish sex.

Statistical differences in infection rates between size classes were observed in *P. erythrinus* and *P. acarne* infected with parasitic nematode larvae of the genus *Hysterothylacium*, and in *T. trachurus* infected with larvae of the genus *Hysterothylacium* and *Anisakis*, with larger specimens being most infected. Ichalal et al. (2015) and Abattouy et al. (2011) reported size-dependent infection rates in fish hosts from off the Mediterranean coasts of Morocco and Algeria. They postulated that intermediate prey, i.e. intermediate hosts of these parasites, constitute a significant part of large fish diet, which accounts for the increased ingestion of these parasites and, consequently, increased infection rates.

According to Abattouy et al. (2011), the highest prevalence of infection with Anisakid larvae in *T. trachurus* and in *P. erythrinus* was recorded in summer, and Eissa et al. (2018), reported that the highest prevalence of infection with *A. pegreffii* in *T. trachurus* was also observed in summer. However in *P. acarne*, the highest infection rates were recorded in autumn.

Variations in infection levels in the examined fish species could be related to many environmental factors (temperature, prey availability, etc.), behavior of host species (juvenile, adult, male, female), food availability (intermediate host), and feeding behavior of host fish species (pelagic, benthic).

Parasitic nematodes can affect physiological functions of fish. If the necessary prophylactic measures are not taken, consumption of infected fish could pose health risks. Further investigations into the origins of these infections and their avoidance should be carried out. It is also important that a strategy for infection mitigation and control be implemented in all Algerian fisheries. The aims should be to limit the spatio-temporal spread of infection with parasitic nematodes by regularly monitoring all commercial fish species, with particular attention being paid to those intended for export, and also, to inform consumers and decision makers about the risks these parasitic nematodes pose to human health.

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