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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 (Yuwalee 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

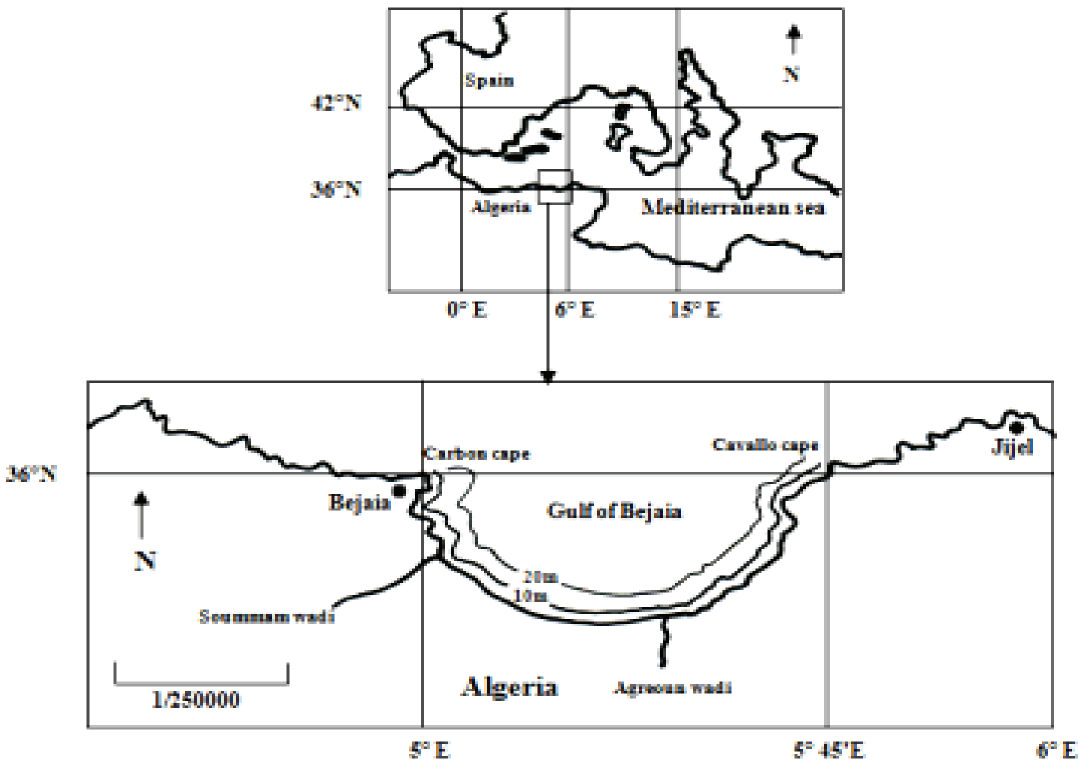

Figure 1. Location of the study area (Ider et al. 2018).

Table 1. Parasitological indexes of the collected Nematodes.

Host/parasites	Total		Females		Males		Attachment sites	Statistic test P (MI)	Statistic test P (P%)
	P%	MI	P%	MI	P%	MI			
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	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	2.25	15.24	2.6	31.08	2.65			
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	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	In	**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	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						
*Sardinella aurita**	40	0	0						
*Sardina pilchardus**	40	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.

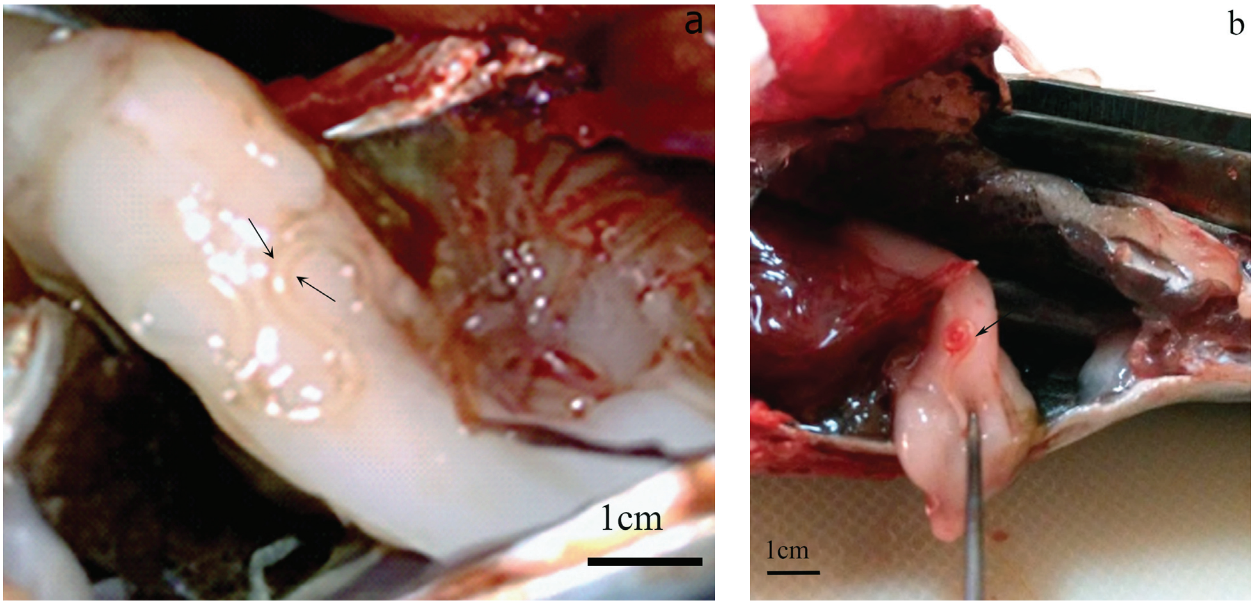

Figure 2. Anisakid larvae in the abdominal cavity of the examined teleost fish species. a, b: Anisakid larvae fixed on the male gonad of *Trachurus trachurus* (see dark arrow) (scale bars = 1 cm).

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).

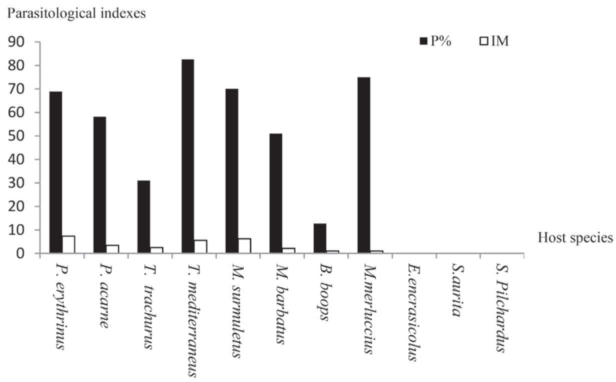

Figure 3. Variation in parasitological indexes by host species. P%: Prevalence; IM: Mean intensity.

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 Tunisia	Hassani and Kerfouf 2014 Farjallah et al. 2006
	Phycis phycis	Algeria Tunisia	Hassani 2015 Farjallah et al. 2006
	Merluccius merluccius	Morocco	Mattiucci et al. 2001
	Trachyrincus scabrus	Morocco	Kijewska et al. 2009

Parasites species	Hôtes species	Area study	References
	Merluccius polli	Morocco	Kijewska et al. 2009
	Hoplostethus cadenati	Morocco	Kijewska et al. 2009
Anisakis brevispiculata	*Merluccius merluccius* *Hoplostethus cadenati*	Morocco Morocco	Mattiucci et al. 2001 Kijewska et al. 2009
Anisakis ziphidarum	*Scomber scombrus* *Merluccius merluccius* *Hoplostethus cadenati*	Morocco Morocco Morocco	Farjallah et al.2008 Farjallah et al.2008 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 Tunisia	Hassani and Kerfouf 2014 Farjallah et al. 2006
	Phycis phycis	Algeria Tunisia	Hassani 2015 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
		Algeria	Present study
	Pagellus erythrinus	Tunisia Algeria	Amor et al. 2011 Present study
	Scorpaena notata	Algeria	Petter and Maillard 1988
	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 Tunisia	Hassani and Kerfouf 2014 Farjallah et al. 2006
	Phycis phycis	Algeria Tunisia	Hassani 2015 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
	Trachurus trachurus	Algeria	Present study
	Pagellus acarne	Algeria	Present study
	Pagellus erythrinus	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* *Trachinus radiatus*	Tunisia Tunisia	Azizi et al. 2017 Azizi et al. 2017
Anisakis sp.	*Trachinus draco* *Trachinus radiatus*	Tunisia Tunisia	Azizi et al. 2017 Azizi et al. 2017
Hysterothylacium incurvum	*Xiphias gladius*	Algeria Tunisia	Petter and Maillard 1987 Petter and Maillard 1987
Hysterothylacium bifidalatum	*Epinephelus aeneus* *Epinephelus guaza*	Algeria Algeria	Petter and Maillard 1987 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

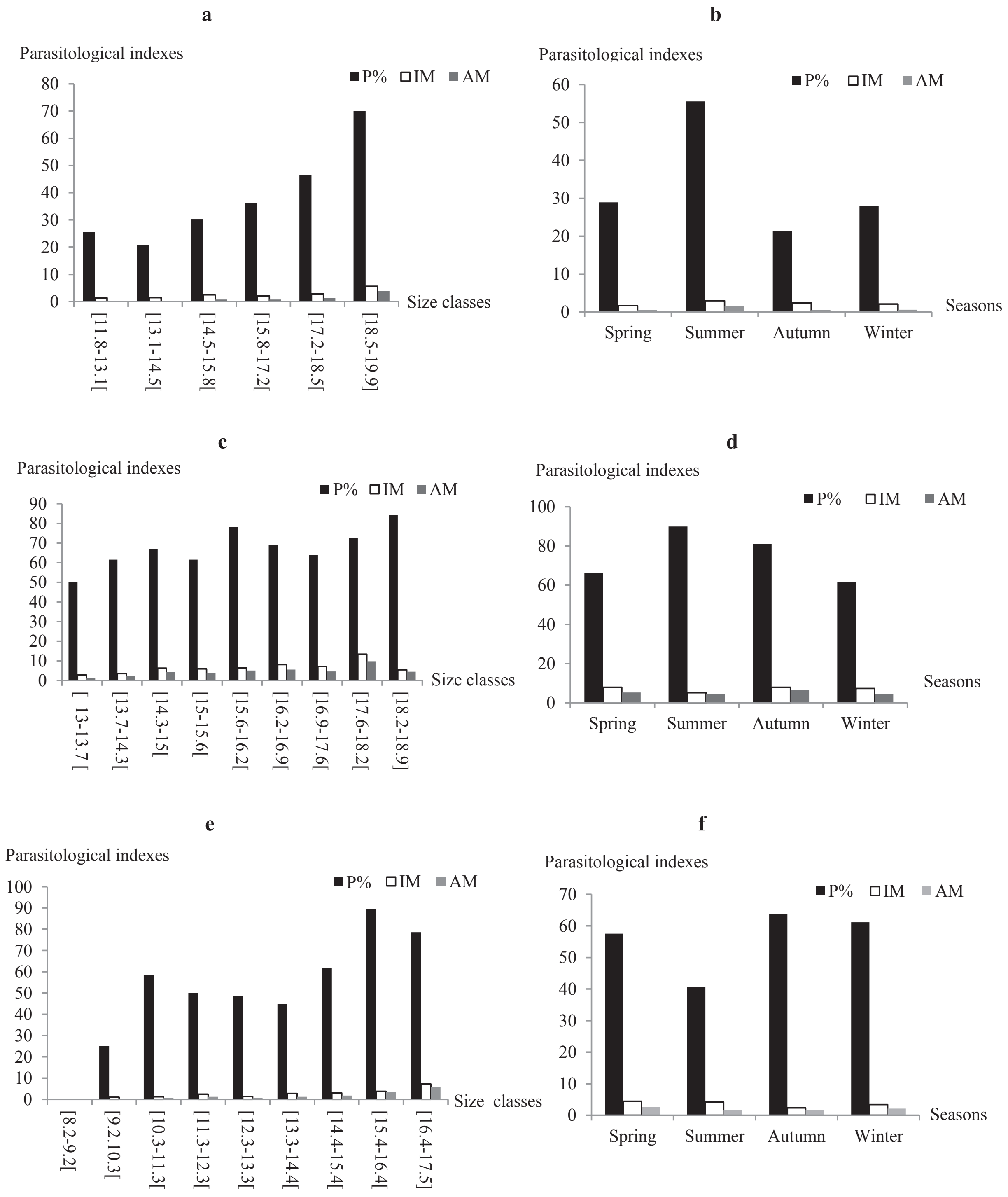

Figure 4. Variation in parasitological indexes by: **a**: size classes of *T. trachurus*; **b**: season of *T. trachurus* capture; **c**: size classes of *P. erythrinus*; **d**: season of *P. erythrinus* capture; **e**: size classes of *P. acarne*; **f**: season of *P. acarne* capture. P%: Prevalence; 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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