

Metazoan parasites of trachinid fishes (Teleostei: Trachinidae) from Tunisian coasts (Mediterranean Sea)

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A parasitological survey of Trachinus draco Linnaeus, 1758; Trachinus araneus Cuvier, 1829 and Trachinus radiatus Cuvier, 1829 collected from Tunisian coasts was performed from January 2014 to January 2015. In total, 18 species of metazoan parasites belonging to 13 genera were found: nine Myxozoa, four Nematoda, one Cestoda, one Digenea, one Monogenea, one Isopoda and one Annelida Hirudinea. Data on morphology, location and infection levels of parasites were provided. The higher species richness was recorded in Trachinus draco (18 species), while Trachinus radiatus and Trachinus araneus harbored 9 and 7 species, respectively. Species richness and diversity according to the host species and the sampling sites based on the Simpson and Shannon-Wiener indices are reported.

Key words: Trachinidae fish, Metazoan parasites, species richness, Tunisia

INTRODUCTION

Trachinids (Teleostei: Trachinidae) are a family of benthic marine fish living on sandy or muddy bottoms, typically on the continental shelf but also in deeper waters of 150 to 200 m. These fish have a wide distribution through the eastern Atlantic coasts, Mediterranean Sea and Black Sea. In Tunisia, the most commonly known species of trachinids are: the greater weever, (*Trachinus draco*), the spotted weever, (*Trachinus araneus*) and the starry weever (*Trachinus radiatus*). Several studies have been performed on the metazoan parasites of trachinids through the word (DILLON & HARGIS, 1965; ORRECHIA & PAGGI, 1978; GEORGES, 1982; PETTER & MAILLARD, 1988; TRILLES *et al.*, 1989; CANNING *et al.*, 1999; HORTON, 2000; AKMIRZA,

2004; ÖKTENER & TRILLES, 2004; FARJALLAH *et al.*, 2008). Nevertheless, in Tunisia, only two studies have been achieved on trachinid fishes, AZIZI *et al.* (2016) described a new species of myxosporean *Zschokkella trachini* from the gallbladder of *Trachinus draco* and FARJALLAH *et al.* (2008) who reported the nematode *Anisakis pegreffii* parasite of *T. draco*. Parasitic diseases may influence weight, reproduction, growth and survival of the host, inducing significant economic losses in fish production particularly in aquaculture. Therefore, data on biodiversity and ecology of parasites in natural ecosystems, the nature of the host/parasite relationship and the possible use of parasites as biological tags are very important in terms of conservation. In order to expand our knowledge on the biodiversity of trachinids parasites, we have undertaken a parasitological

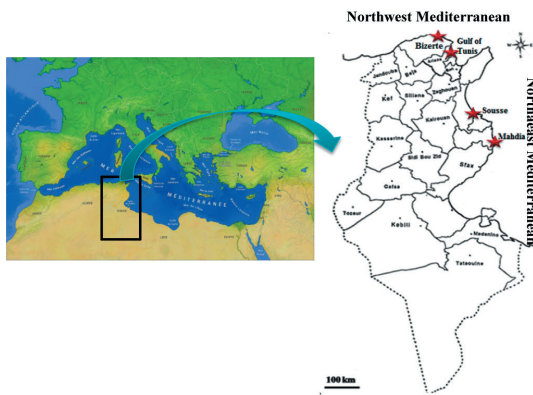


Fig. 1. Map showing the locations of the 4 sampling sites

survey from four different sites along the Tunisian coasts.

MATERIAL AND METHODS

From January 2014 to January 2015, a total of 703 trachinid fishes belonging to *Trachinus draco*, *Trachinus araneus* and *Trachinus radiatus* were collected monthly from four marine regions in Tunisia, located in the northern coast: Bay of Bizerte (37° 20' N, 9° 53' E) and Gulf of Tunis (36° 49' N, 10° 18' E) and in the eastern coast: Sousse (35° 50' N, 10° 38') and Mahdia (35° 29' N, 11° 3' E). The number of examined specimens and the range of total length (TL) according to the locality are given in the Table 1. In the labo-

ratory fish were examined for the presence of ectoparasites and endoparasites. Therefore, skin, fins, gills, eyes body cavity and viscera were examined carefully macroscopically and microscopically. All organs and body fluids were examined as well. Fresh spores of myxosporean isolated from gallbladders were measured according to the guidelines of LOM & ARTHUR (1989). Measurements were based on 30 fresh spores and data were presented as mean \pm SD (range). Permanent preparation of monogeneans, digeneans and cestods were made according to JUSTINE *et al.* (2012). Nematodes isolated from the abdominal cavity and intestine were fixed in 70% ethanol, cleared in Amann lactophenol and studied by direct examination between slide and cover slip. Isopods isolated from the body surface and fins were fixed in 70% ethanol. All measurements were carried out using micrometric ocular. Isopods and annelids were photographed under a stereo microscope however the other parasites were photographed with a Canon Power Shot A2500 digital camera mounted on a Nikon E600 microscope using DIC optics. The prevalence, mean intensity and mean abundance were determined according to BUSH *et al.* (1997). Parasite diversity was described on the bases of the Simpson, and Shannon-Wiener indices. These indices were calculated according to MAGURRAN (1988).

Table 1. Number and range of total length (TL) of the examined hosts according to the locality

Species	Locality	Number	Range of TL (mm)
<i>T. draco</i>	Bay of Bizerte	190	21.5-30.5
	Sousse	110	15.5-28.5
	Mahdia	156	19.5-29.5
	Gulf of Tunis	65	15.5-23.5
<i>T. araneus</i>	Bay of Bizerte	26	19.5-34.5
	Sousse	18	23.5-34.8
	Mahdia	47	21.5-33.9
	Gulf of Tunis	0	-
<i>T. radiatus</i>	Bay of Bizerte	27	19.5-35.9
	Sousse	18	14.5-31.5
	Mahdia	46	14.5-34.5
	Gulf of Tunis	0	-

RESULTS

Composition of the parasite communities

A total of 18 parasite species representing 13 genera were collected from trachinid fishes: *Ceratomyxa* Thélohan, 1892, *Zschokkella* Auerbach, 1910, *Ortholinea* Shulman, 1962, *Myxidium* Bütschli, 1882, *Chloromyxum* Mingazzini, 1980, *Gnathia* Leach, 1814, *Helicometra* Odhner, 1902, *Aspinatrium* Yamaguti, 1963, *Bothriocephalus* Rudolphi, 1808, *Stribarobdella* Leigh-sharpe, 1925, *Anisakis* Dujardin, 1845, *Hysterothylacium* Rudolphi, 1819, and *Philometra* Costa, 1845. Data on the prevalence, mean intensity, mean abundance, site of infection and locality of parasite species are given in the Table 2.

Myxozoa

Myxosporean was the most diverse group found during the present study, nine species were collected from trachinids (Table 2; Fig.

2). Only two species have been reported in trachinid fishes from different geographical areas: *Myxidium trachinorum* Canning, Curry, Anderson & Okamura, 1999 and *Zschokkella trachini* Azizi, Rangel, Castro, Santos & Bahri, 2016. However, other species belonging to the genera *Ceratomyxa*, *Chloromyxum* and *Ortholinea* were unidentified (Table 3). In the present study, infection by myxosporean species was recorded on fish during summer, winter and spring. The highest infection occurred in summer. Significant differences in the prevalence of infection by myxosporean were found between localities ($df=3$, $P<0.05$).

Cestoda

Bothriocephalus scorpii Müller, 1776 was the only cestod found in the examined fish (Table 2; Fig. 3). This species was found in the intestine of *T. draco*, *T. radiatus* and *T. araneus* from the Bay of Bizerte, during spring and summer. The maximum prevalence (33%) and the maximum mean intensity (2 ± 4) were noted in

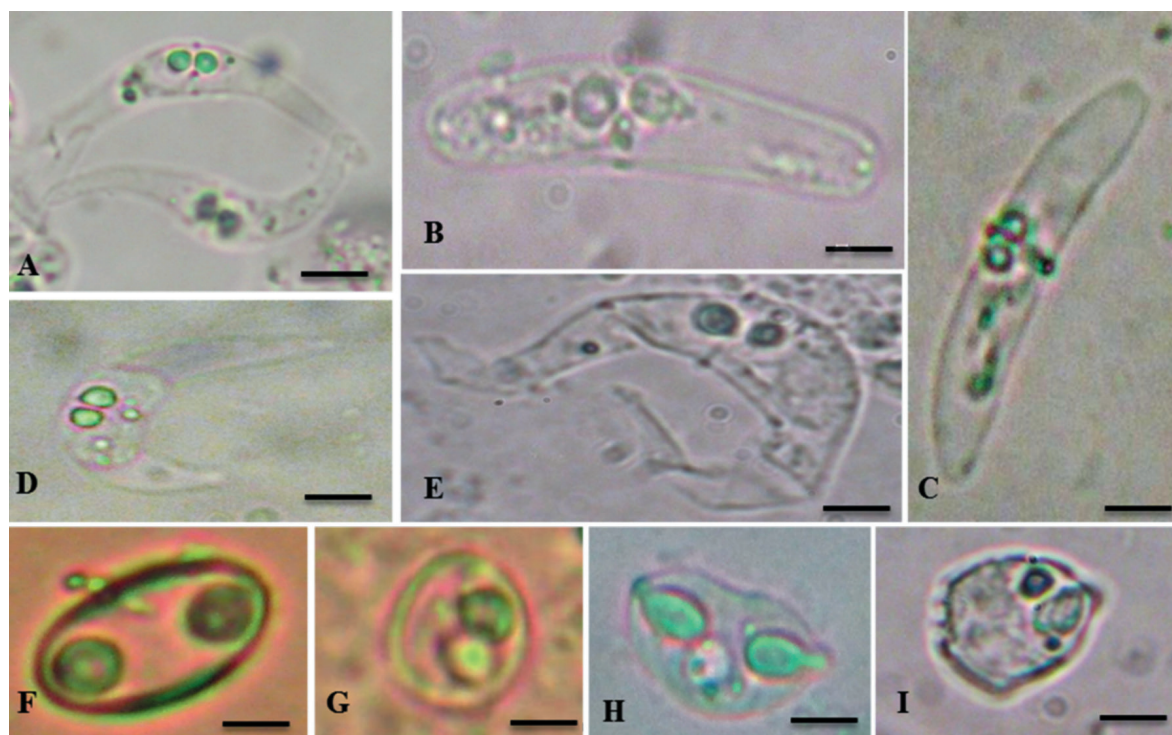


Fig. 2. Mature spores of Myxosporean species isolated from trachinid fishes from Tunisian coasts. A: *Ceratomyxa* sp. 1; B: *Ceratomyxa* sp. 2; C: *Ceratomyxa* sp. 3; D: *Ceratomyxa* sp. 4; E: *Ceratomyxa* sp. 5; F: *Zschokkella trachini*; G: *Ortholinea* sp.; H: *Myxidium trachinorum*; I: *Chloromyxum* sp. (Scale bars = 8 μ m)

Table 2: List of parasite species found on Trachinid fishes from Tunisian coasts and their infection rates

N.I.F: Number of infected fish; N.P: Total number of parasite specimens; Ac: Abdominal cavity; G: Gill; GB: Gallbladder; B: Body; In: Intestin; Ovary: O

Parasites Species	Host species	Locality	Site of infection	Prevalence (%)	Mean intensity	Mean abundance
Myxozoa						
<i>Ceratomyxa</i> sp. 1	<i>T. draco</i>	Bay of Bizerte	GB	49.4	36 ± 24	17.8
		Sousse	GB	46.3	48 ± 31	22.2
		Mahdia	GB	41.5	35 ± 12	14.5
	<i>T. draco</i>	Bay of Bizerte	GB	33.7	62 ± 27	11
		Sousse	GB	27.2	49 ± 9	13.3
		Mahdia	GB	17.8	35 ± 14	11.8
<i>Ceratomyxa</i> sp. 2	<i>T. araneus</i>	Bay of Bizerte	GB	24.8	51 ± 22	27.9
		Mahdia	GB	21.3	64 ± 16	26.4
	<i>T. draco</i>	Bay of Bizerte	GB	57.2	36 ± 14	15.9
		Mahdia	GB	44.2	41 ± 32	19.3
<i>Ceratomyxa</i> sp. 3	<i>T. araneus</i>	Bay of Bizerte	GB	31.0	46 ± 22	10.9
		Mahdia	GB	23.8	46 ± 13	14.2
<i>Ceratomyxa</i> sp. 4	<i>T. draco</i>	Bay of Bizerte	GB	26.2	42 ± 16	7.5
	<i>T. araneus</i>	Bay of Bizerte	GB	17.8	39 ± 09	10.2
	<i>T. draco</i>	Bay of Bizerte	GB	46.3	38 ± 19	12.8
Gulf of Tunis		GB	36.9	31 ± 21	11.6	
Sousse		GB	27.9	39 ± 19	10.9	
Mahdia		GB	33.6	32 ± 27	14.8	
<i>Zschokkella trachini</i> Azizi, Rangel, Severino, Santos & Bahri, 2016	<i>T. draco</i>	Bay of Bizerte	GB	57.8	74 ± 05	42.8
		Gulf of Tunis	GB	43.0	71 ± 11	30.5
		Sousse	GB	53.8	64 ± 09	34.4
		Mahdia	GB	49.0	62 ± 17	30.4
	<i>T. radiatus</i>	Bay of Bizerte	GB	41.1	68 ± 21	28
		Mahdia	GB	24.4	71 ± 16	17.3
<i>Ortholinea</i> sp.	<i>T. draco</i>	Bay of Bizerte	GB	38.1	46 ± 16	9.2
		Mahdia	GB	20	62 ± 12	17.4
	<i>T. radiatus</i>	Bay of Bizerte	GB	39.4	36 ± 26	10.5
Mahdia		GB	26.6	38 ± 14	10.1	
<i>Myxidium trachinorum</i> Canning, Curry, Anderson & Okamura, 1999	<i>T. draco</i>	Bay of Bizerte	GB	49.1	42 ± 17	18.3
		Gulf of Tunis	GB	35.3	42 ± 11	28.4
		Sousse	GB	43.6	54 ± 09	23.8
	Mahdia	GB	21.1	38 ± 21	18.6	
		<i>T. radiatus</i>	Bay of Bizerte	GB	38.2	54 ± 07
Mahdia	GB		23.3	48 ± 15	16	
<i>Chloromyxum</i> sp.	<i>T. draco</i>	Bay of Bizerte	GB	0.5	14 ± 07	0.07

Cestoda

<i>Bothriocephalus scorpii</i> Müller, 1776	<i>T. draco</i>		In	26,1	2 ± 4	0.1
	<i>T. araneus</i>	Bay of Bizerte	In	33	3 ± 6	0.8
	<i>T. radiatus</i>		In	26,4	5 ± 4	1.3

Nematoda

<i>Anisakis sp.</i>	<i>T. draco</i>	Bay of Bizerte	In, Ac	85.4	21.1 ± 2.6	9.4		
		Gulf of Tunis	In, Ac	75.3	15.1 ± 3.2	11.4		
		Sousse	In, Ac	72.7	10.7 ± 0.9	0.7		
		Mahdia	In, Ac	47.8	10.2 ± 1.3	8.7		
	<i>T. aranaeus</i>	Bay of Bizerte	In, Ac	62	20.2 ± 0.6	10.1		
		Sousse	In, Ac	50	14 ± 2.5	5.4		
		Mahdia	In, Ac	38	5.7 ± 0.2	3.5		
	<i>T. radiatus</i>	Bay of Bizerte	In, Ac	62.2	3.5 ± 0.4	1.6		
		Sousse	In, Ac	56.2	10.4 ± 2.5	5.8		
		Mahdia	In, Ac	47	3.7 ± 0.2	2.3		
	<i>Hysterothylacium sp.</i>	<i>T. draco</i>	Bay of Bizerte	In, Ac	50.5	3.1 ± 0.7	1.5	
			Gulf of Tunis	In, Ac	36.9	10.8 ± 2.4	4	
Sousse			In, Ac	40.9	4.0 ± 2.8	1.6		
Mahdia			In, Ac	41.0	5.3 ± 1.6	2.2		
<i>T. radiatus</i>		Bay of Bizerte	In, Ac	35.2	5.7 ± 0.9	2		
		Sousse	In, Ac	21.1	10.8 ± 1.3	3.3		
<i>Hysterothylacium fabri</i> Rudolphi, 1819 (3 rd larval stage)		<i>T. draco</i>	Bay of Bizerte	In, Ac	75.4	2.9 ± 0.5	1.6	
			Sousse	In, Ac	62.3	2.5 ± 1.2	1.5	
	Mahdia		In, Ac	54.7	1.9 ± 2.4	1.4		
	<i>T. draco</i>	Bizerte	In, Ac	70.9	6.2 ± 0.7	2.7		
<i>Hysterothylacium fabri</i> Rudolphi, 1819 (4 th larval stage)	<i>T. draco</i>	Sousse	In, Ac	61	8.0 ± 2.1	4.8		
		Mahdia	In, Ac	44.2	7.8 ± 1.3	5.5		
		<i>T. radiatus</i>	Bay of Bizerte	In, Ac	47.0	8.8 ± 0.5	4.1	
<i>Philometra sp.</i>	<i>T. draco</i>	Mahdia	In, Ac	28.6	4.4 ± 0.9	2		
		Bay of Bizerte	Ov	5.7	2 ± 1.4	0.04		
Digenea	<i>Helicometra fasciata</i> Rudolphi, 1819	<i>T. draco</i>	Bay of Bizerte	In	4.21	1.6 ± 0.5	0.06	
Monogenea	<i>Aspiatrium trachini</i> Parona & Perugia, 1889	<i>T. draco</i>	Bay of Bizerte	G	16.8	2 ± 1	0.06	
			<i>T. radiatus</i>	Bay of Bizerte	G	19.8	3 ± 2	0.6
			<i>T. araneus</i>	Bay of Bizerte	G	18.1	3 ± 2	0.3

Isopoda

<i>Gnathia</i> sp	<i>T. draco</i>	Bay of Bizerte	B	89.0	3 ± 5	2.2
		Gulf of Tunis	G	64.6	3 ± 3	1.9
		Sousse	B	73.6	3 ± 4	1.9
		Mahdia	G	66.8	3.5 ± 2	3.5
	<i>T. radiatus</i>	Bay of Bizerte	G	62.2	4 ± 2	2
		Sousse	G	50	3 ± 1	1.6
		Mahdia	G	56.2	4 ± 2	2.4
	<i>T. araneus</i>	Bay of Bizerte	G	65.5	2 ± 2	0.8
		Sousse	G	55.5	3 ± 1	1.6
Mahdia		G	40.4	3 ± 2	1.9	

Hirudinea

<i>Stibarobdella loricata</i> Schmarda, 1861	<i>T. draco</i>	Gulf of Tunis	G	1	1 ± 0	0.01
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Table 3. Spores measurements (μm) of myxosporean spp. parasite of trachinid fishes. D: Diameter, L: length, W: width

Species	Spore Length	Spore Width	Size of Polar Capsule
<i>Ceratomyxa</i> sp. 1	9.2 ± 1.4 (8-11)	49.2 ± 1.9 (48-52)	D: 3.5 ± 0.4 (3.2-4)
<i>Ceratomyxa</i> sp. 2	7 ± 2.3 (6-9)	24.8 ± 1.6 (24-28)	D: 3.5 ± 0.2 (3.0-4.0)
<i>Ceratomyxa</i> sp. 3	8	48.7 ± 1.5 (48-52)	D: 3.6 ± 0.4 (3.2-4)
<i>Ceratomyxa</i> sp. 4	8	39 ± 1 (38- 40)	D: 4
<i>Ceratomyxa</i> sp. 5	10.8 ± 1.8 (8-12)	40.7 ± 1.5 (40-42)	D: 3.6 ± 0.4 (3.2-4)
<i>Ortholinea</i> sp.	10.1 ± 0.57 (9-11)	12.3 ± 0.64 (12-14)	D: 5 L:3±0.6, W:1.7±0.4
<i>Chloromyxum</i> sp.	13.1 ± 0.6 (13-13.3)	10.3 ± 0.6 (10.2-10.5)	

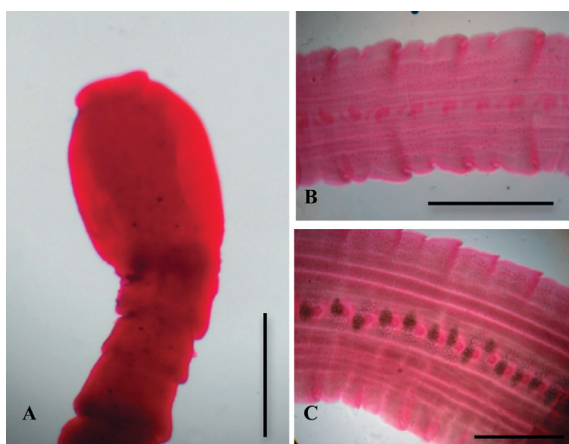


Fig.3. *Bothriocephalus scorpii* from the intestine of trachinid fishes. A: Scolex; B: Immature proglottis; C: Mature proglottis

T. araneus. However, there was no significant difference in the prevalence of infection by *Bothriocephalus scorpii* between host species ($df=2$, $P>0.05$).

Nematoda

Four nematode species were recorded during the sampling period. These species were found along the four seasons with maximum level of infection in summer.

Anisakis sp. (Table 2; Fig. 4) was collected from the intestine and the abdominal cavity of *T. draco* from the Bay of Bizerte, Gulf of Tunis, Sousse and Mahdia, and also from *T. araneus* and *T. radiatus* found in the previous locali-



Fig. 4. *Anisakis simplex* from the intestine of trachinid fishes. A: Anterior part of body; B: Lateral view of cephalic end; C: Lateral view of caudal end. (Scale bars: A = 0.5 mm; B, C = 0.2 mm)

ties except in the Gulf of Tunis where they are absent. The prevalence of infection was relatively higher in all infected fish and varied from 38% to 85.4%. The maximum mean intensity (21.1 ± 2.6) was noted in *T. draco* from the Bay of Bizerte. There was a significant difference in the prevalence of infection between localities ($df=2$, $P < 0.05$).

Hysterothylacium sp. (Table 2; Fig. 5) was collected from the abdominal cavity and the



Fig. 5. *Hysterothylacium* sp. from the intestine of trachinid fishes. A: ventral view of body and anterior region; B: Lateral view of cephalic end; C: Lateral view of caudal end. (Scale bars: A = 0.5 mm; B, C = 0.1 mm)

intestine of *T. draco* from the Bay of Bizerte, Gulf of Tunis, Sousse and Mahdia, and from the body cavity and the intestine of *T. radiatus* from the Bay of Bizerte and Sousse. Maximum prevalence of this species was noted in *T. draco* from the Bay of Bizerte with 50.5 % and the maximum mean intensity (10.8 ± 2.4) was registered in *T. draco* from the Gulf of Tunis. A significant difference in the prevalence of infection between the localities was noted ($df=3$, $P < 0.05$).

Hysterothylacium fabri Rudolphi, 1819 (3rd larval stage) (Table 2; Fig. 6) was collected from the abdominal cavity and the intestine of *T. draco* from the Bay of Bizerte, Sousse and Mahdia. However, *Hysterothylacium fabri* Rudolphi, 1819 (4th larval stage) was collected from the body cavity and the intestine of *T. draco* from the Bay of Bizerte, Sousse and Mahdia, and *T. radiatus* from the Bay of Bizerte and Mahdia. The maximum prevalence of *Hysterothylacium fabri* (third and fourth-stage

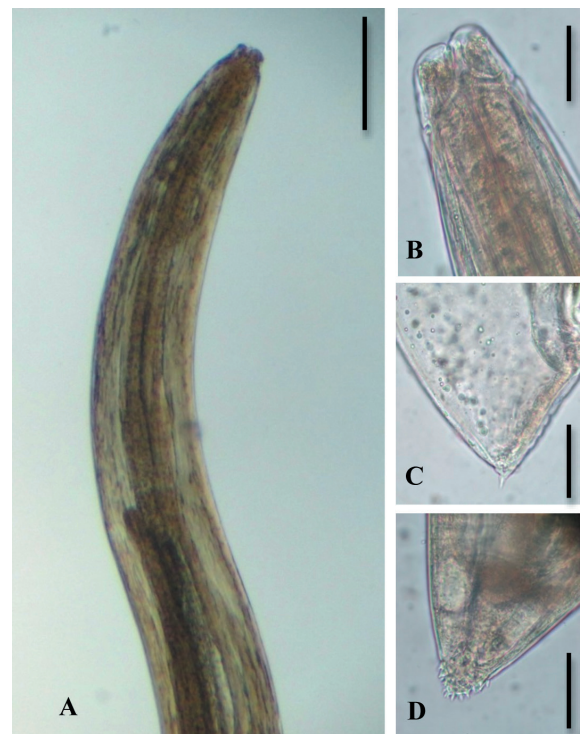


Fig. 6. *Hysterothylacium fabri* from the intestine of trachinid fishes. A: Anterior part of body; B: Lateral view of cephalic end of; C: Lateral view of caudal end of the 3rd larval stage; D: Lateral view of caudal end of the 4rd larval stage. (Scale bars: 0.5 mm)

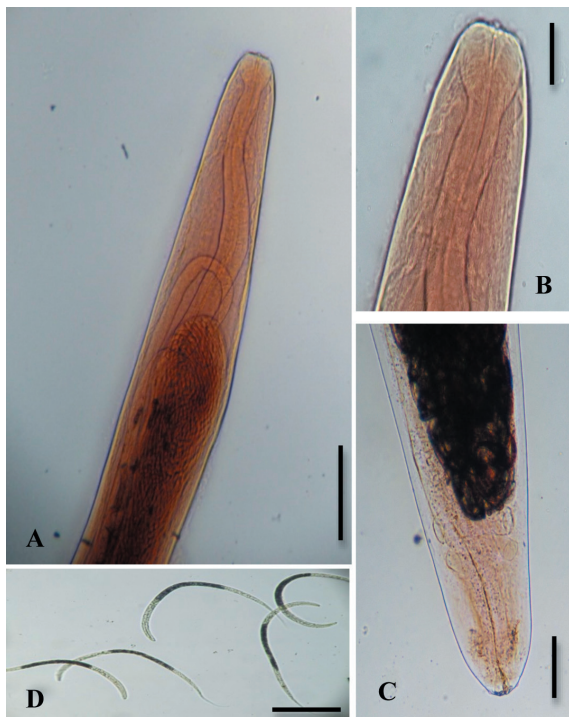


Fig. 7. *Philometra* sp. from the ovary of trachinid fishes. A: Anterior part of body; B: Lateral view of cephalic end of; C: Lateral view of caudal end; D: Larva from uterus. (Scale bars: A, B, C = 0.5 mm; D = 0.1 mm)



Fig. 8. *Helicometra fasciata* from the intestine of trachinid fishes. Scale bar: 0.5 mm

larvae) was observed in *T. draco* from the Bay of Bizerte with respectively 75.4% and 70.9%. The maximum mean intensity was noted for the fourth-stage larvae of *H. fabri* in *T. radiatus* from the Bay of Bizerte with 8.8 ± 0.5 . There was significant difference in the prevalence between localities ($df=3$, $P < 0.05$).

Philometra sp. (Table 2; Fig. 7) infecting the ovary of *T. draco* from the Bay of Bizerte was collected with a prevalence of 5.7%, and a mean intensity of 2 ± 1 . The main measurements of *Anisakis* sp., *Hysterothylacium* sp. and *Philometra* sp. collected from trachinid fishes are reported in table 4.

Monogenea

Aspinatrium trachini Parona & Perugia, 1889 (Table 2; Fig. 9) was collected from the gills of *T. draco*, *T. radiatus* and *T. araneus* from the Bay of Bizerte. The maximum prevalence (19.8%) and mean intensity (22) of *A. trachini* were recorded in *T. radiatus*. No significant difference was found in the prevalence of infection between host species ($df=2$, $P > 0.05$).

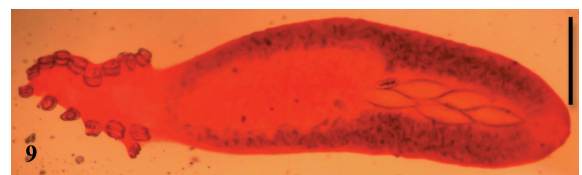


Fig. 9. *Aspinatrium trachini* from the gills of trachinid fishes. Scale bar: 2 cm

Isopoda

Praniza larvae of *Gnathia* sp. (Table 2, Fig. 10) were collected from the gills and the body surface of *T. draco*, *T. radiatus* and *T. araneus* from the Bay of Bizerte, Sousse, Mahdia and Gulf

Table 4. Morphometric measurements (mm) of nematode species parasite of trachinid fishes

Species	Total length	Maximum width	Nerve ring	Oesophagus length	Ventriculus length
<i>Anisakis</i> sp.	18-20.3	0.3-0.4	0.26-0.28	1.56-1.60	0.23-0.25
<i>Hysterothylacium</i> sp.	12.6 – 16.5	0.13 – 0.38	0.14-0.43	0.25-1.13	0.07-0.15
<i>Philometra</i> sp.	46.3 – 52.3	0.2 – 0.3	-	-	-



Fig. 10. *Gnathia* sp. from the gills of trachinid fishes. Scale bar: 1 mm

of Tunis. This species was found throughout the whole year. Maximum prevalence of *Gnathia* sp. was noted during summer in *T. draco* from the Bay of Bizerte (89%). However, the highest mean intensity (4 ± 2) was noted in *T. radiatus* from the Bay of Bizerte and Sousse. A significant difference was found in the prevalence of infection by *Gnathia* sp. between the host species ($df=2$, $P<0.05$).

Hirudinea

Stibarobdella loricata Schmarda, 1861 parasitizing gills of *T. draco* (Table 2, Fig. 11) was collected in spring from the Gulf of Tunis with low prevalence (1%) and mean intensity (1).

Parasite diversity

For the study of parasite diversity of Trachinids from Tunisian coasts, three measures of biodiversity were considered: the species richness (SR), Shannon-Weaver index (H') and Simpson index (D). The different fish species

presented component communities with different diversity; each fish-host presented at least seven parasites species. The richest component community was in *T. draco* with 18 parasites species followed by *T. radiatus* (8 species) and *T. araneus* (7 species) (Table 5).

The Simpson index varied between 0.14 and 0.54. The highest value (0.54) was noted in *T. araneus*. Furthermore, *T. radiatus* and *T. draco* presented different values of the Simpson index: 0.28 and 0.14 respectively (Table 5). The highest value of Shannon-Weaver index of species diversity was observed for the community of *T. draco* (3.11). However, the Shannon-Weaver index was almost the same for *T. radiatus* (2.05) and *T. araneus* (2.1) (Table 5).

The study of parasite diversity according to the sampling site showed that the Bay of Bizerte presented the most important richness species with 17 parasites species followed by Mahdia with 11 species, Sousse with 9 species and the Gulf of Tunis with 7 species (Table 6). The maximum value of the Simpson index was noted in the Gulf of Tunis (0.26), however the minimum value was observed in the Bay of Bizerte



Fig. 11. *Stibarobdella loricata* from the gills of trachinid fishes. Scale bar: 0.5 cm

Table 5. The indicators characteristics of the parasite diversity of the *T. draco*, *T. radiatus* and *T. araneus*

Index	Host	<i>T. draco</i>	<i>T. radiatus</i>	<i>T. araneus</i>
Richness species (RS)		19	8	7
Simpson (D)		0.14 ± 0.29	0.28 ± 0.12	0.54 ± 0.43
Shannon-Weaver (H')		3.11 ± 0.12	2.05 ± 0.23	2.01 ± 0.10

Table 6. The indicators characteristics of the parasite diversity from the different sampling sites

Index	Localities	Bay of Bizerte	Gulf of Tunis	Mahdia	Sousse
Richness species (RS)		17	7	11	9
Simpson (D)		0.12 ± 0.32	0.26 ± 0.22	0.13 ± 0.10	0.19 ± 0.33
Shannon-Weaver (H')		3.94 ± 0.18	2.87 ± 0.20	3.85 ± 0.28	3.81 ± 0.5

(0.12). The Shannon-Weaver index values were relatively higher in all the sampling sites and varied from 2.87 to 3.94. The maximum value was noted in the Bay of Bizerte (Table 6).

DISCUSSION

In this study, we provided for the first time a data on metazoan parasites of trachinid fishes from Tunisian coasts and their infection indices. Endoparasites collected from trachinids were most dominant than ectoparasites. Indeed, myxosporeans represent the most species-rich group (nine parasites species). Diversity of myxosporean species can be related to the diversity of actinospores parasitizing the invertebrate hosts (polychaetes) present in the sampling sites. These invertebrate hosts living in the sediment were in direct contact with trachinids, so they can easily be exposed to the myxospores released from these fish.

According to literature, this is the first record of *Ceratomyxa* spp. in Trachinidae from eastern Mediterranean waters. *Ceratomyxa reticularis* Thélohan, 1895 was previously reported from the gallbladder of *Trachinus draco* from Mediterranean coasts off France (EIRAS, 2006). However, this species differs greatly, in dimensions and shape, from the *Ceratomyxa* species of the present study. Among the 300 *Ceratomyxa* species previously described from different geographical areas (EIRAS, 2006; GUNTER & ADLORD, 2010; ROCHA *et al.*, 2015; THABET *et al.*, 2015; MANSOUR *et al.*, 2016), no one was morphologically similar to the specimens found.

Zschokkella trachini Azizi, Rangel, Castro, Santos & Bahri, 2016 was already described in *Trachinus draco* from the Bay of Bizerte (AZIZI *et al.*, 2016). In the present work, this species was found in *T. radiatus* from three localities along the Tunisian coasts (Gulf of Tunis, Sousse and Mahdia).

In this study we report for the first time the presence of *Ortholinea* sp. in trachinid fishes. *Ortholinea* sp. parasitizing *T. draco* and *T. radiatus* from the Bay of Bizerte and Mahdia was morphologically different from the 23 species of the genus *Ortholinea* available in the litera-

ture (LOM & DYKOVÁ, 2006; ABDEL-GHAFFAR *et al.*, 2008; KARLSBAKK & KØIE, 2011; RANGEL *et al.*, 2014; ABDEL-BAKI *et al.*, 2015; RANGEL *et al.*, 2016).

Myxidium trachinorum previously collected from the gallbladder of lesser weever *Echiichthys vipera* off England (CANNING *et al.*, 1999) was reported for the first time from the gallbladders of *T. draco* and *T. radiatus* living in Tunisian waters and in the Mediterranean Sea.

In this study we report for the first time the presence of *Chloromyxum* sp. in Trachinids. Among the 140 species of *Chloromyxum* described worldwide (EIRAS *et al.*, 2012), only *Chloromyxum tanakai* Fujita, 1936 collected from *Oncorhynchus keta* from Japan (EIRAS *et al.*, 2012) is relatively similar to the present one but differs greatly in dimensions. *Chloromyxum* sp. has been found only in *Trachinus draco* from the Bay of Bizerte with a very low prevalence (0.5%).

In the present work, the prevalence of myxosporeans infection varies in relation to the host species and the sampling site. Indeed, we have noted gradual decreases of prevalence from the north to the center coasts and in the most cases, the maximum values of prevalence were recorded in the Bay of Bizerte. These variations were generally associated to the environmental conditions, specially water temperature that have an important effect on the development of myxosporeans in fish and invertebrate hosts (MCGEORGE *et al.*, 1996; KENT *et al.*, 2001; YOKOYAMA, 2003; CANNING & OKAMURA, 2004). In fact, during the sampling period we have noted that the high water temperatures were recorded in the Bay of Bizerte (14,1 – 31,1°C), followed by the Gulf of Tunis (8 – 28°C) then Sousse and Mahdia (11.8°– 27°C). These observations showed that the high water temperatures favored the release of actinospores from invertebrate hosts and the development of myxospores within the fish hosts. Other authors (YOKOYAMA *et al.*, 2012; FONTES *et al.*, 2015) reported this finding.

Concerning the nematodes infections, we report for the first time the presence of *Philometra* sp. in *T. draco* from Tunisian coasts. In fact, two species of the genus *Philometra* Costa, 1845 have been previously reported from trachi-

nid fishes: *Philometra filiformis* Stossich, 1896 infecting the gonads of *T. draco* from the Adriatic Sea and Italy (STOSSICH, 1896; ORECCHIA & PAGGI, 1978) and *Philometra globiceps* Rudolphi, 1819 parasitizing the body cavity of *T. draco* from the Black Sea (MORAVEC, 2006). Nevertheless, *Philometra* sp. was morphologically different from these two species of *Philometra*.

In this study, *Anisakis* sp. was detected in trachinid fishes from Tunisian coasts. According to our knowledge, only the work of FARJALLAH *et al.* (2008) reported the presence of *Anisakis pegreffii* (CAMPANA-ROUGET & BIOCCA, 1955) from *T. draco* collected from Mahdia. Moreover, we report for the first time the presence of two species of *Hysterothylacium* in trachinid fishes from the Tunisian coasts.

Prevalence, mean intensity and mean abundance of nematodes in trachinid fishes were variable depending on the host species and the sampling site. *Anisakis* sp. was the most abundant species, followed by *Hysterothylacium fabri*, *Hysterothylacium* sp. and *Philometra* sp. We noted a gradual decrease of the prevalence rate from the north to the central coasts. It seems that infected intermediate hosts of nematodes are more abundant in the north coasts. The variations of the prevalence and the abundance of nematodes were probably related to the type and quantity of food consumed by hosts (BAGHERPOUR *et al.*, 2011; OLASUNMIBO OLUMUYIWA & OLATUNDE, 2014).

Bothriocephalus scorpii was the only species of cestods collected from trachinids and reported for the first time in the intestine of the three *Trachinus* species from the Tunisian coasts. Otherwise, this species was also reported in *Trachinus draco* from Turkey (AKMIRZA, 2004).

Digenean parasites collected in this study were limited to the species *Helicometra fasciata* infecting the intestine of *Trachinus draco* from the Bay of Bizerte, with a low prevalence of 4.21%. This species was previously reported in *Trachinus draco* from Turkey (AKMIRZA, 2004).

Aspinatrium trachini was recorded for the first time from trachinid fishes in Tunisian waters. According to the literature data, this

monogenean species has been reported in *T. draco* from Spain (LOPEZ-ROMAN & GUEVARA-POZO, 1973), in *T. radiatus* from Greece (PAPOUT-SOGLU, 1976), and in *T. araneus* from Montenegro (RADUJKOVIĆ & EUZET, 1989). Infection caused by *A. trachini* was observed only in the Bay of Bizerte. It seems that the environmental conditions in particular water temperature stimulate the development of *A. trachini*. Indeed, the higher temperatures were recorded in the Bay of Bizerte, which can influence the parasite abundance and the egg production in monogenean life cycle. The present results are supported by other studies where the highest mean intensity and abundance were found in spring and summer (RAWSON & ROGERS, 1973; KADLEC *et al.* 2003; OZTURK & ALTUNEL, 2006; MARTINS *et al.* 2014).

The Gnathiid isopods are the most common ectoparasites infecting a wide host range of fish worldwide. The present study report the presence of praniza larvae from trachinids in different sampling sites. These larvae belong to the genus *Gnathia*. According to literature, praniza larvae of *Gnathia* sp. have been previously reported in *T. draco*, *T. radiatus* and *T. araneus* from North African Mediterranean coasts (RAMDANE *et al.* 2009).

The Leeches are parasites of various fish species, little is known about the distribution of these parasites in Tunisia. In the present study *Stibarobdilla loricata* was reported for the first time from *Trachinus draco* from Tunisian coasts with a very low prevalence (1%). However, this species was previously reported in *Trachinus draco* from Turkey by AKMIRZA (2004).

In the present study, the species richness (SR) of trachinids was relatively important. Indeed, each fish host presented at least seven parasites species. The highest SR was recorded in *T. draco*. According to Simpson index, *T. draco* carried the highest parasite diversity. This result was confirmed by Shannon index, thus, the maximal value was observed in *T. draco*. However, the Shannon-Weaver index was the same for *T. araneus* and *T. radiatus*.

The important SR and diversity of parasitic species found in *T. draco*, could be explained by the higher number of the examined fish

(519) compared to the other fish host species. Moreover, *T. draco* may be more susceptible to the infection by parasites, compared to the other trachinid fishes.

Concerning diversity of the parasite meta-communities according to the sampling sites, the Bay of Bizerte presented the richest community followed by Mahdia. The two other sites, Gulf of Tunis and Sousse showed a less important species richness. The values of the Shannon-Wiener and Simpson's index show the richest diversity of parasite species in the Bay of Biz-

erte. Parasite diversity in relation to the locality can be affected by the seasons; in fact the sampling period was different in the fourth sampling sites. On the other hand, each sampling site was characterized by specific environmental conditions such as temperature and salinity, which may influence the development of the different parasites species. In addition to the presence of appropriate environmental conditions for the parasite, abundance of appropriate intermediate hosts can affect the parasite diversity.

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Metazoični nametnici kod paukovki (Teleostei: Trachinidae) sa obala Tunisa (Sredozemno more)

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SAŽETAK

U ovom radu se iznose istraživanja nametnika kod predstavnika porodice Trachinidae: *Trachinus draco* Linnea, 1758; *Trachinus araneus* Cuvier, 1829. i *Trachinus radiatus* Cuvier, 1829, koji su prikupljeni sa obala Tunisa. Istraživanje je trajalo od siječnja 2014. do siječnja 2015. godine. Ukupno je utvrđeno 18 vrsta metazoičnih nametnika iz 13 rodova: devet iz Myxozoa, četiri iz Nematoda, jedna iz Cestoda, jedna iz Digenea, jedna iz Monogenea, jedna iz Isopoda i jedna iz Annelida Hirudinea. Tijekom znanstvenog istraživanja istraživani su podaci o morfologiji, lokaciji i razini infekcije parazita.

Veće bogatstvo vrsta zabilježeno je kod *Trachinus draco* (18 vrsta), dok su *Trachinus radiatus* i *Trachinus araneus* imali 9 i 7 vrsta. Navodi se bogatstvo i raznolikost vrsta prema vrstama domaćina i lokacijama uzorkovanja na temelju Simpson i Shannon-Wiener indeksa.

Ključne riječi: Trachinidae, metazoični nametnici, raznolikost vrsta, Tunis

