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ORIGINAL ARTICLE

Parasite diversity from two deep-sea fishes *Phycis blennoides* (Brunnich, 1768) and *Phycis phycis* (Linne, 1758), from the western Algerian coasts

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This study investigated the diversity of metazoan parasites of 132 greater forkbeards and 91 forkbeards, from the western Algerian coasts, a total of 19 taxa: 15 taxa from *Phycis blennoides*; 11 taxa from *Phycis phycis*, allocated to 15 genera in 12 families were recovered, including 7species common to the two hosts. 90% are endoparasites, mostly located in the intestine and the stomach, encapsulate forms were in the liver, whereas crustaceans were found in the gills of the hosts. The Anisakidae Railliet & Henry, (1912) is the most diverse group with two genera: *Hysterothylacium* Ward & Magath, (1917) and Anisakis Dujardin, (1845) with 5 species. The nematode *Hysterothylacium fabri* (P= 55%) and the digenean *Stephanostomum pristis* are the most abundant and the most prevalent parasites from *P. phycis* (P=94%), while *Hysterothylacium aduncum* (P=49%) and *Lepidapedon guevarai* (P=87%) are from *P. blennoides*. 14 parasites species are present as adult stage, indicated that these fish act as their definitive hosts, while cosmopolite species are present in the larval stage. We also noticed a high ectoparasites infection level from hosts gills *Clavella alata* (P=45%) in greater forkbeards and *Gnathia* sp (P=65%) from forkbeards. *Phycis blennoides* and *Phycis phycis* are new hosts records for *Cucullanus cirratus*, *Capillaria gracilis*, *Derogenese varicus* and *Lecithocldium excisum*.

Keywords: Parasites; Gadiform fishes; Deep sea; Western Algerian coasts

Introduction

Inventories of fish parasites are operated for decades in order to have informations on biodiversity in aquatic ecosystems (Poulin and Rohde, 1997; Morand and Gonzales, 1997), moreover in large bathymetries, that still poorly explored because of their inaccessibility (Klimpel et al., 2010).

Fish parasites of the Algerian coasts were first studied by Dollfus (1935), later; Petter and Maillard (1988) described some nematodes from Dollfus collection. Since little works on marine fish parasites have been published besides,they focused on digenea trematodes group from the western Algerian coasts (Abid-Kachour et al., 2013; Marzoug et al., 2012, 2014; Rima et al., 2017; Brahim tazi et al., 2016) and ectoparasites, mainly monogenean and copepods, from the eastern coasts (Boualleg et al., 2011; Kouachi et al., 2014; Ramdane et al., 2013), studies on nematodes are even rarer (Hassani and Kerfouf, 2014; Hassani et al., 2015; Ichalal et al., 2015). *Phycis blennoides* and *Phycis Phycis*, two congeneric gadiform fish, caught in depths of up to -1000 m, and with great economic value in Algeria were the subject of two studies that focused on Nematodes Anisakidae because of their pathogenicity by Valero et al., (2005) and Farjallah et al., (2006) in Southern Spain and eastern Mediterranean coasts, Tunisia respectively, Dallares et al., (2016) provided a complete description of the parasite community of the greater forkbeard. The aim of this study, is to drew up an inventory of parasites of both fish *P. blennoides*, and especially *P. phycis* that parasite fauna remains insufficient in Algerian and Mediterranean coast.

Materials and Methods

Fish and collection site

The 132 Phycis. blennoides were harvested near the fishing ports (Benisaf, Oran and Mostaganem) and the 91 *Phycis phycis* were captured by the fishermen of small trades (Ain el turck and Kristel located in Oran). Sampling sites along the Algerian coast of the Western Mediterranean located at 35°43′ N - 0°37′ W (the total length of fishes ranged from 16 to 32 cm. Fishes were examined for ecto- and endoparasites according to a standardized protocol from June 2015 to October 2016.

Collection and analysis of parasites

All organs were dissected out and examined under a stereomicroscope. This included examination of the content (digestive tubes and appendices and their gonads as well. Stomach, pyloric caecums, intestine) of the parts of the intestinal tract separately. The contents were cleared by successive rinsing in physiological saline water (9%). The intestinal mucosa was scraped and the liver, gallbladder and gonads were squeezed between two Petri dishes and examined. Harvested parasites were fixed and preserved at ethanol (70)

Specimens were stained with iron acetocarmine according to the protocol of Georgiev et al. (1986), dehydrated in a graded ethanol series, cleared in Eugenol and examined as permanent mounts in Canada balsam. All parasites were identified to the lowest taxonomic level possible and counted.
The identification of parasites was carried out using the identification keys of (Anderson, 1992) and (Moravec, 1998) for Nematodes. (Gibson et al., 2002) for the Digenea, (Kabata, and Gusev, 1966) for Crustaceans, (Khalil et al., 1994) for the Cestoda and finally (Amin's, 1987) identification keys for Acanthocephalans.
The ecological terms defined by Bush et al. (1997) have been used in our present study. Prevalence represents the percentage (P%) of host individuals infested with a parasitic species in the sample, divided by the number of host fish examined. Average abundance (AM) refers to the total number of individuals of the particular parasite species divided by the total number of hosts examined in the sample (Figure 1).

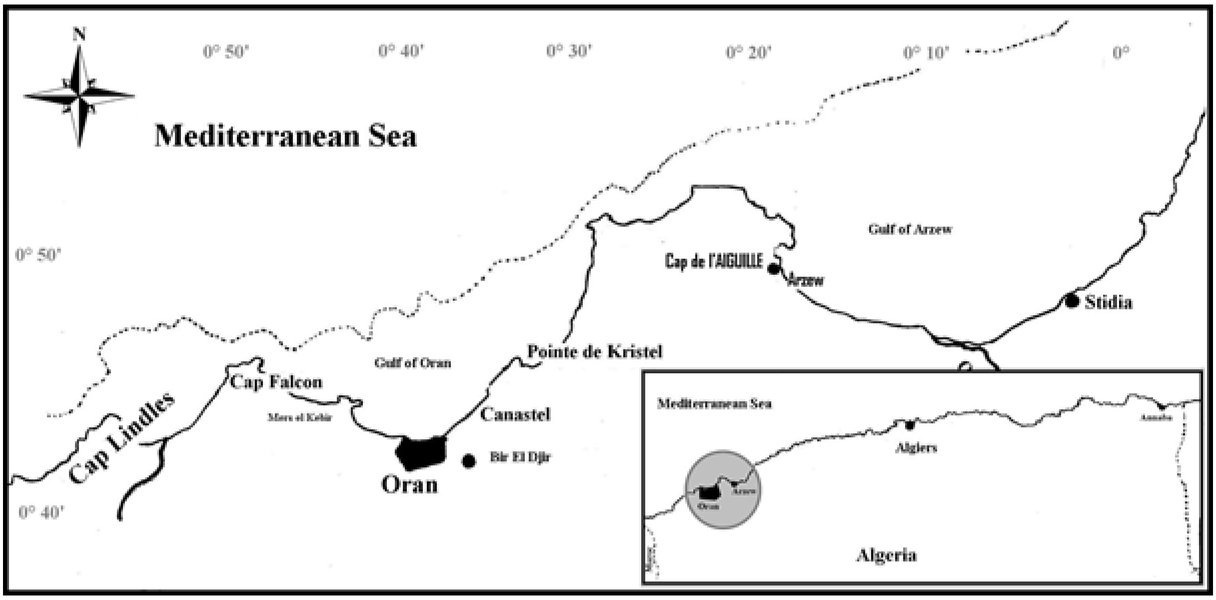

Figure 1. Geographical location of the studied area. (Kerfouf et al., 2007).

Results

A total of 1984 specimens of helminthes parasites were recovered from both host species, representing 19 species and 14 genera, as listed below (Table 1). (9 Nematoda 1 Acanthocephalan, 6 Digenea, 1 Cestoda and 2 Crustaceans).

Table 1. Metazoan parasite of *Phycis blennoides* and *Phycis phycis* from the western Algerian coasts (with citations of other regions).

Parasite species from present study with taxonomic position	Host	P%	AM	Site Infection	Other report reference	Area
Phylum Platyhelminthes* Claus, 1887** Class *Trematoda Rudolphi*, 1808 Sub-class Digenea Carus, 1863 Super family Allocreadioidea Loos, 1902 Family Opecoelidae Ozaki, 1925 Sub family Plagioporinae Manter, 1947 Genus Bathycreadium Kabata, 1961 1. ***Bathycreadium elongata Maillard, 1970 (adult stage)	PPHY	20%	1,75	Posterior intestine rectum	Bartoli, et al., 2005 Akmirza 2013	[7] [12]
2. ***Bathycreadium brayi*** Pérez-del-Olmo, 2014 (adult and juvenile) Synonymes: *Nicolla elongata Maillard*, 1970 *Bathyreadium elongatum* Maillard, 1970	PBLE	76%	20,8	Stomach anterior intestine	Perez Del Olmo et al., 2014 Dallarès et al., 2016	[13] [14]
Super family *Hemiuroidea* Looss, 1899 Family *Deroginidae Nicoll*, 1910 Sub family *Derogeninae* Nicoll, 1910 Genus *Derogenes* Janiszewska, 1953 3.* ***Derogenes varicus*** Müller, 1784 (adult stage)	PBLE PPHY	0,5% 2%	0,25 1	Stomach	Bartoli, et al., 2005 Ternengo et al., 2009 (as Derogenes latus)	[7] [11]
Family *Hemiuridae* Loos, 1899 Sub family *Elytrophallinae* Skrjabin et Guschanskaja, 1945	PBLE	1%	0,03	Stomach		

Genus *Lecithocladium* Lühe, 1901 4.****Lecithocladium excisum*** Rudolphi, 1819 (adult)						
Super family *Lepocreadioidea* Odhner, 1905 Family *Acanthocolpidae* Lûhe, 1909 Genus *Stephanostomum* Loss, 1899 5.***Stephanostomum pristis*** Deslongchamps 1824 (adult and juvenile)	PPHY	94%	18,3	Stomach anterior intestine	Papoutsoglou 1976 Bartoli et Bray 2001 Bartoli, et al., 2005 Ternengo et al ., 2009	[3] [7] [8] [11]
Family *Lepocreadiidae* Odhner, 1905 Genus *Lepidapedon* Stafford, 1904 6.***Lepidapedon guevarai*** Lopez-Roman et Maillard, 1973 (adult and juvenile)	PBLE	87%	13	Stomach, pylorique caeca intestine	Lopez Roman et Maillard 1973 Orecchia et Paggy Bray et Gibson, 1997 Dallarès et al., 2016 (as L Lepidapedon.sp) Perz Del Olmo et al., 2019	[2] [4] [6] [14] [15]
Class Cestoda Subclasse Eucestoda 7.Order **Tetraphyllidae** Carus 1863 (larvae stage)	PBLE	10%	0,5	Intestine	Dallarès., 2016 Ternengo et al ., 2009	[14] [11]
Phylum *Nematoda Rudolphi*, 1808 Class Secernentea Von Linstow, 1905 Order Ascaridida Skrjabin et Shultz, 1940 Superfamily Ascaridoidea Railliet et Henry, 1915 Family Anisakidae Railliet et Henry, 1912 Genus Hysterothylacium Ward et Magath, 1917 8.***Hysterothylacium fabri*** Ward et Magath, 1917 (third stage larvae) Synonymes: *Ascaris fabri Rudolphi*, 1819; *Ascaris biuncinata* Molin, 1858; *Ascaris filiformis* Stossich, 1904	P BLE PPHY	12% 55%	0,22 3,62	Stomach, intestine liver	Petter et Radujkovic,1989 Akmirza 2013 Ternengo et al.,2009 Valero et al., 2005 Farjallah et al., 2006	[5] [13] [11] [9] [10]
9. ***Hysterothylacium aduncum*** **Rudolphi**, 1802 (adult stage)	P BLE PPHY	49% 11%	1,35 0,12	Oesophagus, Stomach, intestine rectum	Valero et al., 2005 Farjallah et al., 2006	[9] [10]
10.* ***Hysterothylacium sp1*** (larval stage)	PBLE	3%	0,03	Intestine	Petter et Radujkovic,1989	[5]
Genus Anisakis Dujardin, 1845 11. ***Anisakis simplex*** **Rudolphi, 1809** (Third stage larvae) Synonymes: Anisakis marina Linné, 1767; Anisakis sp. Berland, 1961	PBLE PPHY	7% 6%	0,1 0,09	Liver (cysts), intestine stomach	Valero et al., 2005 Farjallah et al., 2006 Dallarès et al., 2016 (as Anisakis sp)	[9] [10] [14]
12. ***Anisakis physeteris*** **Baylis, 1923** (third stage larvae) Synonymes: Anisakis sp. larvaII Berland, 1961	PBLE PPHY	11% 9%	0,25 0,09	Liver (cysts), intestine stomach	Valero et al., 2005 Farjallah et al., 2006	[9] [10]
Superfamily *Seuratoidea* Hall, 1916 Family *Cucullanidae* Cobbold, 1864 Genus *Cucullanus* Müller 1777 13.* ***Cucullanus cirratus*** **Müller, 1777** Synonymes: *Cucullanus muticus* Müller,1777; *Cucullanus marinus* Müller, 1779 ; *Cucullanus cirrhatus* Pallas, 1781; *Cucullanus foveolatus* Rudolphi, 1809; *Dacnitis gadorum* Beneden, 1858; *Heterakis foveolata* Schneider, 1866; *Cucullanus globosus* Linton, 1901	PBLE PPHY	32% 23%	0,40 0,65	Posterior intestine rectum	Dallarès et al., 2016 (as Cucullanus sp)	[14]
Order Spirurida Chitwood, 1933 Super family *Dracunculoidea* Stiles, 1907 Family *Philometridae* Baylis et Daubney, 1926 Genus Philometra Costa, 1845 14. ***Philometra globiceps*** **Rudolphi, 1819** (adult stage) Synonymes: *Filaria globiceps* Rudolphi, 1819; *Philometra retricaudata* Costa, 1845; Ichtyonema globiceps Diesing, 1861	PPHY	6%	0,15	Gonades	Ternengo et al.,2009 Petter et Radujkovic,1989	[11] [5]

Super family *Habronematoidea* Chitwood et Wehr, 1932 Family *Cystidicolidae* Skrjabin, 1946 Genus *Collarinema*, Sey, 1970 15. ***Collarinema collaris* Petter, 1970 (adult stage)** Synonym: Ascarophis collaris	PBLE	2%	0,025	Oesophagus	Petter, 1970 Dallarès et al., 2016	[1] [14]
Class Adenophorea Linstow, 1905 Order Enoplida Super family *Trichuroidea Railliet*, 1916 Family *Capillariidae* Railliet, 1915 Genus *Capillaria* Zeder, 1800 Sub-genus *Procapillaria* Moravec, 1987 16.* ***Capillaria gracilis* Bellingham, 1840 Travassos, 1915 (adult stage)** Synonymes: *Trichosoma gracile Bellingham*, 1840; *Capillaria kabatai* Inglis and Cole, 1963 ; *Capillaria merluccii* Reimer, 1991	PBLE PPHY	26% 17%	1 0,40	Posterior intestine Rectum	Dallarès et al., 2016	[14]
***Phylum Acanthocephala* Meyer, 1931** Class *Palaeacanthocephala* Meyer, 1931 Order Echinorhynchida Southwell et Macfie, 1925 Family *Echinorhynchidae* Cobbold, 1876 Sub- family *Echinorhynchinae* Cobbold, 1876 Genus *Echinorhynchus* Zoega in Müller, 1776 (adult stage) 17. ***Echinorhynchus* sp** Synonymes: *Metechinorhynchus* Petrochenko, 1956	PBLE	10%	0,21	Intestine pyloric caeca	Dallarès et al., 2016	[14]
Phylum Arthropodes Class Maxillopodes, Dahl, 1956 Order Siphonostomatoida Thorell, 1859 Family *Lernaeopodidae* Olsson 1869 Genus Clavella Oken, 1815 18. ***Clavella alata* Brian, 1906 (Adult satge)**	PBLE	45%	2,4	Gills	Dallarès et al., 2016	[14]
Classe Malacostraca Latreille 1806 Sub class Eumalacostraca Grobben 1892 Super order Peracarida Calman 1904 Order IsopodesLatreille 1817 Sub ordre *Gnathiidea* Leach 1814 Family *Gnathiidae* Harger 1880 Genus *Gnathia Leach*, 1813(Adultes) 19. **Gnathia sp**	PPHY	65%	23	Gills	Ternengo et al.,2009	[11]

[1] A Coruna, Spain; [2] Alboran sea, Spain; [3] Saronicos, Gulf Athens, Greece; [4] Ligurian sea, Italy; [5] Montenegro; [6] North east atlantic; [7] Natural Reserve of Scandola, the Gulf of Marseilles, France; [8] Natural reserve off Corsica, France; [9] Mediterranean coasts of Andalucia, Southern Spain; [10] eastern Mediterranean coasts, Tunisia; [11] Bonifacio Strait Marine Reserve, Corsica Island, Mediterranean Sea; [12] Coastal Waters of Gökçeada, Turkey; [13] western Mediterranean; [14] Balearic Sea, Spain; [15]western Mediterranean.
PBLE: *Phycis blennoides*; **PPHY:***Phycis phycis*; **P:** prevalence; **AM:** mean abundance.* New host record.

Discussion

A total of 1984 parasites were collected in this study, 1190 from Phycis. blennoides and 794 from Phycis. phycis, in the studied area with total prevalence of 99% and mean abundance of 9 parasites per host fish (Table 1). In Corsica Ternengo et al., (2009), identified 7 taxa from *P. phycis*; in the Balearic Sea, Dallares et al., (2016) identified 17 from *P. blennoides*. Nematodes are the parasite taxa with the most common species to the two forkbeards. Cucullanus cirratus and Capillaria gracilis, were reported by Perdiguero- Alonso et al. (2008) in atlantic cod with similar abundance and prevalence and appointed as gadoids specialists' nematodes with great host specificity (Moravec et al., 1997). Ternengo et al., (2009) identified Cucullanus longicollis from *P. phycis* while Dallares et al., (2016) identified Cucullanus sp from *P. blennoides*.
The Cystidicolidae Collarinema collaris was identified from *P. blennoides* by Petter (1970) in A Coruña in Spain, and assigned it to the genus Ascarophis Van Beneden, 1870, it was assigned to Collarinema after scanning electron microscopy of its cephalic ultrastructure (Moravec & Sobecka, 2012).
However, H. aduncum is more prevalent and more abundant in *P. blennoides*, while H. fabri is more prevalent and more abundant in *P. phycis* Similar findings have been also reported in other Mediterranean areas (Valero et al., 2005; Farjallah et al ., 2006; Dallares et al., 2016). Otherwise, the community of digenea was composed of Derogense varicus, which is the only common digenean to both fishes with low infestation. Ternengo (2009) identified a Derogenidae from *P. phycis* as D. latus, Manter (1955) pointed out that D. varicus, while a shallow-water parasite in northern latitudes, also occurs in deep water in lower latitudes (Bray, 2020). *Stephanostomum pristis* and *Lepidapedon guevarai* are the most prevalent and abundant parasites from *P. Phycis* and *P. blennoides* respectively, L. guevarai is the only report of *P. blennoides* parasite out of the Mediterranean waters in North east atlantic (Bray & Gibson, 1997). Most digenea parasites of deep water fishes are belonging to the genus Lepidapedon (Bray, 2004), it appears that the deep-sea fauna is constituted of a mixture of higher taxa which have radiated in the deep-sea as Lepidapedon,

that is later reinforced by molecular studies, but there is a distinct set of deep-sea digenea that are not found in shallow waters (Perez Del Olmo et al., 2019).
The family Opecoelidae Ozaki, 1925 is represented by one species in each host, Bathycreadium brayi from the anterior portion of digestive tract of *P. blennoides*, was identified by Perez Del Olmo et al., (2014) in western Mediterranean and reported by Dallares et al. (2016), it is sometimes confused with Bathycreadium biscayense Bray, 1973 which is narrower with a longer esophagus (Perez-Del-Olmo et al., 2014). Bathycreadium elongata from the posterior portion of digestive tract of *P. phycis* was reported from the natural reserve of Scandola in the gulf of Marseilles in France (Bartoli et al., 2005) and from the coastal waters of Gökçeada in Turkey (Akmirza 2013).
The only Cestoda from the order of Tetraphyllidae and the acanthocephalan belonging to the genus Echinorhynchus were present only in *P. blennoides*, also reported in western Mediterranean (Dallares et al., 2016) with higher levels of infection than in our samples. We found different ectoparasite species in the gills of each host: Gnathia sp in *P. phycis* and C. alata in *P. blennoides*, that been reported too from Balearic sea with similar ecological indices.
In the other hand, Paterson & Gray (1997) estimated that taxonomic compositions of the parasite communities are generally similar when the hosts are phylogenetically related. This could be one of the direct consequences of a shared inheritance, Le Pommelet et al., (1997) found no significant differences in the composition of the parasitic communities of red stripped mullet and red mullet from the Gulf of Lion and the Corsican coast, despite their different habitats, while Abid-Kachour et al., (2019) noticed that the two congener sparid fishes Pagellus erythrinus (Linnaeus, 1758) and Pagellus acarne (Risso, 1827), from the western Mediterranean coast of Algeria hosts different digenea parasites structure. In this study phylogeny seems not to be a factor structuring the parasite community, Hysterothylacium sp1; Collarinema collaris; *Lepidapedon guevarai* and Bathycreamium. brayi have been reported only in *P. blennoides*, as well as *P. globiceps*; Lecithocladium excisum; *Stephanostomum pristis* and Bathycreamium elongata that were present only in *P. phycis*, this hosts one less digenean species than *P. blennoides*.
According Sorbe (1977), Macpherson (1978) and Morte et al., (2002), *P. blennoides* is a nectobenthic, predatory and euryphagous fish, its wide range of prey consists mainly of crustaceans, with a predominance of decapods, teleost fish represent a small proportion of the total ingested prey. While, *P. phycis* is carnivorous that feed mainly on mobile prey, unlike *P. blennoides*, his diet consists largely of fish with a small part of decapods (Papaconstantinou & Caragitsou, 1989; Morato et al., 1999). Since most common parasites to both forkbeards are in larval stages, indeed, many studies have reported the approximation of host fish based solely on their sub-communities of adult parasites, considering that the larvae are more generalist and that their presence in the host is often random (Morand et al., 2000).
The digenea Podocotyle sp and Steringotrema sp, in addition of the nematoda: Capillostrongyloides morae and Raphidascaris sp, the Isopode Cymothoidae sp as well as the Cestoda Grillotia erinaceus were reported from *P. blennoides* from Balearic sea (Dallares et al. 2016), the digenean D. varicus, the nematodes Hysterothylacium sp1 and A. physeteris were found herein. These differences may be related to the difference in habitat and therefore availability of prey. *P. blennoides* has different diet associated with bathymetric migration involving different composition macro invertebrate communities along the continental slope; diet influences the composition of the community of endoparasites because the majority of them are transmitted by the ingestion of infected preys (Price & Clancy, 1983; Morand et al., 2000). Thus, Dallares et al., (2016) estimate that *P. blennoides* is one of the most parasited species in the family of Phycidae, despite its deep-water habitat, where parasite diversity tends to decrease the further one gets away from the continental slope, as direct consequence of the decline of populations of benthic invertebrates that can serve as intermediate hosts to parasites (Klimpel et al., 2010; Bray, 2020). Despite some differences in taxonomic composition of parasites communities, numerical descriptors are mostly similar to those of Valero et al. (2005), Farjallah et al. (2006) and Dallares et al. (2016), in Andalusia, Tunisia and Balearic sea respectively, this can be explained by the relative constancy of the abiotic factors in the Mediterranean deep sea (salinity, oligothrophy, oxygenation and temperature) (Hopkins, 1984) that could influencing the composition of intermediate hosts.

Conclusion

Very little is known about deep-sea digenea and moreover nematodes, herein, the taxonomic and numerical descriptors (parasitological indexes) of parasitic community of forkbeards differs despite their close phylogeny, because hosts often have ecological differences in habitat, geographical distribution or diet, these factors act as filters that can affect and modify the structure and dynamics of parasitic infracommunities (Holmes and Price, 1980), the latter being ultimately the result of compromises between host phylogeny and ecological processes during the evolutionary history of each species of parasite, this trait remains one of the most important variable of parasite distribution.

Aknowlegments

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