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A CHECKLIST OF MACROPARASITES REPORTED OF RED MULLET, *MULLUS BARBATUS* (LINNAEUS, 1758) AND STRIPED RED MULLET, *MULLUS SURMULETUS* (LINNAEUS, 1758) (PERCIFORMES: MULLIDAE) OF MEDITERRANEAN SEA

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ABSTRACT

Checklists about parasites of economically important fishery species at either one and/or many parts of the globe are available in (relevant) scientific literature. However, recent/up-to-date checklist about parasite of mullidsspecific to Mediterranean Sea seems not available. Thus, thespecific objective of present study was to produce a checklist from published records about (macro) parasites of two *Mullus* spp. fish species, namely: *Mullus* barbatus (Red Mullet) and *Mullus surmuletus* (Striped Red Mullet) of Mediterranean Sea. Google Scholar served as the primary search engine to acquire all relevant literature. Scientific name(s) of fish parasites were checked (and crosschecked) via World Register of Marine Species (WoRMS). Results showed four different parasite phyla namely: *Platyhelminthes*, *Nematoda*, *Acanthocephala* and *Crustacea*, within the Mediterranean Sea. *Platyhelminthes* was represented by 35 species, *Nematoda* by 16 species, *Acanthocephala* by 6 species and *Crustacea* by 5 species. Composition of parasite fauna demonstrated the importance of these two mullids species as final host of parasites of piscivorus fish. Overall, this checklist provides an update of parasites phyla/species richness - feasibly the first research step into studying the phyla of such parasite(s).

Keywords: *Mullidae*, checklist, parasite, demersal species, Mediterranean Sea.

INTRODUCTION

Striped Red Mullet (*Mullus surmuletus*, Linnaeus, 1758) and Red Mullet (*Mullus barbatus*, Linnaeus, 1758) are typical demersal species of mullids distributed throughout the Mediterranean Sea and lengthwise its shelf (Özbilgin *et al*., 2004; Barreiro *et al*., 2017). Adults of Striped Red Mullet occuring a depth range from 5 up to 409 metres at bottom of sea with heterogeneous granulometry and often in *Posidonia* beds where as Red Mullet usually can gatherat depths up to 200 metres, indicative of preference to the muddy bottoms (Renones *et al*., 1995; Lombarte *et al*., 2000; Tserpes *et al*., 2002). *Mullus* spp. known by Family Mullidae and also by goatfish shows rather successful adaptations although the diet varies from small to medium-sized animals. In fact, no goat fish species appears to be a food specialist, as for example, *Mullus surmuletus* uses its snout in feeding to occasionally plough up mud and subsequently expels water from its mouth while doing so (Gosline, 1984). Particularly, such benthic invertebrates as *Decapoda*, *Mysidacea*, *Tanaidacea*, *Amphipoda*, *Polychaeta*, *Mollusca* to gether with (some) benthic fishes make up the main component of *Mullus* spp. diet (Labropoulou *et al*., 1997; Mazzola *et al*., 1999; Bautista-Vega *et al*., 2008). Goat fishes are largely among the (most) valuable edible and high commercial value species for fisheries in all Mediterranean areas (Figus *et al*., 2004; Barreiro *et al*., 2017). Both Red and Striped Red Mulletbeing the main target demersal species of small scale and semi-industrial fisheries operating within Mediterranean Sea (Relini, 1999; Tserpes *et al*., 2002; Ferrer-Castelló *et al*., 2007; Vogiatzi *et al*., 2012) are considered as heavily exploited, such that some stocks have shown increasing signs of over fishing amidst the very low biomass (Caddy, 1993; Farrugio *et al*., 1993; Vogiatzi *et al*., 2012).

Meanwhile, parasite fauna of these two species of mullids (Red and Striped Red Mullet) has aroused the interest of parasitologists (Hassani *et al*., 2014). Parasites essentially represent a cost-effective method when used as a biological indicator to acquire meaningful information

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about host ecology and migration patterns. Because parasite distribution would directly relate with final and intermediate hosts, there is high chance that it (parasite distribution) is able to cover a wide area/distance when it (parasite) infects migratory (fish) species (Klimpel *et al*., 2008). Fish parasites would more particularly reflect the adverse effects of complex and variable environmental stresses. This may probably account for why over the years parasites have served as population tags for marine fish species with great success. Therefore, investigation(s) into fish parasite community and subsequent structures should be seen as a more sensitive indicator compared with the study of fishes themselves (Ferrer-Castelló *et al*., 2007; Carreras-Aubets *et al*., 2011). Considering the (above mentioned) important insights, the continuous reviewing/scoping of existing reported cases across broader regions for example, the Mediterranean and related Seas should be worth while to pursue in the view to update the knowledge base, state-of-the-art as well as ecological/infection perspectives of fish parasites.

In our opinion, checklist (with respect to fisheries) can refer to a compilation of (specific) organisms of interest, identified by (either) various individual/collective characteristics, specific features and/or possibly (some) overall species variations. Implementing a checklist (in fisheries) should be considered as relevant especially when the primary aim targets to establish (some) variations that broadly represent such organism(s) either within a location or across a wider coverage area/region. Indeed, checklists performed on parasites of fishery species of economic importance specific to either one and/or many parts of the globe are available in scientific literature. Despite the many studies conducted about parasites of mullids in addition to some checklists covering a number of notable/relevant locations (Manfredi *et al*., 2000; Bariche and Trilles, 2005; Bartoli *et al*., 2005; Ferrer *et al*., 2005; Moravec *et al*., 2006; Ramdane *et al*., 2007; Ramdane and Trilles, 2008; Derbel *et al*., 2012; Debenedetti *et al*., 2013; Cinar, 2014; Hassani *et al*., 2014; Öktener, 2014), recent up-to-date checklist about parasites of mullids specific to Mediterranean Sea seems not available. It appears the work of Hassani *et al*. (2014) is the most recent checklist about parasite of *Mullus* spp. that was specific to the Bay of Kristel area in Algeria. In our opinion, this work of Hassani *et al*. (2014) would be considered as some what localized. Given the economic importance of *Mullus* spp., a broader and more inclusive checklist of parasite that captures/covers a wider region, if possible, across such species is therefore needful/warranted.

Supplementing existing information therefore, the specific objective of this current study was to produce an inclusive yet up-to-date checklist of macroparasites reported about *Mullus barbatus* and *Mullus surmuletus* fish species of Mediterranean Sea, as compiled from published scientific literature. This checklist aims to provide an update about the phyla and species richness of these parasites, which can help facilitate the first steps of research into the phyla of such parasites.

MATERIALS AND METHODS

The present checklist has been prepared by compiling all existing literature concerning macroparasites reported about two *Mullus* spp., namely: *M. barbatus* and *M. surmuletus* with particular reference to the Mediterranean Sea. Specifically, Google Scholar served as the primary search engine that was used to acquire all relevant literature, whereas scientific name of parasites of fishes were checked (and crosschecked) according to electronic site as World Register of Marine Species (WoRMS) Editorial Board (2018). Every published article we found that contained reports of parasites in Mediterranean Sea and specific to the two *Mullus* spp., namely *Mullus barbatus* and *Mullus surmuletus* was (further) scrutinized in order to extract the main information, in line with the context/objective of this current study. Wherever possible, parasites species list has been developed from synthesized relevant literature and presented by tabulation in terms of phylum and class, providing phyla and parasite species name and its corresponding host fish, body part infected of host fish, location(s)/site(s) of reported case and reference source.

In addition, all reports that emerged about Black Sea were completely excluded to allow for an improved focus on those of the Mediterranean Sea. Moreover, the search had much focus on the endo/ectomacroparasites as an artificial group of metazoan parasites that constituted largely of member of the *Platyhelminthes* (flatworms, including monogenean, digeneans, trematodes as well as cestodes), Nemathelminthes (roundworms and allies, including nematodes and acanthocephalans), Annelids (such as leeches) and Arthropods (true lice and parasitic copepods) (Barber *et al*., 2000). To better appreciate/understand the variations in reported body part habitable by parasite and infected of host fish (Refer to Fig. 1) and its corresponding location/site of reported cases about *Mullus* spp. parasites of current study, a further quantification of emergent tabulated information was carried out and relayed subsequently in figures to allow for additional elaboration(s)/explanation(s).

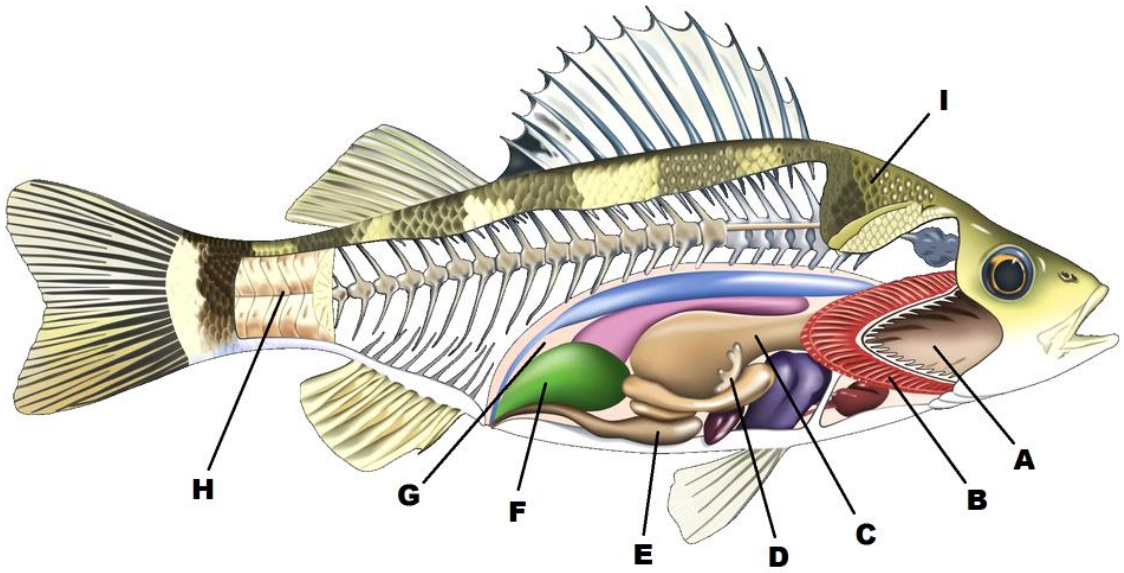

Fig. 1. Pictorial (anatomy) representation of typical bony fish showing body parts where parasites can habitparticularly with reference to the two *Mullus* fish species host of current study. The labels are as follows: (A) Branchial cavity; (B) Gills; (C) Esophagus and stomach; (D) Pyloric caeca; (E) Intestine (mid and posterior); (F) Gonads; (G) Abdominal cavity; (H) Muscles; (I) Body Surface (Fish diagram has been adapted with slight modification from website: https://www.dkfindout.com/uk/animals-and-nature/fish/inside-fish/; Accessed 11 May 2019, 18.52 h GMT).

RESULTS AND DISCUSSION

Individual fish species found in any marine environment can suffer parasitic attacks (Sasal *et al*., 1997). Specific to this current study, groups/species list of parasites across the two studied hosts (Red and Striped Red Mullet) involving phyla *Platyhelminthes*, *Nematoda*, *Acanthocephala* and Crustacea with respect to body part infected and location(s)/site(s) of reported cases, are presented in Table 1 (Refer to all references cited in Table 1: Papoutsoglou, 1976; Amel *et al*., 2009; Paggi *et al*., 1998….up to Gaglio *et al*., 2011). We found a total of 71 different taxa from parasite phyla reported about *Mullus barbatus* and *Mullus surmuletus* fish species, out of which 51 were identified at species level. Regarding the *Platyhelmintes*, there were a total of 32 taxa within the classes of *Trematoda* and *Cestoda*, divided into 18 families and particularly within this division, 24 and 8 taxa have been classified as species and genus, respectively. Regarding the *Nematoda*, there were a total of 18 taxa divided into 7 families and particularly within this division, 8 and 10 taxa have been classified as genus and species, respectively. Regarding the *Acanthocephala*, there were a total of 6 taxa divided into 3 families and particularly within this division, 4 and 2 taxa have been classified as species and genus, respectively. Regarding the *Crustacea*, especially within the classes of *Hexanauplia* and *Malacostraca*, there were a total of 15 taxa divided into 7 families and particularly within this division, 13 and 2 taxa have been classified as species and genus, respectively.

Table 1. Group/species of parasites across two studied hosts (Red and Striped Red Mullet), involving phyla *Platyhelminthes, Nematoda, Acanthocephala* and *Crustacea* with respect to body part infected and location(s) /site(s) of reported cases. Acronyms include: MSUR = *Mullus surmuletus*, and MBAR = *Mullus barbatus*.

Group/species	Host	Body parts	Site of reportedcases	Refs
Phylum: PLATYHELMINTHES Class: Trematoda Subclass: Digenea Family: Acanthocolpidae (Lühe,1901)				
Stephanostomum spp. (Looss, 1899)	MSUR MBAR	Gills	Coasts of Greece	1
	MSUR	Gills	Coasts of Tunisia	2
	MSUR MBAR	Gills, Hypodermis	Strait of Sicily	3, 53, 54
	MSUR	Pharynx	Gulf of Cagliari (Italy)	4

	MBAR			
	MSUR	Stomach	Bay of Gabes (Tunisia)	5
Family: Acanthostomidae (Poche, 1926)				
Anisocoelium capitellatum (Rudolphi, 1819) Lühe, 1900	MSUR	Gallbladder	Adriatic Sea	6
Anisocladium fallax (Rudolphi, 1819) Looss, 1902	MBAR	Gallbladder	Adriatic Sea	6
Family: Bothriocephalidae (Blanchard, 1849)				
Bothriocephalus spp.	MSUR	Body cavity; Organs (generic)	Bonifacio Strait Marine Reserve (Corsica)	7
Family: Bucephalidae (Poche, 1907)				
	MSUR	Organs (generic)	Gulf of Cagliari (Italy)	4
Prosorhynchus crucibulum (Rudolphi, 1819)	MBAR	Organs (generic) Muscles	Catalonian coast (Spain)	8
	MSUR	Body cavity Organs (generic)	Bay of Kristel (Algeria)	9
Prosorhynchus spp.	MSUR	Muscles	Barcellona-Burriana-Santa Pola (Spain)	10
Family: Cryptogonimidae (Ciurea, 1933)				
	MSUR	Esophagus	Gulf of Oran (Algeria)	2
Aphallus tubarium (Rudolphi, 1819) Poche, 1926	MBAR	Organs (generic); Muscles	Catalonian Coast (Spain)	8
	MSUR	Body cavity; Organs (generic)	Bay of Kristel (Algeria)	9
Monilicaecum spp. (Yamaguti, 1942)	MSUR	Stomach Intestine	Israel	2; 11
Family: Derogenidae (Nicool, 1910)				
	MBAR	Intestine	Adriatic Sea	12
	MSUR	Gallbladder Intestine	Scandola Nature Reserve (Corsica)	13
	MSUR	Gallbladder	Scandola Nature Reserve (Corsica)	52
	MSUR	Gallbladder	Gulf of Oran (Algeria)	2
Derogenes latus (Janiszewska, 1953)	MSUR	Body cavity Organs (generic)	Bonifacio Strait Marine Reserve (Corsica)	7
	MBAR	Organs (generic) Muscles	Catalonian coast (Spain)	8
	MSUR	Body cavity Organs (generic)	Bay of Kristel (Algeria)	9
		Gallbladder	Adriatic Sea (Italy)	14
Derogenes varicus (Muller, 1784)	MSUR	Gastrointestinal tract	Ligurian Sea (Italy)	15
		Gallbladder	Gulf of Oran (Algeria)	2
Family: Fellodistomidae (Nicoll, 1909)				
	MSUR	Esophagus	Coasts of Libano	16
	MBAR			
Proctoeces maculatus (Looss, 1901) Odhner, 1911	MSUR	Organs (generic) Muscles	Barcellona-Burriana-Santa Pola (Spain)	10
	MSUR	Stomach	Gulf of Oran (Algeria)	2

	MBAR	Stomach	Valencian coast (Spain)	17
	MSUR	Gastrointestinal tract	Bay of Bizerte (Tunisia)	18
Family: Gorgoderidae (Looss, 1899)				
Prosorhynchus spp.	MBAR	Organs (generic) Muscles	Catalonian coast (Spain)	8
Family: Hemiuridae (Lühe, 1901)				
	MSUR	Stomach	Israel	11
	MSUR MBAR	Esophagus	Libano	16
	MSUR	Organs (generic) Muscles	Barcellona-Burriana-Santa Pola (Spain)	10
Lecithocladium excisum (Rudolphi, 1819) Lühe, 1901	MSUR	Stomach	Gulf of Annaba (Algeria)	2
	MBAR	Organs (generic) Muscles	Catalonian coast (Spain)	8
	MSUR	Body cavity Organs (generic)	Bay of Kristel (Algeria)	9
	MSUR	Mid-intestine	Scandola Nature Reserve (Corsica)	13, 52
Lecithochirium musculus (Looss, 1907) Nasir and Diaz, 1971	MBAR	Organs (generic) Muscles	Catalonian coast (Spain)	8
Family: Lecithasteridae (Odhner, 1905)				
	MSUR MBAR	Gastrointestinal tract	Gulf of Lion, Scandola Nature Reserve (Corsica)	19
	MSUR	Stomach	Gulf of Cagliari (Italy)	4
	MSUR	Stomach	Scandola Nature Reserve (Corsica)	13, 52
Aponurus laguncula (Looss, 1907)	MSUR	Organs (generic) Muscles	Barcellona-Burriana-Santa Pola (Spain)	10
	MSUR	Gastrointestinal tract	Gulf of Annaba (Algeria)	2
	MBAR	Stomach	Valencian coast (Spain)	17
Aponurus mulli (Looss, 1907)	MBAR	Organs (generic) Muscles	Catalonian coast (Spain)	8;20
Family: Lepocreadiidae (Nicoll, 1935)				
	MSUR	Intestine	Scandola Nature Reserve (Corsica)	21
	MSUR	Rectum, duodenum, mid and posterior intestine	Scandola Nature Reserve (Corsica)	13, 52
Holorchis legendrei (Dollfus, 1946)	MSUR	Gastrointestinal tract	Adriatic Sea	15
	MSUR	Intestine	Gulf of Oran (Algeria)	2
	MSUR	Gastrointestinal tract	Bay of Bizerte (Algeria)	18
Neolepidapedon israelense (Fischthal, 1980)	MSUR	Intestine	Israel	11

Family: Monorchiidae (Odhner, 1911)

Lasiotocus mulli (Stossich, 1883)	MSUR MBAR	Rectum	Gulf of Marseille (France)	22
	MSUR	Pyloriccaeca	Gulf of Oran (Algeria)	23
	MSUR	Posterior intestine	Gulf of Cagliari (Italy)	4
	MSUR	Rectum	Scandola Nature Reserve (Corsica)	13, 52
	MSUR	Organs (generic) Muscles	Barcellona-Burriana-Santa Pola (Spain)	10
	MSUR	Pyloric caeca Rectum	Gulf of Oran (Algeria)	2
	MSUR	Body cavity Organs (generic)	Bonifacio Strait Marine Reserve (Corsica)	7
	MBAR	Organs (generic) Muscles	Catalonian coast (Spain)	8
	MSUR	Body cavity Organs (generic)	Bay of Kristel (Algeria)	9
Proctotrema bacilliovatum (Odhner, 1911)	MSUR MBAR	Rectum	Gulf of Marseille (France)	22
	MSUR	N/A	Aegean Sea	24
	MSUR	Posterior intestine	Gulf of Cagliari (Italy)	4
	MSUR	Rectum Pyloric caeca	Scandola Nature Reserve (Corsica)	13, 52
	MSUR	Organs (generic) Muscles	Barcellona-Burriana-Santa Pola (Spain)	10
	MSUR	Rectum	Gulf of Oran (Algeria)	2
	MSUR MBAR	Stomach	Gulf of Gabes (Tunisia)	5
	MBAR	Organs (generic) Muscles	Catalonian coast (Spain)	8
	MSUR	N/A	Aegean Sea	25
	MSUR	N/A	Aegean Sea	26
	MSUR	Body cavity Organs (generic)	Bay of Kristel (Algeria)	9
	MSUR	Gastrointestinal tract	Bay of Bizerte (Tunisia)	18
Timonia mediterranea (Bartoli and Prevot, 1966)	MSUR MBAR	Pyloric caeca	Gulf of Marseille (France)	21
	MSUR	Pyloriccaeca	Scandola Nature Reserve (Corsica)	13, 52
	MSUR	Gastrointestinal tract	Adriatic Sea	15

Family: Opecoelidae (Ozaki, 1925)

Opecoeloides furcatus (Odhner, 1928)	MSUR	Gastrointestinal tract	Gulf of Palermo (Italy)	27
	MSUR	NA	Adriatic Sea	24
	MSUR MBAR	Gastrointestinal tract	Spanish south-eastern Mediterranean	28
	MSUR	Stomach	Gulf of Cagliari (Italy)	4
	MSUR	Pyloric caeca, duodenum,	Scandola Nature Reserve (Corsica)	13, 52

		mid and posterior intestine, rectum		
	MSUR	Organs (generic) Muscles	Barcellona-Burriana-Santa Pola (Spain)	10
	MSUR	Intestine	Syrt coast (Lybia)	29
	MSUR	Gastrointestinal tract	Adriatic Sea Tyrrhenian Sea Ligurian Sea (Italy)	15
	MSUR	Intestine, Cecum	Gulf of Oran (Algeria)	2
	MSUR	Body cavity Organs (generic)	Bonifacio Strait Marine Reserve (Corsica)	7
	MBAR	Muscles	Catalonian coast (Spain)	8
	MSUR MBAR	Gastrointestinal tract	Gulf Of Gabes (Tunisia)	5
	MBAR	Intestine	Valencian coast (Spain)	17
	MSUR		Aegean Sea	26
	MBAR	Gastrointestinal tract	Tyrrhenian sea	30
	MSUR	N/A	Aegean Sea	31
	MSUR	Body cavity Organs (generic)	Bay of Kristel (Algeria)	9
	MSUR	Gastrointestinal tract	Bay of Bizerte (Tunisia)	18
	MSUR	Intestine	Scandola Nature Reserve (Corsica)	13
	MSUR MBAR	Gastrointestinal tract	Spanish southeastern Mediterranean	28
	MSUR	Organs (generic)	Gulf of Cagliari (Italy)	4
	MSUR	Gastrointestinaltract	Bonifacio Strait Marine Reserve (Corsica)	32
	MSUR	Organs (generic) Muscles	Barcellona-Burriana-Santa Pola (Spain)	10
	MSUR	Duodenum, mid and posterior intestine, pyloric caeca, rectum	Scandola Nature Reserve, (Corsica)	13, 52
Poracanthium furcatum (Odhner, 1928)	MSUR	Intestine, cecum	Gulf of Oran (Algeria)	2
	MSUR	Body cavity Organs (generic)	Bonifacio Strait Marine Reserve (Corsica)	7
	MBAR	Organs (generic) Muscles	Catalonian coast (Spain)	8
	MSUR	Stomach	Gulf Of Gabes (Tunisia)	5
	MSUR	Body cavity Organs (generic)	Bay of Kristel (Algeria)	9
	MSUR	Gastrointestinal tract	Bay of Bizerte (Tunisia)	18

Helicometra fasciata (Rudolphi, 1819) Odhner, 1902	MSUR	Gastrointestinal tract	Gulf of Palermo (Italy)	27
Family: Zoogonidae (Odhner, 1911)				
Propavipyrum israelense (Fischthal, 1980)	MSUR	Intestine, Cecum	Israel	11
Diphterostomum brusinae (Stossich, 1889)	MBAR	Organs (generic) Muscles	Catalonian coast (Spain)	8
Steganoderma retroflexum (Molin, 1859)	MSUR	Gastrointestinal tract	Gulf of Palermo (Italy)	27
Class: Cestoda				
Family: Tentaculariidae (Poche, 1926)				
Nybelinia lingualis (Cuvier, 1817) Dollfus, 1929	MSUR	Body cavity Organs (generic)	Bay of Kristel (Algeria)	9
	MSUR	Intestine	Saronic Gulf (Greece)	1
	MBAR	N/A	Mediterranean Sea	35
	MBAR MSUR	N/A	Gulf of Lion, Scandola Nature Reserve (Corsica)	19
Nybelinia sp.	MSUR	Gills Esophagus, Stomach	Syrt coast (Lybia)	29
	MBAR	N/A	Aegean Sea	31
Family: Tetraphyllidea incertae sedis				
Tetraphyllidea indet.	MSUR	Intestine	Ligurian Sea (Italy)	15
Scolex pleuronectis (Müller, 1788)	MBAR	Organs (generic) Muscles	Catalonian coast (Spain)	8
Family: Trypanorhyncha incertae sedis				
Trypanorhyncha spp.	MSUR	Organs (generic)Muscles	Barcellona-Burriana-Santa Pola (Spain)	10
	MBAR	Organs (generic) Muscles	Catalonian coast (Spain)	8
Phylum: NEMATODA				
Class: Chromadorea				
Family: Anisakidae (Railliet and Henry, 1912)				
Anisakis simplex (Rudolphi, 1809)	MSUR MBAR	Body cavity Organs (generic) Muscles	Ligurian Sea (Italy)	25
	MSUR	N/A	Aegean Sea	31
	MBAR	Mesenteries	Valencian coast (Spain)	17
Anisakis pegreffii (Campana-Rouget and Biocca, 1955)	MSUR	Body cavity	Coasts of Sardinia (Italy)	33
	MBAR	Body cavity	Gulf of Antalya, Iskenderum Bay (Turkey)	34
Anisakis spp.	MSUR	Gastrointestinal tract	Gulf of Palermo (Italy)	27
Contracaecum spp.	MBAR	Organs (generic) Muscles	Catalonian coast (Spain)	8

Hysterothylacium spp.	MSUR	Organs (generic) Muscles	Barcellona-Burriana-Santa Pola (Spain)	10
	MBAR	Mesenteries Muscles	Valencian coast (Spain)	17
	MSUR	Body cavity walls and Organs (generic)	Bay of Kristel (Algeria)	9
	MBAR MSUR	N/A	Gulf of Lion, Scandola Nature Reserve (Corsica)	35
	MSUR	Gastrointestinal tract	Gulf of Palermo (Italy)	27
Hysterothylacium aduncum (Rudolphi, 1802)	MSUR	Stomach lumen Pyloric caeca Intestine	Adriatic Sea (Italy) Ligurian Sea (Italy) Thyrrhenian Sea (Italy)	15
	MBAR	Organs (generic)Muscles	Catalonian coast (Spain)	8
	MBAR MSUR	Intestine Stomach	Saronic Gulf (Greece)	1
	MBAR MSUR	N/A	Adriatic Sea (Montenegro)	36
	MSUR	Gastrointestinal tract	Gulf of Palermo (Italy)	27
	MSUR	N/A	Aegean Sea	31
Hysterothylacium fabri (Rudolphi, 1819)	MBAR	Organs (generic) Muscles	Catalonian coast (Spain)	8
	MSUR	Body cavity walls Organs (generic)	Bay of Kristel (Algeria)	9
	MSUR	Gastrointestinal tract	Ionian Sea	37
Family: Cystidicolidae (Skrjabin, 1946)				
	MSUR	Stomach	Valenciancoast (Spain)	38
	MSUR	Organs (generic) Muscles	Barcellona-Burriana-Santa Pola (Spain)	10
Ascarophis valentina (Ferrer, 2005)	MSUR	Stomach lumen, pyloric caeca and intestine	Ligurian Sea (Italy)	15
	MSUR	Body cavity Organs (generic)	Bay of Kristel (Algeria)	9
Ascarophis mullus (Naidenova and Nikolaeva, 1968)	MBAR	Organs (generic) Muscles	Catalonian coast (Spain)	8
Family: Ascarididae (Baird, 1853)				
Ascaris mulli (Rudolphi, 1819)	MBAR	N/A	Adriatic Sea (Italy)	39
Ascaris wedli (Stossich, 1896)	MBAR	N/A	Adriatic Sea (Italy)	39

Family: Capillariidae (Railliet, 1915)				
Capillaria spp.	MSUR	Organs (generic) Muscles	Barcellona-Burriana-Santa Pola (Spain)	10,
	MSUR	N/A	Aegean Sea	31
Paracapillaria spp.	MBAR	Organs (generic) Muscles	Catalonian coast (Spain)	8
Family: Cucullanidae (Cobbold, 1864)				
Cucullanus spp.	MSUR	Organs (generic) Muscles	Barcellona-Burriana-Santa Pola (Spain)	10
Cucullanus longicollis (Stossich, 1899)	MSUR MBAR	Intestine	Saronic Gulf (Greece)	1
	MBAR	N/A	Adriatic Sea (Montenegro)	36
	MSUR	Gastrointestinal tract	Gulf of Palermo (Italy)	27
	MSUR MBAR	N/A	Gulf of Lion, Scandola Nature Reserve (Corsica)	19
	MSUR	N/A	Aegean Sea	31
	MSUR	Intestine	Syrt coast (Lybia)	29
	MBAR	Organs (generic) Muscles	Catalonian coast (Spain	8
	MSUR	N/A	Aegean Sea	26
	MSUR	Body cavity Organs (generic)	Bay of Kristel (Algeria)	9
Family: Philometridae (Baylis &Daubney, 1926)				
Philometra justinei (Moravec *et al*., 2006)	MSUR	Body cavity Gonads	Bonifacio Strait Marine Reserve (Corsica)	40
Philometra sp.	MSUR	Body cavity Gonads	Bonifacio Strait Marine Reserve (Corsica)	40
Family: Oncholaimidae (Filipjev, 1916)				
Metoncholaimus spp.*	MSUR	Gastro-intestinal tract	Gulf of Oran (Algeria)	41
Phylum: ACANTHOCEPHALA **Class: Eocanthocephala** **Family: Arhythmacanthidae (Yamaguti, 1935)**				
Breizacanthus irenae (Golvan, 1969)	MSUR	Organs (generic)	Bay of Kristel (Algeria)	9
	MSUR	N/A	Gulf of Lion, Scandola Nature Reserve (Corsica)	19
Euzetacanthus simplex (Rudolphi, 1810)	MSUR	Organs (generic)	Bay of Kristel (Algeria)	9, 42
	MSUR	Body cavity Organs (generic)	Bonifacio Strait Marine Reserve (Corsica)	7
	MSUR	Body cavity Organs (generic)	Bay of Kristel (Algeria)	9

Family: Neoechinorhynchidae (Ward, 1917)				
Neoechinorhynchus (Hebesoma) agilis (Rudolphi, 1819)	MSUR MBAR	N/A	Marmara Sea Aegean Sea	26
Family: Echinorhynchidae (Cobbold, 1879)				
Echinorhynchus spp.	MSUR	N/A	Aegean Sea	31
Echinorhynchidae spp.	MSUR	Organs (generic) Muscles	Barcellona-Burriana-Santa Pola (Spain)	10
Echinorhynchus gadi (Zoega in Müller, 1776)	MSUR	N/A	Syrt coast (Lybia)	29
	MBAR	Intestine	Valencian coast (Spain)	17
Subphylum: CRUSTACEA **Class: Hexanauplia** **Subclass: Copepoda** **Family: Philichthyidae (Vogt, 1877)**				
Colobomatus mulli (Essafi *et al*., 1983)	MBAR MSUR	NA	Mediterranean Sea	43
Colobomatus steenstrupi (Richiardi, 1876)	MBAR MSUR	N/A	Mediterranean Sea	43
Family: Hatschekiidae (Van Beneden, 1851)				
Hatschekia mulli (Van Beneden, 1851**)**	MBAR	Gill	Saronic Gulf (Greece)	1
	MSUR MBAR	Gills	Mediterranean Sea	43
	MSUR	Gills	Aegean Sea	44 24
	MSUR	Organs (generic) Muscles	Barcellona-Burriana-Santa Pola (Spain)	10
	MSUR	Gills	Ligurian Sea Adriatic Sea Thyrrhenian Sea	15
	MSUR	Body cavity Organs (generic)	Bonifacio Strait Marine Reserve (Corsica)	7
	MBAR	Body surface	Catalonian coast (Spain)	8
	MBAR	Branchial cavity Body surface	East coast of Algeria	45
	MSUR	N/A	Aegean Sea	31
Family: Pennellidae (Burmeister, 1835)				
Peniculus fistula (Nordmann, 1832)	MBAR MSUR	N/A	Mediterranean Sea	43
Family: Caligidae (Burmeister, 1835)				
Caligus centrodonti (Baird, 1850)	MSUR	Body surface	Mediterranean Sea	43
Caligus uranoscopi (Vaissière, 1955)	MBAR	Branchial cavity Body surface	East coast of Algeria	45
Family: Lernaeidae (Cobbold, 1879)				
Lernaea spp.	MSUR	Body surface	Aegean Sea	44

Class: Malacostraca **Order: Isopoda** **Family: Aegidae (White, 1850)**				
Aega rosacea (Risso, 1816)	MBAR	Body surface	Gulf of Bejalia, Jijel, Annaba (Algeria)	46
Family: Cymothoidae (Leach, 1818)				
Anilocra frontalis (Milne Edward, 1840)	MBAR	Body surface	Gulf of Béjaïa	47
	MBAR	Body surface	Gulf of Bejalia, Jijel, Annaba (Algeria)	46
	MBAR	Branchial cavity Body surface	East coast of Algeria	45
Anilocra physodes (Linnaeus, 1758)	MSUR	Body surface	Saronic Gulf (Greece)	1
Nerocila bivittata (Risso, 1816)	MSUR	Organs (generic)	Coast of Valencia (Spain)	48
	MSUR	Pectoral and dorsal fins	Central Mediterranean Sea (Sfax, Tunisia)	49
Gnathia spp.	MSUR	Organs (generic) Muscles	Barcellona-Burriana-Santa Pola (Spain)	10
	MSUR	Gills	Ligurian Sea, Adriatic Sea, Thyrrhenian Sea	15
	MBAR	Branchial cavity Body surface	East coast of Algeria	45
	MBAR	External body surface	Catalonian coast (Spain)	8
Gnathia maxillaris (Montagu, 1804)	MSUR MBAR	Body Surface	Saronic Gulf (Greece)	1
Ceratothoa oestroides (Risso, 1826)	MBAR	N/A	West/Central Mediterranean Sea	48
	MSUR	N/A	Aegean Sea	50, 24
Ceratothoa parallela (Otto, 1828)	MSUR	N/A	Aegean Sea	50, 51

[1, Papoutsoglou, 1976; 2, Amel *et al*., 2009; 3, Paggi *et al*., 1998; 4, Figus *et al*., 2004; 5, Derbel *et al*., 2012; 6, Paradiznik, 1992; 7, Ternengo *et al*., 2009; 8, Carreras-Aubets *et al*., 2012; 9, Hassani *et al*., 2014; 10, Ferrer-Castello *et al*., 2007; 11, Fishthal, 1980; 12, Janiszewska 1953; 13, Bartoli and Gibson, 1991; 14, Sey, 1970; 15, Klimpel *et al*., 2008; 16, Saad-Farès, 1985; 17, Debenedetti *et al*., 2013; 18, Antar and Gargouri, 2018; 19, Le Pommelet *et al*., 1997; 20, Carreras-Aubets *et al*., 2011; 21, Bartoli and Bray, 1996; 22, Bartoli and Prévot, 1966; 23, Boudaoued-Krissat, 1979; 24, Akmirza, 2000; 25, Manfredi *et al*., 2000; 26, Cinar, 2014; 27, Arculeo*et al*., 1997; 28, Martinez-Vicaria *et al*., 2000; 29, Bayoumi *et al*., 2008; 30, Bottari *et al*., 2014; 31, Öktener, 2014; 32, Levron *et al*., 2004; 33, Meloni *et al*., 2011; 34, Pekmezci *et al*., 2004; 35, Orecchia and Paggi, 1978; 36, Petter and Radujkovic, 1989; 37, Tedesco *et al*., 2018; 38, Ferrer *et al*., 2005; 39, Bruce *et al*., 1994; 40, Moravec *et al*., 2006; 41, Hassani *et al*., 2012; 42, Sasal *et al*., 1997; 43, Raibaut *et al*., 1998; 44, Oguz and Öktener, 2007; 45, Ramdane *et al*., 2013; 46, Ramdane and Trilles, 2008; 47, Ramdane *et al*., 2007; 48, Bariche and Trilles, 2005; 49, Charfi-Cheikhrouha *et al*., 2000; 50, Öktener and Trilles, 2004; 51, Özbilgin *et al*., 2004; 52, Bartoli *et al*., 2005; 53, Arru *et al*., 1968; 54, Gaglio *et al*., 2011].

As showed in Table 1, the body part of host infected by parasite species as well as location(s)/site(s) of reported case can indeed vary across these two *Mullus* fish host species (Refer to all references cited in Table 1: Papoutsoglou, 1976; Amel *et al*., 2009; Paggi *et al*., 1998……up to Özbilgin *et al*., 2004). To give additional emphasis on these body parts, we consider again diagram of typical anatomy of bony fish depicting body parts where parasites can habit and with particular reference to *M. barbatus* and *M. surmuletus* fish species herein, as showed in Figure 1. Placing therefore both Figure 1 and

Table 1 side-by-side, body parts such as gills, gallbladder, body cavity/mesenteries, organs, muscles, esophagus, stomach, intestine (duodenum/rectum), pyloric caeca, external body surface, branchial cavity and gonads can be enumerated. To elaborate on Table 1, variations in total number of body parts of *Mullus* spp. (*M. barbatus* and *M. surmuletus*) infected by parasites as we found reported in published literature, are showed in Figure 2. Organs (generic) appear to be most parasitically infected body part reported of *Mullus* spp. host, followed by the muscles and intestine/mesenteries/body cavity. The least parasitically infected body part appears to be gonads/pharynx followed by duodenum, then branchial cavity/esophagus, before gallbladder/pyloric caeca, as showed to be increasing in this order/sequence. These organs may well serve as biological indicators for ecology and migration patterns of parasites (Klimpel *et al*., 2008) of *Mullus* spp. host of this current study. To elaborate further on Table 1, variations in total number of Mediterranean location(s)/site(s) reporting *Mullus* spp. (*M. barbatus* and *M. surmuletus*) parasites as we found reported in published literature, are showed in Figure 3. Parasite cases of *Mullus* spp. were highest at Catalonian Coast and yet equally leastat eleven other places, from Coasts of Sfax (Tunisia), Greece, up to West and Central Mediterranean Sea. Similarly, some *Mullus* spp. parasite reports were equally matched, for example, that of Bay of Bizerte (Tunisia) equaled with Coasts of Israel, whereas those of Coast of Valencia (Spain) equaled with Gulf of Cagliari (Italy), Gulf of Palermo (Italy) and Ligurian Sea (Italy). This aspect of location(s)/site(s) may well substantiate the direct relationship of distribution of parasitic organisms with final and intermediate hosts and hence, high chance/probability for such parasitic organisms with infected migratory (fish) species to capture/cover a relatively wide area/distance (Klimpel *et al*., 2008). Clearly, parasite(s) can feasibly reflect the life habits of fish either as interaction with the benthic, planktonic and fish communities or movement of fish hosts prior to the capture, as highly effective migration marker(s), which moreover should help to monitor both physiological and immunological state of fish hosts (Lester, 1990; Landsberg *et al*., 1998; Lewis *et al*., 2003).

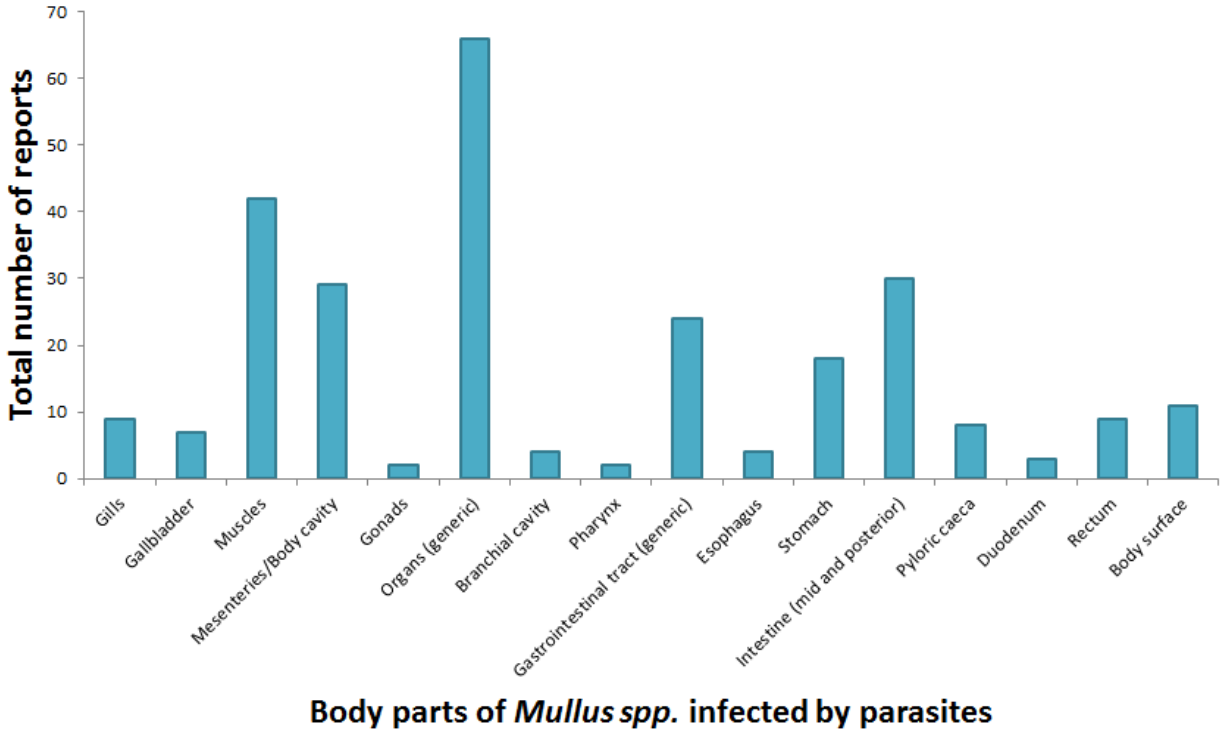

Fig. 2. Variations in total number of body parts of *Mullus* spp. (*M. barbatus* and *M. surmuletus*) infected by parasites, as we found reported in published scientific literature. Note that organs and gastrointestinal aspects incorporate others not detailed by reported works and therefore considered generic.

Body part(s) where parasites would habit can be influenced byfish species feed type, feeding routine, environmental condition of water body, size and type as well as position (depth and location) in water body, (Kennedy, 1977). In addition, *Mullus* spp. can be relatively sizeable, given that it can have length range of between 12 and 23 cm (Martínez-Vicaria *et al*., 2000). From this current checklist, one can visualize importance of host size, which we believe can serve as a predictor parameter/variable of external parasites. This can also be

so, considering that larger hosts show a more diverse availability to parasite colonization (Sasal *et al*., 1997). Notably, parasite richness is a term used to describe the degree of quantity (as well as quality) of parasite species within one host species. Why some fish species have a higher richness of parasite species compared with others and how parasite communities build-up on these hosts, is still yet to be fully understood (Sasal *et al*., 1997). To quantify the richness of parasite species could thusbe quite relative. To establish a common ground between richness of parasites and size of fish species as is in this case of *Mullus* spp., could specifically be by determining how detrimental the effects of parasites have become apparent in the (set of) fish species host(s).

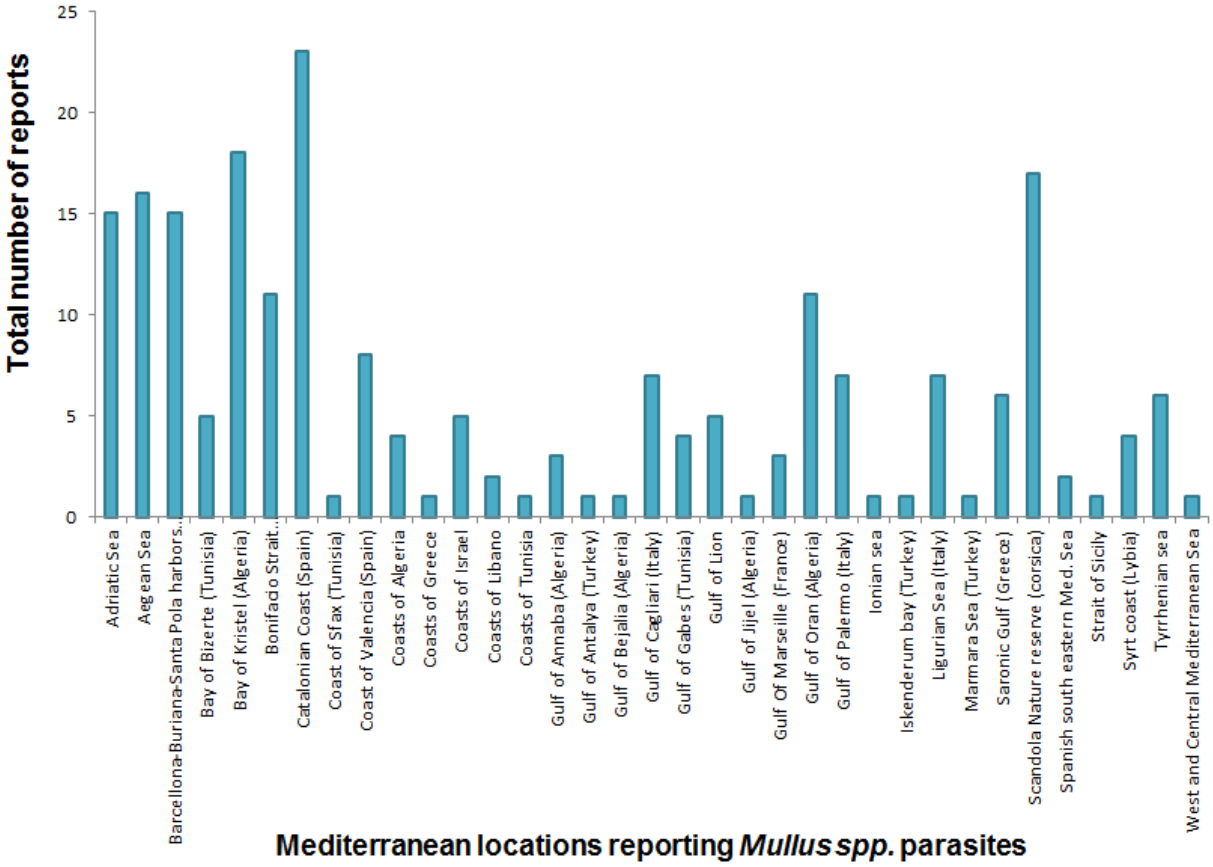

Fig. 3. Variations in total number of Mediterranean location(s)/site(s) reporting *Mullus* spp. (*M. barbatus* and *M. surmuletus*) parasites, as we found reported in published scientific literature. Details of Mediterranean waters are presented based on reports.

Table 1 also reveals a realistically varied yet wide-like helminth and crustacean parasitic fauna of *M. barbatus* and *M. surmuletus* within the Mediterranean Sea. The *Digenea* are representative of largest group of parasites (found in scientific literature), specific to the above mentioned two species of mullids. The largest group of internal metazoan parasite and extraordinarily ubiquitous group appears to be parasitic at all the major vertebrate groups and as definitive hosts, with gasteropods and other mollusks group as first intermediate hosts and several phyla as second intermediate hosts (Olson *et al*., 2003). Previously reported field investigations would show the prevalence of digeneans in intermediate/definitive hosts, which could inversely relate to the degree of disturbance/pollution of aquatic ecosystems (Sures *et al*., 2017). Feasibly, the composition of this helminth fauna would associate with water quality and preservation of aquatic ecosystem (Debenedetti *et al*., 2013). Owed to their complex multi-host lifecycles, trematodes would posit as reliable indicator(s) of free-living species with its corresponding diversity, subsequently associated with the trophic interactions within an ecosystem (Sures *et al*., 2017). We believe helminthes still remain among the most abundant (parasite) group especially in terms of numbers of species. Large number of post-larval helminth species representing particularly both digenea and nematodes

would be underscoring the importance of *Mullus barbatus* and *Mullus surmuletus* as an intermediate and host.

CONCLUSION

In this study, we have produced an inclusive yet up-to-date checklist of macroparasites reported about two *Mullus* spp., namely: *M. barbatus* and *M. surmuletus* fish species of Mediterranean Sea. This involved a thorough scrutiny and synthesis of relevant published literature and further quantification of emergent tabulated information. At each phyla *Platyhelminthes*, *Nematoda*, *Acanthocephala* and *Crustacea* parasites and with respect to body part infected and corresponding location(s)/site(s) of reported cases, different taxa/families were classified into species and genus. Further quantification of emergent tabulated information helped to establish the variations in both total number of body parts of *Mullus* spp. infected by parasites as well as Mediterranean location(s)/site(s) of reporting *Mullus* spp. parasites as found in published literature. Indeed, this current checklist has revealed the most parasitically infected body part as organs (generic) as well as parasite cases of *Mullus* spp. to be highest at the Catalonian coast. Realistically, both helminth and crustacean parasitic fauna of *M. barbatus* and *M. surmuletus* can vary within the Mediterranean Sea. Overall, this checklist provides an update of parasites phyla/species richness – feasibly the first research step into studying the phyla of such parasite(s).

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