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Helminth parasites of grey mullets (Teleostei: Mugilidae) in the Mediterranean region: a review

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Helminths are a diverse and rich group of fish parasites, some of which are dangerous pathogens of epidemic potential. The present review is focused on helminth parasites from grey mullets (Mugilidae) in the Mediterranean and Azov-Black Seas. These fish are of great economic importance, for supplying food and recreation services. This study covers helminth parasites of six species: *Mugil cephalus* (L.), *Chelon labrosus* (Risso), *C. auratus* (Risso), *C. ramado* (Risso), *C. saliens* (Risso) and *Planiliza haematocheila* (Temminck, Schlegel). This paper gives a brief overview of the history of taxonomic and faunistic studies of helminth parasites from grey mullets in the Mediterranean. The history of the helminth parasites from grey mullets goes back to over 200 years ago to the first species described by Rudolphi in 1819. One hundred and four helminth species have been recorded in about 130 published papers. Fewer than 10 species have been recorded prior to 1900. Since 1960s, taxonomic efforts have rapidly increased, reaching the highest level in the first decade of the 21st century. Only one new species has been recorded in Mediterranean mullets in the last decade. We suggest that the decrease in the number of described species observed in the last decade is the consequence of previous intensive taxonomic efforts result in actual estimation of species diversity for the studied area. Digeneans and specialist (oioxenic and stenoxenic) parasites dominated in the structure of helminth fauna of mullets. The highest richness of helminths is found in the Azov-Black Seas mullets, while the poorest in the Eastern Mediterranean. A relatively large number of species (20) identified only to generic or family levels remain the taxonomic subject of future studies.

Гельмінти кефалей (Teleostei: Mugilidae) Середземноморського регіону: літературний огляд

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Гельмінти - різноманітна і багата група паразитів риб, серед яких є небезпечні збудники захворювань, що можуть призводити до масових епізоотій серед популяцій риб. Огляд присвячено гельмінтам кефалевих риб (Mugilidae), що мешкають у водах Середземного та Азово-Чорноморського басейнів. Кефалі мають велике економічне значення з огляду на споживання та рекреацію. Дослідження охоплює огляд гельмінтів від шести видів: *Mugil cephalus* (L.), *Chelon labrosus* (Risso), *C. auratus* (Risso), *C. ramado* (Risso), *C. saliens* (Risso) та *Planiliza haematocheila* (Temminck, Schlegel). Наведено стислий огляд історії таксономічних та фауністичних досліджень паразитів гельмінтів від кефалей у Середземномор'ї. Історія вивчення гельмінтів кефалей сягає понад 200 років та бере початок від опису акантоцефали, виконаного Рудольфі в 1819 році. Сто чотири види гельмінтів було відзначено у близько 130 опублікованих працях. До 1900 року було зареєстровано менше ніж 10 видів, переважно досить великих. Із 1960-х років таксономічні зусилля дослідників гельмінтів кефалей швидко зростали, сягнувши найвищого рівня в першій декаді XXI століття (описано 13 нових видів). Але за останнє десятиріччя було виявлено та описано лише один новий вид гельмінтів від кефалей. Ми припускаємо, що зменшення кількості описаних видів, що спостерігалося протягом останнього десятиріччя, є наслідком попередніх інтенсивних таксономічних зусиль. Імовірно, це призвело до фактичної оцінки різноманітності видів для досліджуваної території. У структурі гельмінтофауни переважають дигенеї і специфічні паразити. Найбагатше різноманіття гельмінтів виявлено в Азово-Чорноморських кефалей, тоді як найбідніше – у східному Середземномор'ї. Порівняно велика кількість видів (20), визначених до родового або родинного рівня, залишають перспективи для подальших таксономічних досліджень гельмінтів кефалей.

Introduction

Helminths represent one of the most diverse group of fish parasites. Many species are dangerous pathogens of epidemic potential, that may cause serious damage in both wild and farmed animals[1,2]. Taxonomic and faunistic studies are the first step in ecological and epidemiological investigations and are important for discovering and documenting species diversity, their geographic distribution, host specificity and pathogenicity.

The present study focuses on a variety and number of helminth parasites from grey mullets (Mugilidae) in the Mediterranean and Azov-Black Seas. Mullets are of great economic importance[3], supplying food and recreation services. The demand for mullet roe has grown considerably in recent decades elevated the status of grey mullets to be being called «grey gold»[4,5]. This review covers helminth parasites of six species from three genera of the Mugilidae family: flathead mullet *Mugil cephalus*, thicklip mullet *Chelon labrosus*, golden grey mullet *Chelon auratus*, thinlip mullet *Chelon ramado*, leaping mullet *Chelon saliens* and so-iuy mullet, also known as haarder or red-lip mullet, *Planiliza haematocheila*[6]. *Oedalechilus labeo* (Cuvier, 1829) also occurs in the Mediterranean[6], but only one reference reports two species of flatworms from this host[7]. *P. haematocheila* was deliberately introduced in the Black and the Azov Seas. The main goal of the introduction was seeking ways to increase the fishing capacity of natural water reservoirs and to use abundant and underutilized amount of detritus[8]. The fish translocation with subsequent induced breeding and fry release in the 1970s-1980s resulted in the establishment of a self-reproducing population of the so-iuy mullet in the new distribution range[9]. The so-iuy mullet has been officially subject to commercial fishing in Ukraine since 1993[10]. This fish is one of the most important and common commercial fish, which is dominant in catch composition, and effectively replacing the depleted stocks of local mullets[9,11].

The history of the helminth parasites from grey mullets goes back to over 200 years ago to the first species described[12]. The first review of the parasitic species recorded from worldwide mullets was provided by Paperna and Overstreet in 1981[2]. More recently, Radujković and co-authors[7,13–16], and Dmitrieva and Gaevskaya[17] reviewed the parasite species list of grey mullets from the Adriatic and the Azov-Black Seas, respectively. A review of microparasites, also including viral, prokaryotic, and fungal pathogens, of mullets worldwide was performed by Ovcharenko[18]. Thus, a review of helminth parasites of grey mullets at the large geographic scale of the Mediterranean region is needed to analyse the literature available, compile a species list, examine the structure of the helminth fauna and evaluate further perspectives. The present work is specifically designed to cater for these objectives.

History of taxonomic and faunistic studies of helminth parasites from grey mullet fish in the Mediterranean and Azov-Black Seas

It is likely that the first record of parasites from a grey mullet host was published by Rudolphi[12] in 1819. Rudolphi's monograph includes a description of *Neoechinorhynchus* *agilis* (as *Echinorhynchus agilis*) from the Mediterranean flathead grey mullet. Since this first description, this acanthocephalan species has been recorded in numerous marine and freshwater locations in the Northern Hemisphere and from a broad range of host species[15,17,19–24]. The first description of a digenean *Haplosplanchnus pachysomus* (as *Distoma pachysoma*), one of the largest metazoan species reported from *C. auratus* (as *Mugil auratus*), was done by Eysenhardt[25] in the early 19th century. One species of intestinal digenean, *Haploporus benedenii* (Stossich, 1887) (as *Distomum benedeni*) and three species of ectoparasitic monogeneans, *Solostamenides mugilis* (Vogt, 1878) (as *Microcotyle mugilis*), *Ligophorus vanbenedenii* (Parona and Perugia, 1890) (as *Tetraonchus vanbenedenii*) and *Benedenia monticellii* (Parona and Perugia, 1895) (as *Phylline monticellii*) were described in the late 19th century[26–28]. The scarce information gained in 19th century indicate that parasites of grey mullets were studied sporadically at that time (fig.1).

In the early 20th century, Looss published two papers with description of eight new intestinal digenean species from grey mullets off the coast of Trieste[29] and Egypt[30]. Looss[29] erected four new genera (*Haploporus*, *Dicrogaster*, *Saccocoelium* and *Lecithobothris*) to allocate digeneans from Mediterranean mullets, which were later assigned to Haploporidae Nicoll, 1914[31]. The extent of intra- and interspecific variation in species from these four genera is virtually unknown, since most species within the genus are known only from their original descriptions. Although the Mediterranean forms of *Haploporus*, *Dicrogaster*, *Saccocoelium* and *Lecithobothris*, are the most widely reported species, there are few documented reports providing data on their morphology[32–34]. Therefore, a taxonomic review of Haploporidae was needed and this huge work has been recently done by Blasco-Costa and co-authors[32–35]. These author reviewed *Haploporus*, *Dicrogaster*, *Saccocoelium*, *Lecithobothris* and *Forticulcita* Overstreet, 1982, erected a new genus, *Ragaia* Blasco-Costa, Montero, Gibson, Balbuena & Aneta Kostadinova, 2009, and described six new species of haploporid digeneans.

The first record of helminth parasites from the Black Sea mullets was published by Wlassenko[36]. In this work, Wlassenko registered undetected monogenean species *Dactylogyrus* sp. and three digeneans, including *S. tensum* Looss 1902, *H. pachysomus* and a new species of *Haploporus*, *Haploporus longicolum (Vlassenko, 1931).* Skrjabin[37] erected *Wlassenkotrema* Skrjabin, 1956 to allocate the latter species. Yamaguti[38] treated *Wlassenkotrema* as a junior synonym of *Haploporus*, while Overstreet and Curran[39] considered *W. longicolum* as a synonym of *S. obesum* Looss 1902. Osmanov[40], Chernyshenko[41], Butskaya[42] and Pogoreltseva[43] studied parasite fauna of the Black Sea fish, including grey mullets, extending the list of parasite fauna to eight species. The subsequent publication of Reshetnikova[44] merits special attention. This work provided an analysis of faunal, as well as regional, age and seasonal dynamics of infection parameters of parasites from three grey mullet hosts across different localities in the Azov-Black Seas. Thirteen, 15 and 11 species were reported from *M. cephalus*, *C. auratus* and *C. saliens*, respectively. Based on the patterns of seasonal and age dynamics practical recommendations were given for the optimal age for introduction of grey mullets in estuaries for aquaculture exploitation[44]. Thus, studies of the Black Sea grey mullet parasites in the first half of the 20th century were mostly carried out at the Caradag Biological Station, Kurortne, Crimea, Ukraine, but with Department of Ecological Parasitology, O. O. Kovalevsky Institute of Biology of the Southern Seas, Sevastopol, Ukraine in the second half of the 20th century and up to the present time.The team of the Department of Ecological Parasitology together with the Odessa and Karadag branches published over 25 papers devoted to the parasite fauna[17,45–63], taxonomy[53,56,60,64–70], ecology[70,71] and pathogens[72] of grey mullets of the Azov-Black Seas. Researchers of the Sevastopol's team described two monogenean species from grey mullets, *Ligophorus euzeti* Dmitrieva and Gerasev, 1996, and

Polyclithrum ponticum Gerasev, Dmitrieva and Gaevskaya, 2002[53,66]. Recently, a number of monographs published by Gaevskaya[73–75] were devoted to studies of fish parasites and pathogens from the Azov-Black Seas, including parasites of grey mullets. The Black Sea mullets have also been studied along the Bulgarian[76,77] and Turkish[78–80] coastal waters. These studies report new faunistic records of parasites.

Coming back to the Mediterranean, some studies of Euzet and co-authors devoted to monogenean parasites of grey mullets were published in the second half of the 20th century[81–83]. Euzet and Suriano[82] erected *Ligophorus* within the Ancyrocephalidae (Monogenea), and included 11 species parasitizing the gills of grey mullets: *L. vanbenedenii* (Parona and Perugia, 1890); *L. szidati* Euzet and Suriano, 1977; *L. mugilinus* (Hargis, 1955); *L. chabaudi* Euzet and Suriano, 1977; *L. macrocolpos* Euzet and Suriano, 1977; *L. acuminatus* Euzet and Suriano, 1977; *L. minimus* Euzet and Suriano, 1977; *L. heteronchus* Euzet and Suriano, 1977; *L. angustus* Euzet and Suriano, 1977; *L. imitans* Euzet and Suriano, 1977 and *L. confusus* Euzet and Suriano, 1977. Subsequently Euzet and Sanfilippo[83] added one new species to the genus, *L. parvicirrus* Euzet and Sanfilippo 1983. Since the erection of *Ligophorus*, about 60 new species have been described infecting worldwide mullets. The taxonomic revision of the Atlantic and the Pacific of *Ligophorus* has been performed by Sarabeev et al.[84] Thirty-five nominal species of *Ligophorus* known from the Atlantic and the Pacific waters were covered in this review. Thirty of them, were considered valid, one incertae sedis, one species inquirendae, two junior synonyms and one was transferred to another genus.

The Atlantic and Mediterranean grey mullets, *C. labrosus* and *C. ramado*, also harbour another genus of Dactylogyridae, *Ergenstrema* Paperna, 1964, whose members co-occur on gills with species of *Ligophorus*. This genus includes only two species, *Ergenstrema mugilis* Paperna, 1964 and *E. labrosi* Anderson, 1981 from *C. ramado* and *C. labrosus*, respectively[85,86].

Overstreet[87] reviewed the taxonomy of *Saturnius* Manter, 1969, a small hemiurid genus of stomach parasites specific to grey mullets, and described *Saturnius papernai* Overstreet, 1977 from *Mugil cephalus* in Bardawil Lagoon, Eastern Mediterranean. This species has been subsequently reported elsewhere in the Mediterranean basin[17,20,22,56,76,88–90]. Dimitrov[76] provided a redescription of *S. papernai* from the Bulgarian coast of the Black Sea. Two new species of *Saturnius* (*S. minutus* Blasco-Costa, Pankov, Gibson, Balbuena, Raga, Sarabeev & Kostadinova, 2006 and *Saturnius dimitrovi* Blasco-Costa, Pankov, Gibson, Balbuena, Raga, Sarabeev & Kostadinova, 2006) were described from the Western Mediterranean that raised the number of species of the genus up to three in this region[91]. A new genus and species of hemiurid digenean (*Robinia aurata* Pankov, Webster, Blasco-Costa, Gibson, Littlewood Balbuena, Kostadinova, 2006) was proposed[92].

There are several taxonomic and faunistic studies providing information on mullet parasites from the Mediterranean and the Adriatic Sea off Italy[20,22,93–101] and Montenegro[7,13,14,16,102]. Two new species on nematode and acanthocephalan parasites, *Cucullanus bioccai* Orecchia and Paggi, 1987 and *Acanthogyrus (Acanthosentis) lizae* (Orecchia, Paggi, Radujkovic, 1988) Amin, 2005, were described from *M. cephalus* and *C. auratus*, respectively in the Adriatic[95,102].

Paperna and co-authors published a set of papers on helminth parasites from the Eastern Mediterranean grey mullets (Israel and Egypt)[2,86,103,104]. Abu Samak[105–107] reported three species of *Ligophorus* from *C. ramada* in the Mediterranean coastal waters of Egypt. There are also a few papers with helminths records from the Marmara Sea and Turkish Mediterranean[108–110].

First reports of parasites from the introduced population of *P. haematocheila* in the Azov Sea appeared in papers of Sabodash and Semenenko[111,112]. These authors recorded five parasite species in so-iuy mullets from the Molochny Estuary. Maltsev and co-authors studied parasites of the migrated population of *P. haematocheila* through the

Kerch Chanel[113–115]. Their taxonomic works were predominantly focused on monogeneans from the so-iuy mullet. Maltsev and Miroshnichenko[114,115] redescribed *Gyrodactylus mugili* Zhukov, 1970, *G. zhukovi* Ling 1962 and *G. anguillae* Ergens, 1960 and description of a new species *Ligophorus gussevi* Maltsev and Miroshnichenko, 2004 across different localities in the Azov Sea. However, based on comparative analysis of shape and measurements of sclerotized characters of worms from the so-iuy mullet *L. gussevi* was considered as the junior synonym of *Ligophorus pilengas* Sarabeev and Balbuena, 2004[116].

Sarabeev and co-authors studied the parasite fauna of *P. haematocheila* and local fish species across localities in the north-western Azov Sea. Sixty-three species of parasites were recorded in the fish studied[88,117–122]. Two new species were described from the so-iuy mullet in the Azov Sea, digenean *Bunocotyle constrictus* Domnich and Sarabeev, 1999 and monogenean *L. pilengas*. The former species was later considered as the junior synonym of *S. papernai*[90]. In addition, two species of *Ligophorus*, *L cephali* Rubtsova, Balbuena, Sarabeev, Blasco-Costa & Euzet, 2006 and *L. mediterraneus* Sarabeev, Balbuena & Euzet, 2005, were described from the Mediterranean and Azov-Black Seas flathead mullet[123,124]. The taxonomic status of *N. agilis* from grey mullets (Mugilidae) across localities in the North-east Atlantic and the North-west Pacific areas was reviewed by Tkach et al.[125]. This review based on morphological features of acanthocephalans showed that there are three different species of *Neoechinorhynchus* occurring in grey mullet, two of those were recorded in the Atlantic (*Neoechinorhynchus* (*Neoechinorhynchus*) *agilis* and *Neoechinorhynchus* (*Hebesoma*) *personatus* Tkach, Sarabeev et Shvetsova, 2014) and one in the Pacific waters (*Neoechinorhynchus* (*Hebesoma*) *yamagutii* Tkach, Sarabeev et Shvetsova, 2014). Molecular analysis performed on 18S rRNA partial gene sequences has confirmed the species status of *N. personatus* and *N. yamagutii*[126].

Míguez-Lozano et al.[127] provided a detailed description of the helminth communities of *C. auratus* in the Spanish Mediterranean and analysed the role of spatial, temporal, and host variables in shaping the infracommunities. The spatial structure of helminth infracommunities has been found to be determined by a combination of differences in local environmental conditions and the transmission ability of each helminth species along spatial and temporal scales[127]. A quantitative complex analysis of helminth species richness of invasive so-iuy mullet across different native and introduced populations was performed by Sarabeev[128]. This study showed that the helminth diversity was apparently higher in the introduced population of *P. haematocheila* than in those of their native habitat, but this trend was not confirmed when the sampling efforts were controlled for.

The cumulative number of helminth species described in grey mullets is presented in Figure 1. Fewer than 10 species, predominantly large ones, were recorded prior to 1900. After 1900, the three waves of species description are remarkable in the history of taxonomic studies of helminth parasites. Those are related with papers of Looss[30,129], Euzet and Suriano[82] and Blasco-Costa et al.[32–35,91,92,130–132], Sarabeev and co-authors[122–124]. An increase in the number of authors suggests that taxonomic effort has increased since the 1960s reaching the highest number of species described (13) in the first decade of the 21st century, w hile only one new species was found in the last decade. Since the number of species is limited for any community[133], we suggest that the decrease in the number of described species observed for the last decade is the consequence of previous intensive taxonomic efforts probably resulted in actual estimation of species richness for the studied area.

Although taxonomic and faunistic studies of helminth parasites from grey mullets have a long history originating from Rudolphi's work in 1819[12] and were frequent enough (counting up to 130 references), they could not be considered as completed. There are two reasons for this. First, regardless of whether the cause is anthropogenic or natural, the environment is changing mostly due to climate change, pollution and introduction of alien species[134,135].

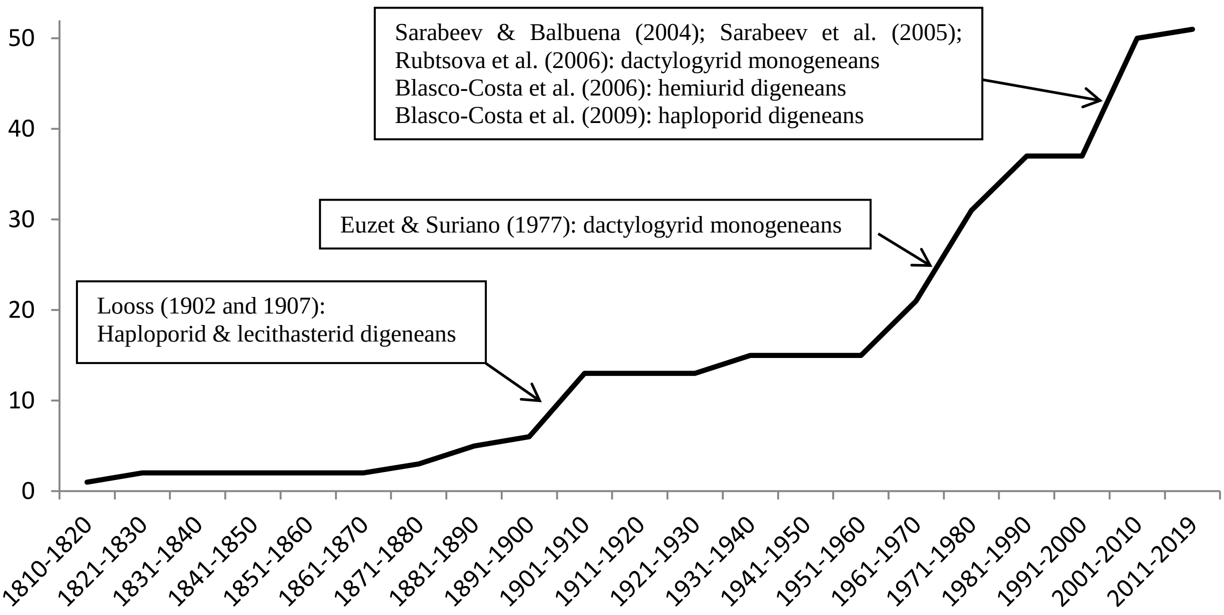

Fig. 1. Cumulative number of helminth species described from grey mullets per decade since 1819.

Environmental change affects species diversity of aquatic and terrestrial ecosystems resulting in the extinction of species or loss of populations from a particular region, and expansion of invasive or introduced species to new areas[134,135]. Since every fish species usually harbors a number of species, it is no surprising that co-introduced parasites commonly make the trip with their invasive host. The Pacific so-iuy mullet introduced in the Azov-Black Seas provides one example of this. Six helminth species of this invasive host have also invaded the new areas[128] (Appendix A). In this context, the Lessepsian migration of grey mullets increases the probability of alien helminth species introduced from the Red Sea to the Mediterranean[136]. For instance, *Forticulcita glabra* and *Saccocoelium gohari* reported in Eastern Mediterranean localities obviously have a Red Sea origin. Second, application of modern tools and techniques, such as transmission and scanning electron microscopy, molecular and population approaches provides new possibilities for the discovery of new species. The description of two species of mixosporidians of the genus *Kudoa* from Mediterranean grey mullets[137,138] is a good example of such research achievement.

Structure of helminth communities from grey mullets in the Mediterranean

Altogether 104 species of helminth parasites from 53 genera and 29 families have so far been reported in Mediterranean grey mullets; of these, 17 and 3 have been identified to generic and family levels only (Appendix A).

Digeneans represent the most diverse group of helminths in these hosts (53%) accounting for 29 (28%) and 26 (25%) species at the adult and larval stages, followed by monogeneans, nematodes, acanthocephalans and cestodes (29 (28%), 12 (11%), 6(6%) and 2(2%) species, respectively) (fig. 2). Specialist parasites accounted for a considerable portion of the parasite communities, including both oioxenic 25 (24%) and stenoxenic 27 (26%) species, vs. 47 (45%) species of generalists; specificity could not be determined for 5 (5%) species. The digestive tract harboured the highest helminth species richness (38 species, 36%). There is almost equal number of species occurring on gills, the external surface of the body (29 species, 28%) and in the body cavity, internal organs and tissues (31 species, 30%).

The number of parasite species reported is unequal in the four Mediterranean geographic areas considered (table 1). The highest number of species was found in the Azov-Black Seas, followed by the Western, Eastern and Central Mediterranean areas. We tend to associate the richest fauna of helminth parasites revealed from the Azov-Black Seas region with the intensity of research efforts. Since the first report of flatworms by Wlassenko[36] in 1931, the studies of grey mullet parasites has been quite intensive amounting to over 60 papers.

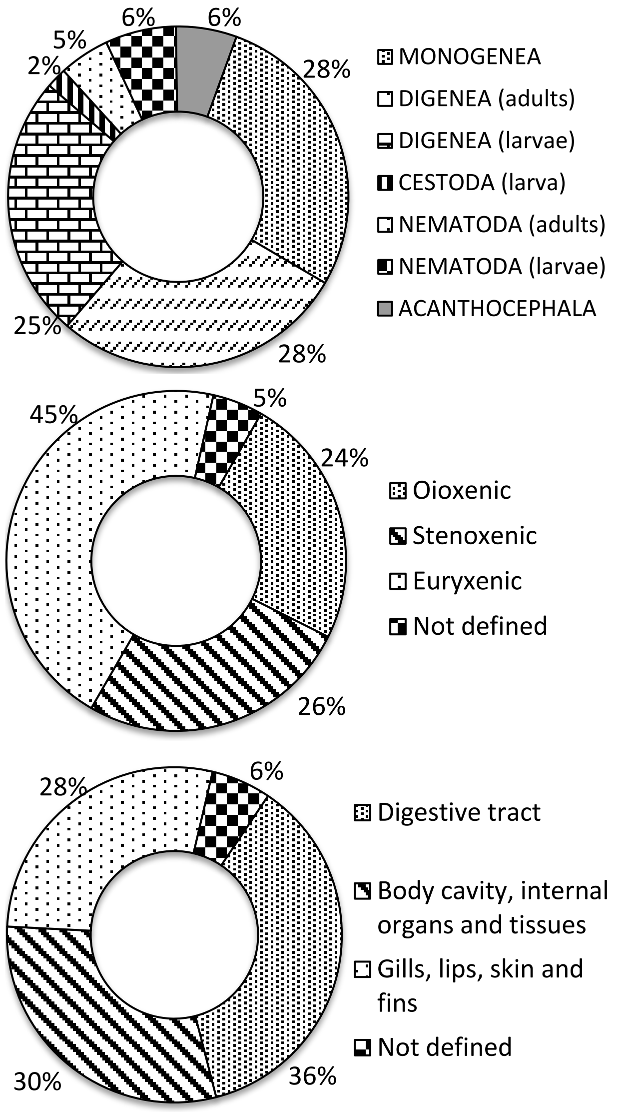

Fig. 2. Structure of the helminth fauna of grey mullets in the Mediterranean region: A – higher-level taxonomic groups and stages, B – host specificity, C – infection site.

Currently, four research teams are active in the Azov-Black Sea, including the Sinop University, Sinop, Turkey; the Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences, Sofia, Bulgaria; the Institute of Biology of the Southern Seas O. O. Kovalevskoho, the National Academy of Sciences of Ukraine, Sevastopol, Crimea; and the Zaporizhzhia National University, Zaporizhzhia, Ukraine. In contrast, only about 10 papers have reported helminths in the Eastern Mediterranean area across marine localities of Egypt, Israel and Turkey. Similarly, since 1949 fourteen papers were published to discover helminth assemblages of Central Mediterranean region providing data for parasites of the Adriatic Sea and Italian coastal waters (see the previous section).

One interesting finding of the present study is that each geographic region is characterized by a specific set of euryxenic parasites. In contrast to oioxenic and stenoxenic helminths, some of which have been reported in all four areas, euryxenic parasites predominantly known for one or maximum two regions (Appendix A). The exception from this pattern is *Ascocotyle longa* metacercaria, which were registered in the Western, Eastern Mediterranean and Azov-Black Seas. This finding opens new possibilities to use helminth parasites as bioindicators of fish catches and the stock location.

Table 1 – Number of helminth species reported from different parts of the Mediterranean region: WM – Western Mediterranean; CM – Central Mediterranean; EM – Eastern Mediterranean; AZ-BL – Azov-Black Seas

Taxon	WM	CM	EM	AZ-BL
MONOGENEA	17	17	10	20
DIGENEA (adults)	19	10	13	19
DIGENEA (larvae)	7	1	7	14
CESTODA (larva)	0	0	1	2
NEMATODA (adults)	1	2	2	3
NEMATODA (larvae)	1	1	1	6
ACANTHOCEPHALA	3	3	2	5
Total	48	34	36	69

Conclusions

As a result of all of these, the current list of helminth species recorded from the Azov-Blck Seas and the Western Mediterranean grey mullets is likely well defined. Marked advances have been made in recent decades, but progress in understanding the helminth fauna, particularly from the Eastern and Central Mediterranean regions, will continue to be restricted by the lack of competent taxonomists specialised in specific groups of helminth parasites and the lack of routing monitoring and appropriate samples. Nevertheless, it is evident from our current knowledge that the helminths form a very diverse group of parasites in the grey mullets accounting at list 103 species in the Mediterranean and Azov-Black Seas. A relatively large amount of species (20) identified at generic or family level remains the opportunity for further taxonomic studies. The Eastern Mediterranean remains an intriguing area for the further faunistic research. There are limited studies on parasites from grey mullets in this region and the Lessepsian migration of fish increases the probability of invasion of new parasite species in the Eastern Mediterranean.

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Appendix A. Helminths species recorded in grey mullets in the Mediterranean with information on host specificity, site of infection and distribution range

Helminth species*	Speci-ficity**	Infection site	Geographic area***
MONOGENEA			
Dactylogyridae Bychowsky, 1933			
1. *Ligophorus acuminatus* Euzet et Suriano, 1977	O	Gills	WM, CM, AZ-BL
2. *Ligophorus angustus* Euzet et Suriano, 1977	O	Gills	WM, CM, EM
3. *Ligophorus cephali* Rubtsova, Balbuena, Sarabeev, Blasco-Costa & Euzet, 2006	O	Gills	WM, AZ-BL
4. *Ligophorus chabaudi* Euzet & Suriano, 1977	O	Gills	WM, CM
5. *Ligophorus confusus* Euzet et Suriano, 1977	O	Gills	WM, CM, EM
6. *Ligophorus heteronchus* Euzet et Suriano, 1977	O	Gills	WM, CM, AZ-BL
7. *Ligophorus imitans* Euzet et Suriano, 1977	O	Gills	WM, CM, EM
8. *Ligophorus kaohsianghsieni* (Gussev, 1962) ^{CO}	O	Gills	AZ-BL
9. *Ligophorus llewellyni* Dmitrieva, Gerasev & Pron'kina, 2007 ^{CO}	O	Gills	AZ-BL
10. *Ligophorus macrocolpos* Euzet et Suriano, 1977	O	Gills	WM, CM, AZ-BL
11. *Ligophorus mediterraneus* Sarabeev, Balbuena & Euzet, 2005	O	Gills	WM, CM, AZ-BL
12. *Ligophorus minimus* Euzet et Suriano, 1977	O	Gills	WM, CM, AZ-BL
13. *Ligophorus parvicirrus* Euzet et Sanfilippo, 1983	O	Gills	WM, CM, EM
14. *Ligophorus pilengas* Sarabeev et Balbuena, 2004 ^{CO}	O	Gills	AZ-BL
15. *Ligophorus szidati* Euzet et Suriano, 1977	O	Gills	WM, CM, EM, AZ-BL
16. *Ligophorus vanbenedenii* (Parona & Perugia, 1890)	O	Gills	WM, CM, EM, AZ-BL
17. *Ergenstrema labrosi* Anderson 1981	O	Gills	WM, CM
18. *Ergenstrema mugilis* Paperna, 1964	O	Gills	WM, CM, EM
Gyrodactylidae van Beneden & Hesse, 1863			
19. *Gyrodactylus mugili* Zhukov, 1970 ^{CO}	O	Gills, skin, fins	AZ-BL
20. *G. zhukovi* Ling, 1962 ^{CO}	O	Gills, skin, fins	AZ-BL
21. *Gyrodactylus anguillae* Ergens, 1960	N	Gills	AZ-BL
22. *G. alviga* Dmitrieva & Gerasev, 2000	E	Gills	AZ-BL
23. *Polyclithrum mugilini Rogers, 1967*	O	Gills	AZ-BL
24. *Polyclithrum ponticum* Gerasev, Dmitrieva & Gaevskaya, 2002	O	Gills	AZ-BL
Microcotylidae Taschenberg, 1879			
25. *Metamicrocotyla cephalus* (Azim, 1939)	S	Gills	WM, CM, EM
26. *Solostamenides mugilis* (Vogt, 1878)	S	Gills	WM, CM, EM, AZ-BL
27. *Solostamenides* sp. 1 ^{CO}	S	Gills	AZ-BL
28. *Solostamenides* sp. 2	N	Gills	AZ-BL
Capsalidae Baird, 1873			
29. *Benedenia monticelii* (Parona et Perugia, 1895)	S	Gills, lips, skin	CM, EM
DIGENEA (adults)			
Haploporidae Nicoll, 1914			
30. *Dicrogaster contracta* Looss, 1902	S	Intestine	WM, CM, EM, AZ-BL
31. *Dicrogaster perpusilla* Looss, 1902	S	Intestine	WM, CM, EM
32. *Forticulcita gibsoni* Blasco-Costa, Montero, Balbuena, Raga & Kostadinova, 2009	S	Intestine	WM
33. *Forticulcita glabra* Overstreet, 1982	S	Intestine	EM
34. *Haploporus benedenii* (Stossich, 1887)	S	Intestine	WM, CM, EM, AZ-BL
35. *Lecithobotrys putrescens* Looss, 1902	S	Intestine	WM, CM, EM, AZ-BL
36. *Ragaia lizae* Blasco-Costa, Montero, Gibson, Balbuena, Kostadinova, 2009	O	Intestine	WM
37. *Saccocoelium brayi* Blasco-Costa, Balbuena, Raga,	S	Pyloric caeca	WM

Helminth species*	Speci-ficity**	Infection site	Geographic area***
Kostadinova & Olson, 2009			
38. *Saccocoelium cephali* Blasco-Costa, Montero, Gibson, Balbuena, Raga & Kostadinova, 2009	S	Intestine	WM, AZ-BL
39. *Saccocoelium currani* Blasco-Costa, Montero, Gibson, Balbuena, Raga & Kostadinova, 2009	S	Intestine	WM
40. *Saccocoelium gohari* Ramadan, Saoud, Ashour & Mansour, 1989	S	Intestine	EM
41. *Saccocoelium obesum* Looss, 1902	S	Intestine	WM, CM, EM, AZ-BL
42. *Saccocoelium tensum* Looss, 1902	S	Intestine	WM, CM, EM, AZ-BL
Haplosplanchnidae Poche, 1926			
43. *Haplosplanchnus pachysomus* (Eysenhardt, 1829)	S	Intestine	WM, CM, EM, AZ-BL
44. *Schikhobalotrema sparisoma* (Manter, 1937)	S	Intestine	WM, AZ-BL
45. *Schikhobalotrema* sp.	N	Intestine	CM, EM
Hemiuridae Looss, 1899			
46. *Bunocotyle cingulata* Odhner, 1928	E	Intestine	AZ-BL
47. *Aphanurus stossichii* (Monticelli, 1891)	E	Oesophagus, stomach	AZ-BL
48. *Hemiurus appendiculatus* (Rudolphi, 1802)	E	Stomach, intestine	CM, AZ-BL
49. *Robinia aurata* Pankov, Webster, Blasco-Costa, Gibson, Littlewood Balbuena, Kostadinova, 2006	S	Stomach	WM
50. *Saturnius minutus* Blasco-Costa, Pankov, Gibson, Balbuena, Raga, Sarabeev & Kostadinova, 2006	S	Stomach	WM, AZ-BL
51. *Saturnius papernai* Overstreet, 1977	S	Stomach	WM, EM, AZ-BL
52. *Saturnius dimitrovi* Blasco-Costa, Pankov, Gibson, Balbuena, Raga, Sarabeev & Kostadinova, 2006	S	Stomach	WM, AZ-BL
53. *Saturnius* sp.	N	Stomach	AZ-BL
Lecithasteridae Odhner, 1905			
54. *Aponurus tschugunovi* Issatschikov, 1928	E	Intestine	AZ-BL
55. *Lecithaster confusus* Odhner, 1905	S	Intestine	WM, CM, EM, AZ-BL
56. *Lecithaster galeatus* Looss, 1907	S	Intestine	EM, AZ-BL
Aporocotylidae Odhner, 1912			
57. *Cardicola mugilis* Yamaguti, 1970	O	Blood vessels of heart and gills	WM
Opecoelidae Ozaki, 1925			
58. *Helicometra fasciata* (Rudolphi, 1819)	E	Intestine	AZ-BL
DIGENEA (larvae)			
Acanthocolpidae Lühe,1906			
59. Acanthocolpidae gen. sp.	E	Muscles	WM
Bucephalidae Poche, 1907			
60. *Rhipidocotyle* sp.	E	Heart, liver, spleen, kidney	WM
61. *Bucephalus minimus* (Stossich, 1887)	E	Heart, liver, spleen	WM
62. *Bucephalus* sp.	E	N	EM
Diplostomidae Poirier, 1886			
63. *Diplostomum spathaceum* (Rudolphi, 1819)	E	Eye lenses	AZ-BL
64. *Diplostomum* spp.	E	Eye lenses	AZ-BL
65. *Posthodiplostomum brevicaudatum* (Nordmann, 1832)	E	Eyes	AZ-BL
66. *Tylodelphys clavata* (Nordmann, 1832)	E	Vitreous humor of eye	AZ-BL
Echinostomatidae Looss, 1899			
67. *Stephanoprora* sp. (as *Mesorchis* sp.)	E	Gills filaments	AZ-BL
Cryptogonimidae Ward, 1917			
68. *Timoniella imbutiforme* (Molin, 1859)	E	Pharyngeal pad, muscles, eyes,	AZ-BL
Clinostomatidae Lühe, 1901			
69. *Clinostomum* sp. (as *Clinostomum piscidium*)	E	Skin, abdominal cavity	AZ-BL
Heterophyidae Odhner, 1914			

Helminth species*	Speci-ficity**	Infection site	Geographic area***
70. *Ascocotyle coleostoma* (Looss, 1896)	E	Gills	AZ-BL
71. *Ascocotyle longa* Ransom, 1920	E	Pharyngeal pad, muscles, esophagus, intestine, heart, liver, spleen, kidney	WM, EM, AZ-BL
72. *Ascocotyle sinoecum* (Ciurea, 1933)	E	Pharyngeal pad, esophagus, intestine, liver	AZ-BL
73. *Cryptocotyle concavum* (Creplin, 1825)	E	Gills filaments	AZ-BL
74. *Cryptocotyle* sp.	E	N	EM
75. *Galactosomum* sp.	E	Brain	WM
76. *Galactosomum timondavidi* Pearson & Prévot, 1971	E	Brain	WM
77. *Haplorchis* sp.	E	N	EM
78. *Heterophyes aequalis* Looss, 1902	E	Pharyngeal pad, muscles, esophagus, intestine, heart, liver, spleen	EM
79. *Heterophyes dispar* Looss, 1902	E	Pharyngeal pad, muscles, esophagus, intestine, heart, liver, spleen	EM
80. *Heterophyes heterophyes* Siebold, 1852	E	Pharyngeal pad, muscles, esophagus, intestine, heart, liver, spleen	EM, CM
81. *Pygidiopsis genata* Looss, 1907	E	Pharyngeal pad, esophagus, intestine, heart, liver, spleen	AZ-BL
82. *Stictodora sawakinensis* Looss, 1899	E	N	EM
Microphallidae Travassos, 1920			
83. Microphallidae gen. sp.	E	N	AZ-BL
Strigeidae Railliet, 1919			
84. *Cardiocephalus longicollis* (Rudolphi, 1819)	E	Brain	WM, AZ-BL
CESTODA (larva)			
Diphyllobothriidae Lühe, 1910			
85. *Ligula* sp.	E	Abdominal cavity	AZ-BL
Tetraphyllidea			
86. Tetraphyllidea gen.sp.	E	Intestine	EM, AZ-BL
NEMATODA			
Acuariidae Railliet, Henry & Sisoff, 1912 (larvae)			
87. *Paracuaria adunca* (Creplin, 1846)	E	Mesentery	AZ-BL
88. *Cosmocephalus obvelatus* (Creplin, 1825)	E	Abdominal cavity, intestine	AZ-BL
Anisakidae (Railliet & Henry, 1912) (larvae)			
89. *Contracoecum rudolphii* (Hartwich, 1964)	E	Gall bladder	AZ-BL
90. *Contracaecum microcephalum* (Rudolphi, 1809)	E	Abdominal cavity, mesentery	AZ-BL
91. *Contracaecum* sp.	E	Abdominal cavity, mesentery	WM, CM, EM, AZ-BL
92. *Hysterothylacium aduncum* (Rudolphi, 1802)	E	Abdominal cavity, liver, mesentery	AZ-BL
Capillariidae Railliet, 1915			
93. *Capillaria* sp.	E	Digestive tract	CM
94. *Pseudocapillaria tomentosa* (Dujardin, 1843)	E	Intestine	AZ-BL
Cucullanidae Cobbold, 1864			
95. *Cucullanus bioccai* Orecchia & Paggi 1987	S	Intestine	WM, CM, EM
96. *Dichelyne minutus* (Rudolphi, 1819) (larva)	E	N	AZ-BL
Philometridae Baylis & Daubney, 1926			
97. *Philometra tauridica* Ivashkin, Naidenova, Kovaleva &	E	Abdominal cavity	AZ-BL

Helminth species*	Speci-ficity**	Infection site	Geographic area***
Khromova, 1971			
98. *Philometra* sp.	N	Esophagus	EM, AZ-BL
ACANTHOCEPHALA			
Neoechinorhynchidae Ward, 1917			
99. *Floridosentis elongata* Ward, 1953	E	Intestine	AZ-BL
100.*Neoechinorhynchus agilis* (Rudolphi, 1819)	S	Intestine	WM, CM, EM
101.*Neoechinorhynchus personatus* Tkach, Sarabeev & Shvetsova, 2014	S		WM, CM, EM, AZ-BL
Quadrigyridae Van Cleave, 1920			
102.*Acanthogyrus (Acanthosentis) adriaticus* Amin, 2005	O	Intestine	WM, CM, AZ-BL
Illiosentidae Golvan, 1960			
103.*Telosentis exiguus* Von Linstow, 1901	E	Intestine	AZ-BL
Polymorphidae Meyer, 1931 (cystacant)			
104.*Southwellina hispida* (Van Cleave, 1925)	E	Abdominal cavity	AZ-BL

Footnotes: *The species status and taxonomic affinities follow the WoRMS data base (http://www.marinespecies.org/); [CO]co-introduced species of helminth parasites reported in *Planiliza haematocheila* after the host translocation from the Sea of Japan to the Azov-Black Sea;
**Specificity abbreviations: O, oioxenic; S, stenoxenic; E, euryxenic; N, not determined.
***WM: Western Mediterranean; CM: Central Mediterranean; EM: Eastern Mediterranean; AZ-BL: Azov-Black Seas