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ORIGINAL ARTICLE

Digenean parasites in saddled seabream *Oblada melanurus* (Teleostei, Sparidae): first insights from Algerian waters

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Abstract: In an attempt to contribute to the understanding of the biodiversity of Digenea in Algeria, we analysed for the first time the community structure of the digenean fauna of *Oblada melanurus* (Linnaeus, 1758). From June 2022 to July 2023, 172 specimens of *O. melanurus* were sampled from various locations off the Algerian waters and their digestive tracts were examined to collect the digenean parasites. We analysed the community structure by calculating the parasitological parameters. Also, a species accumulation curve (SAC) was generated to evaluate the sampling effort, and the Chi-square test was performed to evaluate the effects of seasonal variation on the prevalence of parasites. We collected 434 Digenea, which belonged to three species: *Lepocreadium album* (Stossich, 1890) Stossich, 1904 (Lepocreadiidae Odhner, 1905); *Magnibursatus bartolii* Kostadinova, Power, Fernandez, Balbuena, Raga & Gibson, 2003 (Derogenidae Nicoll, 1910) and *Macvicaria dubia* (Stossich, 1905) Bartoli, Bray & Gibson, 1989 (Opecoelidae Ozaki, 1925). Our findings include a new geographical record for *M. dubia* and the first report of *L. album* and *M. bartolii* from this particular host in Algeria. *L. album* had the highest prevalence and mean abundance values, while *M. dubia* had the highest mean intensity. According to the Chi-square test, significant differences in prevalence between seasons were observed only for *L. album* and *M. bartolii*. We offered the first insights into the Digenea fauna parasitizing *O. melanurus* in Algeria, enriching the knowledge of digenean biodiversity in Algerian marine fish. Additionally, we shed light on the seasonal variations in the prevalence of these digeneans. This study may serve as a valuable reference for future research on Digenea in other marine species and regions.
Keywords: *Oblada melanurus*; Digenea; community structure; Algerian coast

Sažetak: DVORODNI METILJI U UŠATI *OBLADA MELANURUS* (TELEOSTEI, SPARIDAE): PRVA OPAŽANJA U ALŽIRSKIM VODAMA. S ciljem doprinosa razumijevanju raznolikosti reda Digenea u Alžiru, po prvi put je istražena struktura zajednice dvorodnih metilja u vrsti *Oblada melanurus* (Linnaeus, 1758). U razdoblju od lipnja 2022. do srpnja 2023. godine uzorkovana su 172 primjerka vrste *O. melanurus* s različitih lokacija u alžirskim vodama te su pregledani njihovi probavni traktovi kako bi se prikupili paraziti iz reda Digenea. Struktura zajednice analizirana je pomoću parazitoloških parametara. Generirana je i krivulja akumulacije vrsta (SAC) kako bi se procijenio napor uzorkovanja, a korišten je Hi-kvadrat test za procijenu učinaka sezonskih varijacija na prevalenciju parazita. Sakupljene su 434 jedinke dvorodnih metilja, koje su pripadale trima vrstama: *Lepocreadium album* (Stossich, 1890) Stossich, 1904 (Lepocreadiidae Odhner, 1905); *Magnibursatus bartolii* Kostadinova, Power, Fernandez, Balbuena, Raga & Gibson, 2003 (Derogenidae Nicoll, 1910) i *Macvicaria dubia* (Stossich, 1905) Bartoli, Bray & Gibson, 1989 (Opecoelidae Ozaki, 1925). Naša otkrića uključuju novi geografski zapis za vrstu *M. dubia* i prvi nalaz vrsta *L. album* i *M. bartolii* u ovom domaćinu u Alžiru. Vrsta *L. album* imala je najveću prevalenciju i srednje vrijednosti abundancije, dok je vrsta *M. dubia* imala najveći srednji intenzitet. Prema Hi-kvadrat testu, značajne razlike u prevalenciji između sezona uočene su samo za *L. album* i *M. bartolii*. U radu donosimo prve uvide u faunu dvorodnih metilja koji parazitiraju na ušati *O. melanurus* u Alžiru, proširujući tako znanje o bioraznolikosti ovih parazita u morskim ribama u alžirskim vodama. Dodatno, objasnili smo sezonske varijacije u prevalenciji ovih parazita. Ova studija može poslužiti kao vrijedna referenca za buduća istraživanja reda Digenea u drugim morskim vrstama i regijama.
Ključne riječi: *Oblada melanurus*; Digenea; sastav zajednice; alžirska obala

INTRODUCTION

Digeneans are one of the three major taxa of parasitic Platyhelminthes, along with Cestoda and Monogenea (Paperna and Dzikowski, 2006). They are externally characterized by a sucker surrounding the mouth and an additional ventral sucker, or acetabulum, which is used for attachment to the host surface and for locomotion (Mehlhorn, 2016). Despite their status as the most species-rich group of parasitic worms, their overall diversity has not yet been thoroughly studied (Krupenko *et al.*, 2022). In Algeria, several studies have been conducted to explore the diversity of these flatworms in various marine fish, primarily through parasitological surveys (Marzoug, 2012; Bellal *et al.*, 2016; Benhamou *et al.*, 2017; Bellal *et al.*, 2018; Rima, 2018; Gharbi *et al.*, 2023; Boukadoum

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and Tazerouti, 2024). Recently, a new species, *Macvicaria gibsoni* Rima, Marzoug, Pérez-del-Olmo, Kostadinova, Bouderbala & Georgieva, 2017, was described from Algerian waters by Rima *et al.* (2017) using both morphological and molecular techniques from the sparid *Diplodus vulgaris* (Geoffroy Saint-Hilaire, 1817). However, the Digenea of several fish species remain unexplored, and their diversity is not fully understood.

In this study, we aim to expand the understanding of the Digenea in Algeria. To accomplish this, we selected the saddled bream, *Oblada melanurus* (Linnaeus, 1758), as the focus of our investigation. This fish holds great economic value in the Mediterranean Sea due to its significance in both fisheries and tourism (Gkafas *et al.*, 2013). In Algeria, despite *O. melanurus* being highly regarded among consumers, there is a noticeable lack in our understanding of various aspects related to this sparid, especially its parasites. A few authors have delved into this issue, focusing on parasitic crustaceans (Boualleg *et al.*, 2012). Others, like Kouider El Ouahed-Amine (1998) and Kaouachi (2010), investigated the Monogenea species within its gills. However, other groups such as Protozoa, Myxozoa, Acanthocephala, Digenea, and Nematoda have never been explored in Algeria. Although studies in other regions have investigated Digenea (Akmirza, 2001; Bartoli *et al.*, 2005; Gargouri Ben Abdallah and Maamouri, 2008), Nematoda (Moravec *et al.*, 2008), and Myxozoa (Laamiri, 2017) infesting the saddled seabream, a significant research gap remains regarding these parasite groups locally. Therefore, this research seeks to address this gap by analysing, for the first time, the structure of the Digenea community infesting *O. melanurus* from the Algerian coastal waters. We also sought to ascertain whether seasonal fluctuations affect the prevalence of parasites.

MATERIAL AND METHODS

Host and Digenea collection

This study was carried out from June 2022 to July 2023 (Table 1), during which time a total of 172 dead specimens of *Oblada melanurus* were purchased from local fish markets at nine sites along the Algerian coast (Fig. 1): 25 from Bouharoun (36° 37’ 33.625” N, 2° 39’ 12.444” E), 28 from Algiers (36° 46’ 53.373” N, 3° 3’ 50.684” E), seven from Alger plage (36° 46’ 52.180” N, 3° 13’ 45.644” E), eight from Tamenfoust (36° 48’ 19.962” N, 3° 13’ 47.193 “E), 84 from Boudouaou El Bahri (36° 46’ 38.232” N, 3° 23’ 1.975” E), three from Zemmouri El Bahri (36° 48’ 11.596” N, 3° 33’ 39.165” E), three from Cap Djinat (36° 52’ 36.874” N, 3° 43’ 3.994” E), four from Dellys (36° 54’ 54.512” N, 3° 55’ 0.240” E), and 10 from Annaba (36° 54’ 9.866” N, 7° 46’ 23.772” E). We transported the fish immediately to the laboratory for examination and the digestive tract of each fish was carefully opened and examined for parasites under a stereomicroscope. The weight (in g) and the total length (in cm) of each individual were recorded.

Table 1. Number of *Oblada melanurus* specimens collected by sampling date and location.

Sampling date	Number of specimens	Locations
2022-06-02	6	Algiers
2022-06-05	4	Dellys
2022-06-06	2	Tamenfoust
2022-06-08	7	Bouharoun
2022-06-11	3	Algiers
2022-06-14	1	Boudouaou El Bahri
2022-06-27	7	Boudouaou El Bahri
2022-07-06	3	Zemmouri El Bahri
2022-08-11	3	Annaba
2022-10-17	6	Bouharoun
2023-02-01	4	Algiers
2023-02-13	3	Cap Djinat
2023-02-14	5	Bouharoun
2023-02-15	9	Annaba (7), Alger plage (2)
2023-03-14	5	Alger plage
2023-04-16	3	Algiers
2023-05-02	3	Algiers
2023-05-06	6	Algiers
2023-05-09	1	Algiers
2023-05-10	1	Algiers
2023-05-15	1	Algiers
2023-06-08	8	Boudouaou El Bahri
2023-06-12	6	Tamenfoust
2023-06-13	16	Boudouaou El Bahri
2023-06-14	24	Boudouaou El Bahri
2023-07-06	19	Boudouaou El Bahri
2023-07-16	5	Boudouaou El Bahri
2023-07-23	11	Boudouaou El Bahri

Digenea processing and identification

All collected Digenea were slightly flattened between a slide and coverglass, before being fixed for 2-3 minutes with Bouin-Hollande fixative and then stored in 70% ethanol. Later on, the specimens were stained with boracic carmine for 1-2 minutes, dehydrated through an ethanol series with increasing concentrations (70%, 96%, and 100%), each lasting 10-15 minutes and then cleared in clove oil for about 3 minutes, and embedded in Canada balsam. For the identification of Digenea, we relied on the works of Pérez-del-Olmo *et al.* (2007a), Kostadinova and Gibson (2009), and Antar *et al.* (2015). All the parasites were identified to the species level and counted.

Parasitological parameters of the Digenea community

For each Digenea species, the prevalence (P%), mean abundance (MA), mean intensity (MI) and its

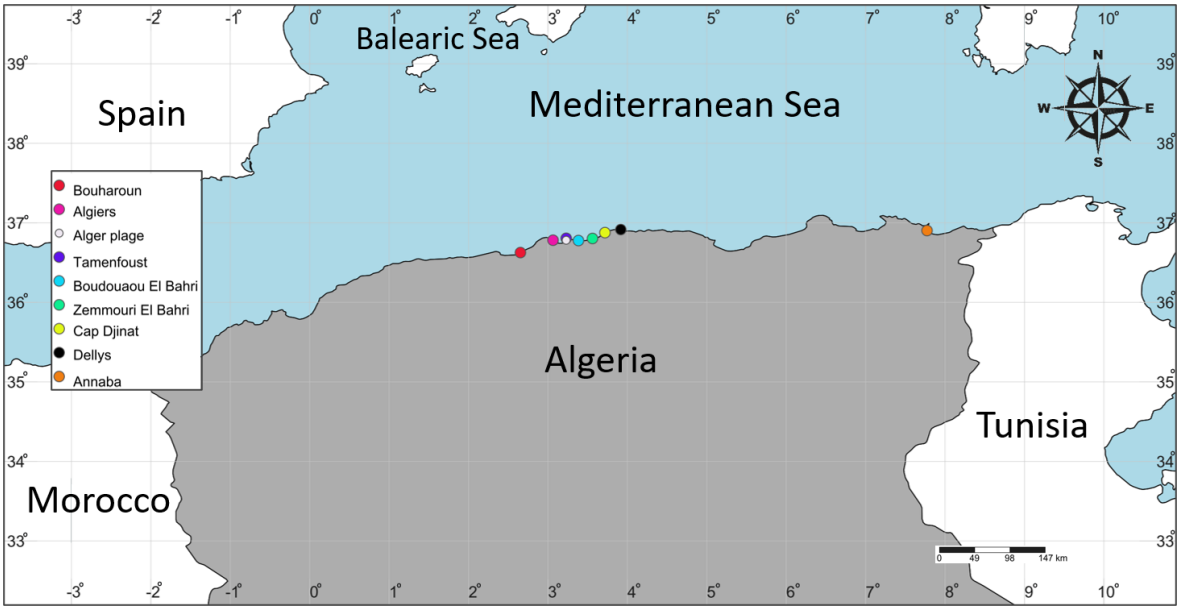

Fig. 1. Collection sites. Created by https://www.simplemappr.net. Accessed September 8, 2024.

range were calculated as determined by Margolis *et al*. (1982) and Bush *et al*. (1997). Prevalences were estimated with 95% confidence intervals (CI), while mean abundance and mean intensity were reported with their corresponding standard deviation (SD) values. We classified the species found based on their prevalences into core (P% ≥ 66.6%), secondary (33.3% < P% < 66.6%), and satellite (P% ≤ 33.3%), following the classification of Bush and Holmes (1986). In terms of the frequency of the infection, it was classified as either common (30% < P% < 50%), frequent (10% < P% < 30%), rare (4% < P% < 10%) or sporadic (P% < 4%), as suggested by Vankara and Chikkam (2015). These parasitological parameters were calculated using Microsoft Excel 2019. In addition, R software version 4.2.2 and the package 'vegan' version 2.6-2 (Oksanen *et al.*, 2022) were employed to generate a species accumulation curve (SAC), a curve assessing the sampling effort.

Statistical analysis

We used the Chi-square (χ^2) test to evaluate differences in parasite prevalence between seasons. All statistical analyses were performed using IBM SPSS Statistics (Version 26) with a significance level set at $p \leq 0.05$.

RESULTS

A total of 434 Digenea specimens were collected, comprising three families: Lepocreadiidae Odhner, 1905, Derogenidae Nicoll, 1910, and Opecoelidae Ozaki, 1925. These families are each represented by one species: *Lepocreadium album* (Stossich, 1890) Stossich, 1904, *Macvicaria dubia* (Stossich, 1905) Bartoli, Bray & Gibson, 1989, and *Magnibursatus bartolii* Kostadinova, Power, Fernandez, Balbuena, Raga & Gibson, 2003 (Fig. 2). Although the primary focus of the study was on Digenea, we also encountered other groups of parasites, such as Nematoda (found in two specimens) and Cestoda (found in one specimen).

The 172 *O. melanurus* specimens used in this study varied in size from 13.0 to 32.1 cm (21.65 ± 3.80 cm) and weighed between 33 and 387.5 g (135.69 ± 74.33 g). Among them, 58 were parasitized, exhibiting an overall prevalence of 33.72%. The parasitological parameters for each Digenea species are presented in Table 2 along with their classification in the community and the frequency of infection. *Lepocreadium album* stands out as the species with the highest prevalence and mean abundance with rates of 22.09% and 1.78, respectively. *M. dubia*, on the other hand, had the highest mean intensity with 8.17 individuals per parasitized host, closely followed by *L. album*. Considering their relatively low prevalence, which is below 33%, these three species are considered satellites. In terms of infection frequency, it appears that *L. album* and *M. bartolii* are the most common, with prevalences ranging from 10% to 30%, while the infection caused by *M. dubia* is sporadic.

The possible species composition within an infested *O. melanurus* is illustrated in Fig. 3. Four fish were found to be parasitized by all three Digenea species simultaneously (6.9%). The remaining fish had either one species (79.31%) or two species (13.79%). The most common occurrence involved a single species, *L. album*, with a prevalence of 46.55%. The lowest prevalence, at 1.72%, involved either *M. dubia* alone or a combination of *M. dubia* and *L. album*.

The total number of hosts examined varied significantly between seasons: six in autumn, 26 in winter, 92 in spring, and 48 in summer (Table 3). Notably, no hosts were parasitized in autumn. In winter, only one out of 26 hosts (3.85%) was parasitized, while in spring, a much

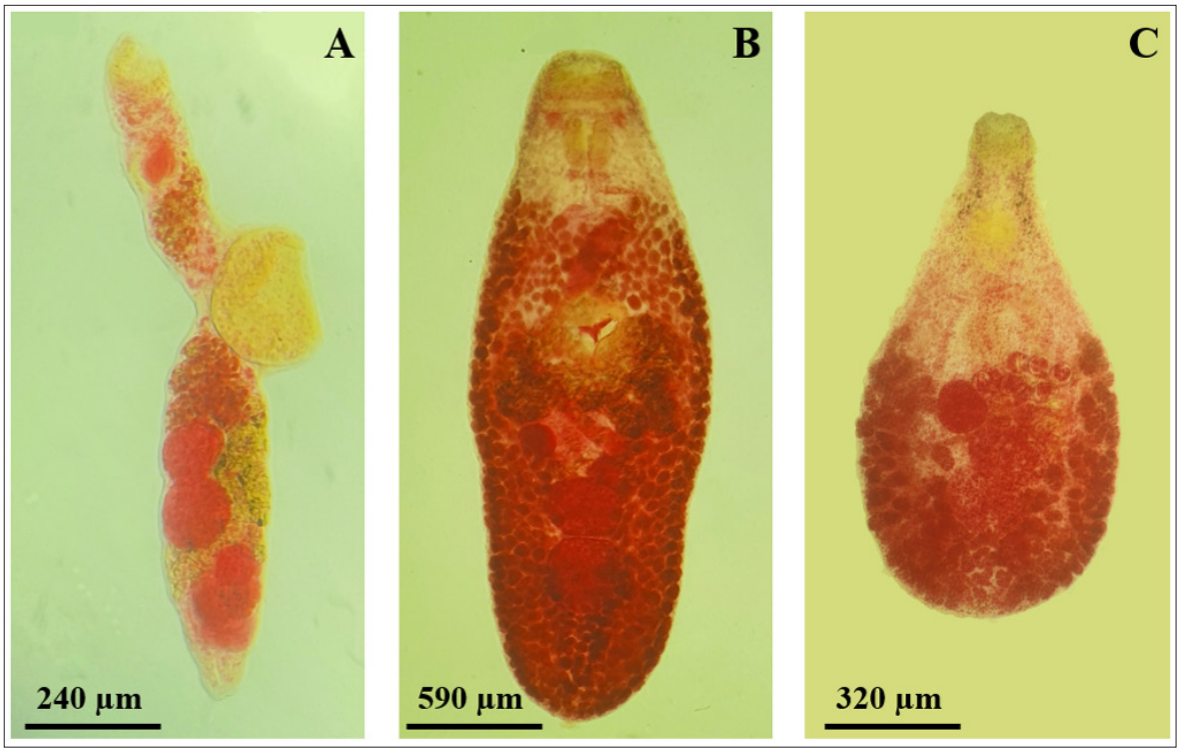

Fig. 2. The Digenea infesting *Oblada melanurus* from the Algerian coastline, *Magnibursatus bartolii* (lateral view) (**A**); *Macvicaria dubia* (ventral view) (**B**); *Lepocreadium album* (ventral view) (**C**).

higher number of hosts (45 out of 92, 48.91%) were parasitized. In summer, 12 out of 48 hosts were parasitized (25%). Regarding the number of parasites, no parasites were detected in autumn. In winter, a single parasite was found. The highest number of parasites (395) was recorded in spring, while summer had a comparatively lower count of 38 parasites.

The parasitological parameters for each digenean species in the different seasons are summarized in Table 4. The data reveal that none of the three parasite species were present in all seasons. *L. album* and *M. bartolii* were found only in spring and summer, while *M. dubia* was detected in winter, spring, and summer.

L. album showed the highest prevalence in spring, and *M. bartolii* was also more common in spring and summer. For these two species, there were significant differences in prevalence between seasons, as indicated by the Chi-square test results (*L. album*: $\chi^2 = 20.248$, $p <$

Table 2. The parasitological parameters of the digenean species from *Oblada melanurus* (n= 172) off the Algerian coast.

Species	Family	Number of infested fish	Number of parasites	Prevalence	Abundance	Intensity	Range of intensity	Frequency of infection	Classification of the species in the community
				% (CI)	mean ± SD	mean ± SD			
Lepocreadium album	Lepocreadiidae	38	307	22.09 (16.13 – 29.04)	1.78 ± 5.67	8.08 ± 9.81	1 - 37	Frequent	Satellite
Magnibursatus bartolii	Derogenidae	30	78	17.44 (12.09 – 23.95)	0.45 ± 1.35	2.60 ± 2.24	1 - 9	Frequent	Satellite
Macvicaria dubia	Opecoelidae	6	49	3.49 (1.29 – 7.44)	0.28 ± 2.55	8.17 ± 12.07	1 - 30	Sporadic	Satellite

CI: confidence intervals at 95% SD: Standard deviation

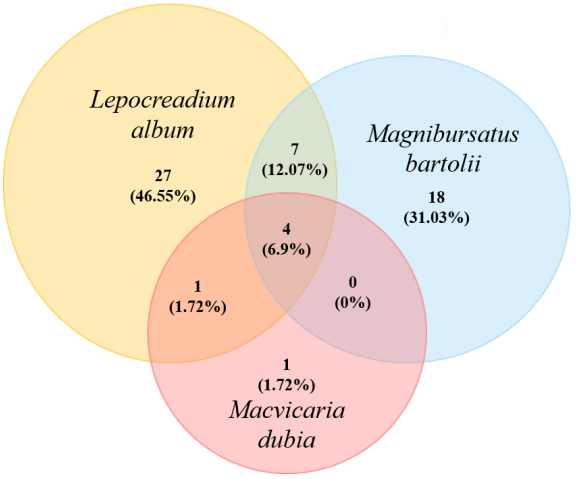

Fig. 3. Species composition of the Digenea community infesting *Oblada melanurus*.

Table 3. Number of hosts examined, hosts parasitized, and parasites found by season.

Seasons	Autumn	Winter	Spring	Summer
Number of hosts examined	6	26	92	48
Number of hosts parasitzed	0	1	45	12
Number of parasites	0	1	395	38

0.001; *M. bartolii*: $\chi^2 = 8.324$, $p = 0.040$). In contrast, *M. dubia* exhibited a lower prevalence compared to the other species, and its prevalence did not significantly differ between seasons ($\chi^2 = 0.710$, $p = 0.871$). Furthermore, species accumulation curve (SAC) is presented in Fig. 4. The curve has reached an asymptotic level, suggesting that the sampling effort was sufficient.

DISCUSSION

During our investigation, we identified three Digenea species in the population of *O. melanurus* that we examined. It is worth noting that among these species, *M. dubia* is a novel parasite in the digenean fauna of Algeria. On the other hand, both *L. album* and *M. bartolii* have been previously documented and collected from various sparid species along the Algerian coastline (Bellal *et al.*, 2016; Benhamou *et al.*, 2017; Bellal *et al.*, 2018; Rima, 2018; Boukadoum and Tazerouti, 2024), but this is their first encounter in *O. melanurus*. Thus, we hereby report for the first time the occurrence of the opecoelid *M. dubia* in the Algerian coastal waters. As for *L. album* and *M. bartolii*, *O. melanurus* is a new host in Algeria**.** The presence of *L. album* and *M. dubia* parasitizing this host has been extensively documented in the Mediterranean Sea, specifically in different regions: in Italy (Stossich, 1904; Stossich, 1905), the Adriatic Sea (Sey, 1970), Greece (Papoutsoglou, 1976), Lebanon (Saad-Fares and Maillard, 1990; Saad-Fares and Combes, 1992a), in Corsica (Sasal *et al.*, 1999; Bartoli *et al.*, 2005), Turkey (Akmirza, 2000; Akmirza, 2001; Öktener, 2005), and along the Tunisian coastline (Gargouri Ben Abdallah and Maamouri, 2008; Antar *et al.*, 2015; Antar and Gargouri, 2018). However, for *M. bartolii*, the current study marks its third occurrence in *O. melanurus* (Gargouri Ben Abdallah and Maamouri, 2008; Antar and Gargouri, 2018) which is understandable, considering that this parasite was discovered in 2003 in *Boops boops* (Linnaeus, 1758) in Atlantic Ocean and there has been limited research on the digenean fauna of *O. melanurus* since then (Kostadinova *et al.*, 2003; Bartoli *et al.*, 2005; Gargouri Ben Abdallah and Maamouri, 2008; Antar and Gargouri, 2018). Based on all available records, *M. dubia* is only found in the Mediterranean region, while *M. barolii* and *L. album* are present in both the Mediterranean Sea and the Atlantic Ocean. Notably, none of these three species have been reported in the Southern Hemisphere. Furthermore, these three parasites have been found to infest not only *O. melanurus* but also other fishes exhibiting either stenoxenous or euryxenous specificity based on the number of host species (Euzet and Combes, 1980; Pojmańska and Niewiadom-

Table 4. Parasitological parameters of the digeneans species by season.

Seasons		Autumn			Winter			Spring			Summer		
Parasitological parameters		**P%**	**MA**	**MI**	**P%**	**MA**	**MI**	**P%**	**MA**	**MI**	**P%**	**MA**	**MI**
Parasites species	***Lepocreadium album*[a]**	0	0	0	0	0	0	34.78	3.16	9.09	12.50	0.33	2.67
	***Magnibursatus bartolii*[b]**	0	0	0	0	0	0	21.74	0.62	2.85	20.83	0.44	2.10
	Macvicaria dubia	0	0	0	3.85	0.04	1	4.35	0.51	11.75	2.08	0.02	1.00

[a] statistically significant difference in prevalence between seasons ($\chi^2 = 20.248$, $p < 0.001$).
[b] statistically significant difference in prevalence between seasons ($\chi^2 = 8.324$, $p = 0.040$).

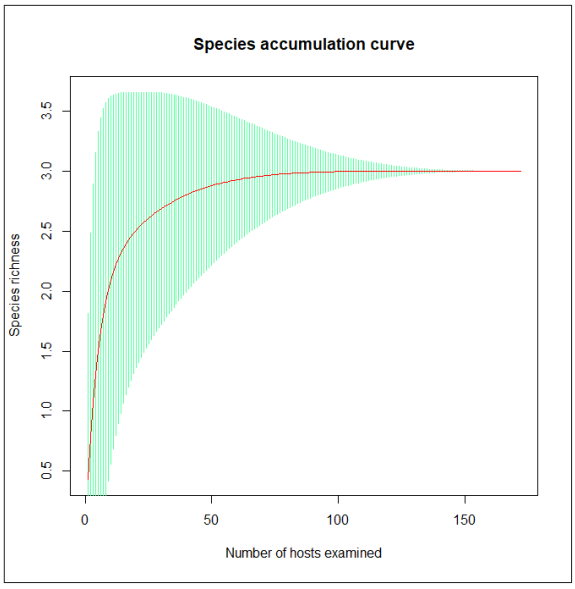

Fig. 4. Species accumulation curve used to evaluate the sampling effort of *Oblada melanurus* (n = 172) from the coast of Algeria and the number of species found.

ska, 2012). *Macvicaria dubia* seems to primarily parasite *O. melanurus*. However, Sasal *et al.* (1999) have also observed cases where *M. dubia* infested another sparid fish, *Spondyliosoma cantharus* (Linnaeus, 1758), indicating a stenoxenous specificity. *Magnibursatus bartolii* exhibits a comparable specificity to the preceding species, *M. dubia,* as it is exclusively registered in sparid hosts from different localities. In the Atlantic Ocean, this Derogenidae has been collected only from *B. boops* (Kostadinova *et al.*, 2003; Pérez-del Olmo *et al.*, 2007b; Pérez-del-Olmo *et al.*, 2011; Pérez-del-Olmo *et al.*, 2022). In the Mediterranean Sea, *M. bartolii* has been found in *B. boops* (Pérez-del Olmo *et al.*, 2008; Pérez-del-Olmo *et al.*, 2011; Marzoug, 2012; Benhamou *et al.*, 2017), *Diplodus sargus* (Linnaeus, 1758) (Bellal *et al.*, 2016), *Sparus aurata* Linnaeus, 1758 (Gargouri Ben Abdallah *et al.*, 2011; Rima, 2018), *Diplodus puntazzo* (Walbaum, 1792) (Sánchez-García *et al.*, 2015), *Spicara maena* (Linnaeus, 1758) (Benhamou *et al.*, 2017), *Diplodus vulgaris* (Rima, 2018), and *Lithognathus mormyrus* (Linnaeus, 1758) (Bellal *et al.*, 2018). As for *L. album*, a broad host range belonging to different families, Sparidae, Blenniidae and Pomacentridae appears to harbour this digenean, displaying an euryxenic specificity (Bartoli, 1987).

In this study, the identification of Digenea was primarily based on morphological characteristics, which remain the cornerstone of digenean systematics (Pérez-Ponce de León and Hernández-Mena, 2019). This approach allowed the description of several new species based on their distinctive features (Machida, 2004; Bayoumy and Abu-Taweel, 2012; Laskowski *et al.*, 2013). However, the importance of molecular techniques cannot be overlooked, as they may be essential for corroborating species delimitation based on morphology and for detecting cryptic species. For example, Bartoli *et al.* (1989) suggested the existence of a species complex within *Macvicaria crassigula* (Linton, 1910) Bartoli, Bray & Gibson, 1989, indicating that what was once considered a single species may actually consist of multiple distinct species. Jousson *et al.* (2000) further confirmed this by using a molecular approach, demonstrating that *M. crassigula* represents a complex of two cryptic species: one restricted to *Diplodus annularis* and the other shared by *D. sargus* and *D. vulgaris*. In 2015, Antar *et al.* (2015) formally described *M. bartolii* Antar, Georgieva, Gargouri & Kostadinova, 2015, a new species infesting *D. annularis* from this complex, using both morphological and molecular techniques. Similarly, Rima *et al.* (2017) later identified another new species within the complex, *M. gibsoni*, further highlighting the hidden diversity that molecular approaches can uncover.

The most prevalent and abundant species in this work was *L. album*, while *M. dubia* had the highest mean intensity value. Comparison of these results with previous studies showed that the prevalence and the mean abundance of *L. album* align with trends reported by Bartoli *et al.* (2005) in Corsica and Antar and Gargouri (2018) in Tunisia. However, in other works in the same localities, *M. dubia* exhibited the highest values in terms of prevalence and mean abundance (Sasal *et al.*, 1999; Gargouri Ben Abdallah and Maamouri, 2008). Regarding the mean intensity, aside from Gargouri Ben Abdallah and Maamouri's findings in 2008 where *M. dubia* showed the highest value, *L. album* seems to consistently demonstrate the highest mean intensity in *O. melanurus*. As mentioned earlier, *M. bartolii* has been harvested only twice from this host in Tunisia and, in both investigations, it displayed values lower than those of *L. album* and *M. dubia* aligning with the results of our work.

The most common presence was caused by one species, in particular *L. album*. This might be the result of interspecific competition. The latter is a common interaction between species that share the same resources or occupy the same space. According to Gilad (2008), competition can manifest in two forms: indirect or direct. Indirect competition arises when one population of a species deprives others of limited resources, while direct competition restricts the access of one population to those resources. These interactions play a significant role in shaping the composition of ecological communities (Neumann and Pinter-Wollman, 2022).

Based on the data collected across different seasons and the Chi-square test, it appears that seasonality influences the prevalence of *L. album* and *M. bartolii*. According to Poulin (2020), parasite infections in aquatic ecosystems often peak during specific seasons. In our study, this peak occurred in spring, which may be related to the number of *O. melanurus* specimens examined during this period (92 specimens) compared to other seasons (autumn: 6; winter: 26; summer: 48). It

is important to note that our sampling was influenced by two key factors: favorable weather conditions for fishing and the availability of the fish. The behavior of *O. melanurus* varies throughout the year, in response to environmental conditions such as food availability (Pallaoro *et al.*, 2003). Speculation exists about its behavior during colder months, suggesting that *O. melanurus* migrates to deeper waters, where temperatures are slightly warmer compared to the surface. However, no studies have yet confirmed these observations. Such behavior could make the fish harder to capture, potentially affecting our sampling efforts and the observed seasonal patterns. Aside from the number of hosts, other factors related to host biology could also explain the observed peak in spring. For instance, increased prevalence of parasites might be linked to the stress associated with reproductive efforts during breeding seasons. The work of Daban *et al*. (2020) indicates that the spawning season of *O. melanurus* extends from May to July, with a peak in June which may further contribute to the observed pattern.

The species accumulation curve gives the expected number of observed species as a function of sampling effort. This curve helps evaluate the effectiveness of sampling efforts and determines the potential benefits of conducting further sampling (Deng *et al.*, 2015). In our study, the curve has reached an asymptotic level, indicating that the sampling effort has been sufficient to collect all the species present in the digestive tract of *O. melanurus*. As a result, further sampling is unlikely to uncover any additional species. Regardless, it appears that *O. melanurus* may host, in addition to *L. album, M. bartolli* and *M. dubia,* eight other digenean species but they have never been collected in the same investigation. Those species are*: Mesometra orbicularis* (Rudolphi, 1819) Lühe, 1901 (Barbagallo and Drago, 1903; Barbagallo and Drago, 1904), *Macvicaria soleae* (Dujardin, 1845) Gibson & Bray, 1982 (Sey, 1970; Radujkovic and Sundic, 2014), *Monorchis monorchis* (Stossich, 1890) Looss, 1902 (Looss, 1902), *Peracreadium idoneum* (Nicoll, 1909) Gibson & Bray, 1982, *Proctoeces lintoni* Siddiqi and Cable, 1960 (Fischthal, 1980; Saad-Fares and Combes, 1992b), *Steringotrema pagelli* (Van Beneden, 1871) Odhner, 1911 (Gijon-Botella and López-Román, 1989), *Diphterostomum brusinae* (Stossich, 1888) Stossich, 1904 (Papoutsoglou, 1976; Lozano *et al.*, 2001), and *Hemiurus communis* Odhner, 1905 (Bartoli *et al.*, 2005; Gargouri Ben Abdallah and Maamouri, 2008).

When we compared the number of species found, i.e. species richness, we found that other studies conducted in Greece (Papoutsoglou, 1976), the Middle East (Fischthal, 1980), Corsica (Bartoli *et al.*, 2005), and Tunisia (Antar and Gargouri, 2018) supported our findings by also collecting three species in the digestive tract of *O. melanurus*. However, investigations carried out in the Canary Islands (Gijon-Botella and López-Román, 1989) and the Iberian Peninsula (Lozano *et al.*, 2001) revealed a lower number of species, specifically one. In another work performed in Tunisia (Gargouri Ben Abdallah and Maamouri, 2008), four species were found, marking the highest recorded species richness to date.

The method selected for examination of the digestive tract can greatly influence the number of species identified. In this study, we examined the digestive tract of each fish under a stereomicroscope to search for Digenea. Employing other techniques, such as gut washes and incubation (Justine *et al.*, 2012; Shamsi and Suthar, 2016), might have uncovered additional Digenea species, potentially revealing a greater diversity of parasites that may have been overlooked during the visual examination.

CONCLUSION

In this paper, we shed light for the first time on the Digenea fauna harbored by *O. melanurus* in Algeria. We identified three Digenea species belonging to three families, with one species (*M. dubia*) reported for the first time in Algeria. This study provides valuable insights into the seasonal variations in the prevalence of digeneans. However, several limitations must be acknowledged. The age of the fish specimens examined may have influenced the observed parasitological patterns, as susceptibility to parasites may vary with age. Furthermore, the sample size varied across seasons, which could affect the generalizability of our results. Future research should aim to include a larger and more diverse sample size, as well as consider the age of fish, to better understand the factors affecting parasite prevalence and to refine the accuracy of the observed seasonal patterns. The absence of local investigations into parasite groups like Myxozoa, Acanthocephala, Nematoda, and Protozoa represents a major research gap, restricting our understanding of their diversity and distribution. To address this, future research should focus on these underexplored groups to broaden our knowledge of Algeria's aquatic parasites.

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