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Digenean parasites in two congeneric sparid fishes and of commercial importance, *Pagellus erythrinus* (Linnaeus, 1758) and *Pagellus acarne* (Risso, 1827), from the western Mediterranean coast of Algeria

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ABSTRACT The investigation into the digenean fauna of two congeneric sparid fishes (Perciformes Sparidae), *Pagellus erythrinus* (Linnaeus, 1758) and *Pagellus acarne* (Risso, 1827), was carried out in the Algerian coasts (Western Mediterranean). These fishes of commercial importance represent an important biological resource for the human population along the Mediterranean coasts. However, the data on their digenean parasites in Algeria are incomplete and the aim of this study is to provide new data on the diversity and species composition of digeneans from these hosts. A total of 240 fishs (120 of each species) were collected from Oran (Northwestern Algeria) during 12 months between September 2016 and August 2017. Eleven species of digeneans were found in the two fish hosts: (i) *Lepocreadium pegorchis* (Lepocreadiidae); *Lepocreadium album* (Lepocreadiidae); *Holorchis pychnoporus* (Lepocreadiidae); *Holorchis spp* (Lepocreadiidae); *Hemiurus comminus* (Hemiuridae); *Hemiurus luehei* (Hemiuridae); *Lepidauchen stenostoma* (Acanthocolpidae) and *Pachycreadium carnosum* (Opecoelidae); *Macvicaria crassigula* (Opecoelidae) in *Pagellus erythrinus*; (ii) *Lepocreadium pegorchis* (Lepocreadiidae); *Macvicaria crassigula* (Opecoelidae); *Zoogonus spp* (Zoogonidae) and *Hemiurus communis* (Hemiuridae) in *Pagellus acarne*. In the evaluation of the dynamics of the epidemiological index of the community of digenean parasites, two species of fish show seasonal variations. Furthermore, higher prevalence of infestation were registered during the summer season for the Opecaelidae family in the two hosts.

KEY WORDS Sparidae; *Pagellus*; congeneric; Digenean; epidemiological index; Algerian coasts.

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INTRODUCTION

Through this study we have identified and compared the digenean endoparasites of two congeneric sympatric sparid fishes (Perciformes Sparidae), which are also of great commercial importance, *Pagellus erythrinus* (Linnaeus, 1758) and *Pagellus acarne* (Risso, 1827). The study area was the west coast of Algeria. This approach is an attempt to highlight the influence of biotic and abiotic factors in structuring the community of digenean parasites. Indeed, the niches of parasite species are strongly influenced by the environment, particularly the quality of the food resources and

their abundance (Price & Clancy, 1983; Bates & Kennedy, 1990; Holmes, 1990; Holmes & Bartoli, 1993). Some authors (Holmes, 1973; Pianka, 1974; Rohde, 1979) suggest that interspecific and intraspecific competition between sympatric host species favor niche restriction for the parasite. A morpho-anatomical study has been carried out to put the digeneans collected from each host in their taxonomic context and a quantitative and qualitative study was carried out in order to compare the community of the digeneans in both congeneric sparid fishes. The digenean fauna of sparid fish has been the subject of various studies in the Mediterranean Sea, among them we will cite the works of: Bartoli, 1987a, 1987b; Bartoli & Gibson, 1989; Bartoli et al., 1989a, 1989b; 2005; Saad-Fares & Maillard, 1990; Bartoli & Bray, 1996; Sasal et al., 1999; Kostadinova & Gibson, 2009; Sanchez et al., 2013, 2014. Moreover, we can also mention recent works undertaken on the parasitofauna of sparidae fishes in the Mediterranean Sea, including the work of Merzoug et al., 2012; Abid Kachour et al., 2013; Antar & Gargouri Ben Abdallah, 2013; Abid Kachour, 2014; Antar et al., 2015; Bellal et al., 2016. However, this contribution is still incomplete, knowing that sparidae are considered as ideal host fish for the larval and adult stages. The biodiverty of the community of the digenean parasites within each host will allow us to highlight their trophic ecology (Brooks & Hoberg, 2000; Khan & Chandra, 2006).

MATERIAL AND METHODS

A total of 240 fishes (120 of each species) from Oran's coasts, north western Algeria (Fig. 1) during the 12 months between September 2016 and 2017, have been sampled. The digeneans found in digestive tract of *Pagellus erythrinus* and *P. acarne* have been set into alcohol of 70%, put for some minutes in Borax Carmine solution (Grenacher) and after in chlorhydric acid, dehydrated in successive baths of alcohol of 70, 85, 95%, then in two baths of absolute ethanol 100%. They have been cleared in Eugenol and mounted in Canada balsam. All the parasitic digenans harvested in this study were identified with taxonomic keys (Yamaguti, 1934 ; Gibson et al., 2002). The different ecological terms used for digenean communities (prevalence, mean intensity and abundance) were calculated as described by Bush et al. (1997).

Terms used as "dominant species" (prevalence> 50%), "satellite species" or common (prevalence 10%-50%) and "rare species" (prevalence <10%) were defined according to Valtonen et al. (1997). Statistical analysis was performed using the STA-

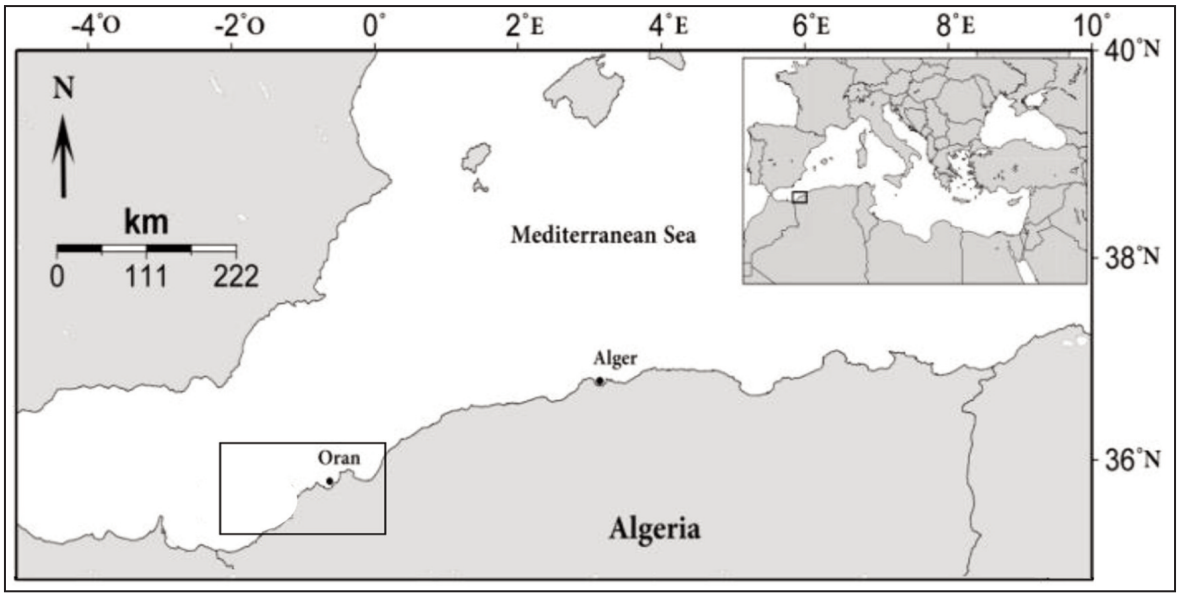

Figure 1. Study area: Oran's coasts, north western Algeria.

TISTICA software (Statsoft statistica version 12.5.192.7).

RESULTS

The two host fishes of this study have in their digestive system a large and variable number of digeneans belonging to different families. However, the composition of the digenean community does not evolve in the same direction in two host fishes and show differences with the seasons. A total of 11 digenean species belonging to 4 families have been identified (Table 1).

In *P. erythrinus*, the family Opecoelidae was dominant, largely represented by the species *Macvi-*

Species	Families	Site(s)	Prevalence	Abundance	Mean Intensity
Pagellus erythrinus **N=120**					
Lepocreadium pegorchis (Stossich, 1901)	Lepocreadiidae	CD	33.33	0.5	1.5
Lepocredium album (Stossich, 1890)	Lepocreadiidae	CD	25	0.33	1.33
Holorchis pycnoporus (Stossich, 1901)	Lepocreadiidae	CDE	7.5	0.09	1.22
Holorchis sp.	Lepocreadiidae	CD	3.33	0.04	1.25
Macvicaria crassigula (Linton, 1910)	Opecoelidae	CD	41.66	0.56	1.36
Pachycreadium carnosum (Rudolphi, 1819)	Opecoelidae	CD	51.66	0.58	1.12
Hemiurus communis Odhner, 1905	Hemiuridae	A	8.33	0.09	1.1
Hemiurus luehei Odhner, 1905	Hemiuridae	AD	3.33	0.04	1.25
Lepidauchen stenostoma Nicoll, 1913	Acanthocolpidae		4.16	0.04	1
Pagellus acarne **n=120**					
Lepocreadium pegorchis (Stossich, 1901)	Lepocreadiidae	CB	25	0.33	1.33
Macvicaria crassigula (Linton, 1910)	Opecoelidae	CD	29.16	0.33	1.14
Zoogonus sp.	Zoogonidae	F	17.5	0.20	1.19
Hemiurus communis Odhner, 1905	Hemiuridae	A	3.33	0.04	1.25

Table. 1. Parasitological indices for digeneans from two Sparid fishes off the western Mediterranean coast of Algeria. Sites: A, stomach; B, pyloric caeca; C, duodenum; D, mid-intestine; E, posterior intestine; F, rectum.

caria crassigula (51.66%) occupying a large part of the intestine, followed by *Pachycreadium carnosum* found in the duodenum and mid-intestine (25%). The family Lepocreadiidae is represented by *Lepocreadium pegorchis* (41.66%), *L. album* (33.33%), found at the duodenum and mid-intestine levels, *Holorchis pycnoporus* (7.5 %), and *H.* sp. (3.33%) both collected in the duodenum, mid-intestine and rectum. *Hemiurus communis* (8.33%) and *H. luehei* (3.33%), are species belonging to the family Hemiuridae. They are rare and were all found at the stomach level. The family Acanthocolpidae was marked by the presence of *Lepidauchen stenostoma* in the duodenum with a prevalence of 3.33%. For *P. acarne*, we recorded the presence on the intestinal level of the species *Lepocreadium pegorchis* (Lepocreadiidae) with a prevalence of 25 %. *Macvicaria crassigula* (Opeceolidae) was recorded in the duodenal part (29%) and mid internal (16%), *Zoogonus* sp. (Zoogonidae) on the anus level (17.5%), and *Hemiurus communis* (Hemiuridae) was found in the stomach (3.33%).

Concerning the ecological aspect, we noted that the community of digenean parasites of two host fishes (*P. erythrinus* and *P. acarne*) varies according to the seasons. The strongest values of prevalence of some species were observed in summer. The histogram of seasonal variations for *P. erythrinus* (Fig. 2) shows that the prevalence of parasitic species varies with a minimum rate of 3.33 in winter up to at 83.33% in summer.

This variation concerns, in particular, *Macvigaria crassigula*, in which we observed a prevalence of 26.66% in winter, a clear progression from spring, reaching its maximum in summer (83.33%) while a decrease is recorded during the autumn (Fig. 2). *Pachycredium carnosum* also showed a significant rate of parasitism for the summer period of about 66.66%. The family of Lepocreadiidae is especially represented by *Lepocreadium* genus, also frequent during the summer. We did not find any significant seasonal change for other digenean parasites (Fig. 2). We recorded variations of digenean fauna according to the change of seasons also in *P. acarne* (Fig. 3). *Macvicaria crassigula* is prevalent with 3.33% in winter, reaching 73.33% in summer period. *Lepocreadium pegorchis* (70%) and *Zoogonus* sp. (50%) are prevalent too during the summer, while no change of the prevalence according to the seasons was observed for *Hemiurus communis*.

DISCUSSION

Through these results, we found that the structure of the digenean community was not completely identical and homogeneous in both the host fishes. These two sparidae belong to the same genus. They are very close phylogenetically and sharing the same biotope and food habits (Bauchot et al., 1990) can determine the infestation of the

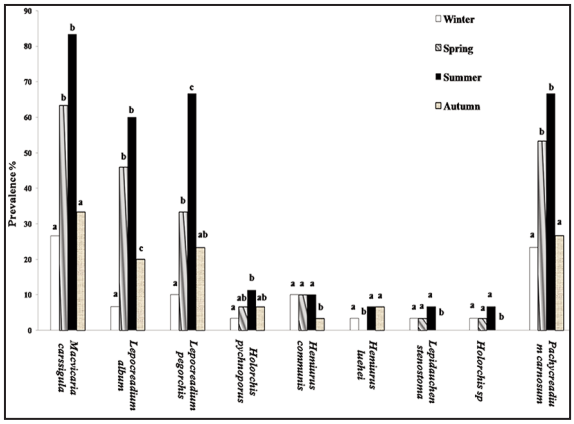

Figure 2. Comparative study of the variances of parasitic species according to the seasons in *Pagellus erythrinus*. Data with different letters expressed significant differences between seasons ($p < 0.05$) for each species of parasitic digenean.

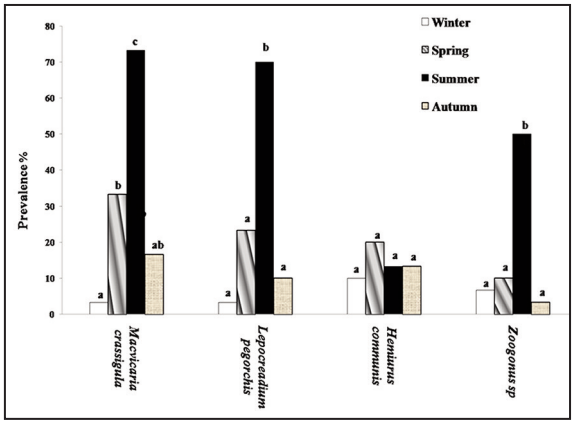

Figure 3. Comparative study of the variances of parasitic species according to the seasons in *Pagellus acarne*. Data with different letters expressed significant differences between seasons ($p < 0.05$) for each species of parasitic digenean.

larval stages of the digenean species by trophic way (Morand, 1996). Indeed, these two congeneric sparidae nourish mainly on shellfish and molluscs, generally the first and second intermediary hosts of the majority of the digenean species. Despite all these convergences, the digenean community in *P. erythrinus* was both important and richer compared to that of *P. acarne*. This difference may be the result of trophic competition between congeners. Indeed, some studies suggest that competition for a resource such as food may be more intense between closely related host species (Harmelin-Vivien et al., 1989; Sala & Ballesteros, 1997; Azzurro et al., 2007). However, we found that some digenean species such as *Macvicaria crassigula* (Opeceolidae) and *Lepocreadium pegorchi*s (Lepocreadiidae) were recorded in both host fishes in the same microbiotope with a high prevalence, giving them the rank of dominant and generalist parasite (Sasal et al., 1999). These species have already been reported several times in sparidae, notably in *P. erythrinus* in the Mediterranean Sea (Bartoli et al., 2005; Antar & Gargouri, 2013). This specificity is qualified strictly from a coevolutive adaptation (Brooks & Hoberg, 2000). In addition, many authors have hypothesized that the parasite's preferential microbiotope is the result of the influence of immune host responses (Holmes, 1990; Holmes & Bartoli, 1993). Others support the theory of the influence of the trophic network (Bartoli et al., 2005). Various studies also show that parasite populations will fluctuate within their hosts depending on the surrounding environmental conditions (Khan & Chandra, 2006). We also found that the rate of infestation was lower at the stomach level, compared to the intestine. These results concur with the hypothesis proposed by several authors in which they suggest that the stomach remains a hostile environment because of its chemical and physical contribution (Holmes, 1990).

Concerning the variations of parasite prevalence according to the seasons, and after use of the statistical test, the impact of the temperature is not similar for all the digenean species resumed in the two host fishes. However, some digeneans show a significant difference in their prevalence with a consequent increase during the summer period, these results coincide with those obtained by Desclaux (2003). *Macvicaria crassicula* (Opecoelidae) and *Lepocredium pegorchis* (Lepocreadiidae), hosted by both *Pagellus*, present this specificity in relation to the seasons. Indeed, if one refers to the work already done on the fluctuations of the parasite abundance of different taxa, especially the digeneans, according to the changes of seasons, show that the various factors, like the increase of the temperature or the salinity can alter the specificity of parasites (Williams et al., 1994; Sasal et al., 1997). However, in certain digenean parasites the increase of the temperature during the summer favors their pululation (De Kinkelin, 1971). Recently, studies have confirmed the effect of light and temperature on their determining role in the emission of digeneans (Desclaux, 2003). With regard to parasites that show no significant variation with the seasons, as is the case for *Hemiurus communis* (Hemiuridae), a generalist species, some studies are concerned with temperature, an environmental parameter involved in the inhibition or reduction of the emission of certain cercariae in the first intermediate host gastropods, thus disturbing the evolutionary cycle of a given species (Prévot, 1974, Williams & Jones, 1994). In addition, the trophic behavior of the two host fishes (*P. erythrinus* and *P. acarne*) changes with the seasons (Bauchot et al., 1990; Fanelli et al., 2011).

CONCLUSIONS

We notice in this study that the composition of the community of digenean parasites of these two sympatric and congeneric host species does not systematically exhibit the same digenean structure in terms of quantity and quality and does not respond with the same variations in prevalence in according to the seasons. Except for some dominant and common species as is the case of *Macvicaria crassigula* and *Lepocreadium pegorchis*, the results were similar in both host fishes. Indeed, these results corroborate the work of some authors such as Poulin (2002) and Sasal & Thomas (2005) and who suggest that host fish sharing the same biotope could develop a parasite exchange between them. However, divergences in the results of digenean species in both sparidae, as mentioned by some authors such as Bartoli (1987b) and Bartoli et al. (2005), are related to the food web and partitioning available to both host fishes. More-

over, our results respond mainly to the competition theory that exists between parasitic species: when one species colonizes a host, it prevents the eventual installation of the other (Sasal & Thomas, 2005).

REFERENCES

Abid-Kachour S., Mouffok S. & Boutiba Z., 2013. Description of a new species of *Sphincteristomum* from Sparid Fishes of the algerian Coast (Western Mediterranean). Journal of Environmental Protection, 4: 1129–1136. https://doi.org/10.4236/jep.2013.410129

Abid-Kachour S., 2014. Contribution à l'étude desparasites Digènes chez trois Poissons téléostéens Merlu (*Merluccius merluccius*), Pageot (*Pagellus erythrinus*) et Chinchard (*Trachurus trachurus*) de la côte oranaise. Thèse Doctorat, Université d'Oran Es-Senia, Algeria, 190 pp.

Antar R. & Gargouri Ben Abdallah L., 2013. Trematodes in fishes of the genus *Diplodus* (Teleostei, Sparidae) from Bizerte Lagoon (Northern coast of Tunisia). European association of Fish Pathologists, 33: 44–52.

Antar R., Georgieva S., Gargouri L. & Kostadinova A., 2015. Molecular evidence for the existence of species complexes within *Macvicaria* Gibson & Bray, 1982 (Digenea: Opecoelidae) in the western Mediterranean, with descriptions of two new species. Systematic Parasitology, 91: 211–229. https://doi.org/10.1007/s11230-015-9577-9

Azzurro E., Fanelli E., Mostarda E. & Catra M., 2007. Resource partitioning among early colonizing *Siganus luridus* and native herbivorous fish in the Mediterranean: an integrated study based on gut-content analysis and stable isotope signatures. Journal of the Marine Biological Association of the United Kingdom, 7: 991–998. https://doi.org/10.1017/S0025315407056342

Bartoli P. 1987a. Les Trématodes digénétiques parasitesdes poissons Sparidés de la Reserve Naturelle de Scandola. Travaux Scientifiques du Parc Naturel Régional et des Réserves Naturelles de Corse, 10: 1–158.

Bartoli P. 1987b. Caractères adaptatifs originaux des Digènes intestinaux de *Sarpa salpa* (Teleostei, Sparidae) et leur interprétation en termes d'évolution. Annales de Parasitologie Humaine et Comparée, 62: 542–576.

Bartoli P., Gibson D.I. & Bray R.A., 2005. Digenean species diversity in teleost fish from a nature reserve off Corsica, France (Western Mediterranean), and a comparison with other Mediterranean regions. Journal of Natural History, 39: 47–70. https://doi.org/10.1080/00222930310001613557

Bartoli P. & Bray R.A., 1996. Description of three species of *Holorchis* Stossich, 1901 (Digenea: Lepocreadiidae) from marine fishes of Corsica. Systematic Parasitology, 35: 133–143.

Bartoli P. & Gibson D.I., 1989. *Wardula sarguicola* n. sp. (Digenea, Mesometridae), a rectal parasite of *Diplodus sargus* (Teleostei, Sparidae) in western Mediterranean. Annales de Parasitologie Humaine et Comparée, 64: 20–29.

Bartoli P., Bray R.A. & Gibson D.I., 1989a. The Opecoelidae (Digena) of sparid fishes of the western Mediterranean. II. *Pycnadenoides* Yamaguti, 1938, *Pseudopycnadena* Saad Fares & Maillard, 1986. Systematic Parasitology, 13: 35–51.

Bartoli P., Bray R.A. & Gibson D.I., 1989b. The Opecolidae (Digenea) of sparid fishes of the western Mediterranean. III. Systematic Parasitology, 13: 167–192.

Bartoli P., Gibson D.I. & Bray R.A., 2005. Digenean species diversity in teleost fish from a nature reserve of Corsica, France (Western Mediterranean), and a comparison with other Mediterranean regions. Journal of Natural History, 39: 47–70. https://doi.org/10.1080/00222930310001613557

Bates R.M. & Kennedy C.R., 1990. Interactions between the Acanthocephala *Pomphorhynchus laevis* and *Acanthocephalus anguillae* in rainbow trout: testing an exclusion hypothesis. Parasitology, 100: 435–444.

Bellal A., Brahim Tazi NA., Hadjou Z. & Zitouni Boutiba, 2016. First records of digenean trematodes of two fishes (Teleostei, Sparidae) from the West algerian coast and comparative study with Tunisian coast (Mediterranean Sea). Biodiversity Journal, 7: 233–240.

Bray R.A. & Gibson. D.I., 1989. The Lepocreadiidae (Digenea) of fishes from the north-east Atlantic: review of the genus *Neolepidapedon* Manter 1954, with a description of *N. smithi* n. sp. Systematic Parasitology, 131: 11–23.

Bray R.A. & Gibson D.I., 1998. Further observations on the Digenea (Platyhelminthes) of deep-sea fishes in the northeastern Atlantic: Fellodistomidae and Zoogonidae. Acta Parasitologica, 43: 194–199.

Bray R.A. & Bartoli P., 1996. A redescription of *Lepidauchen stenostoma* Nicoll, 1913 (Digenea), and a reassessment of the status of the genus *Lepidauchen* Nicoll, 1913. Systematic Parasitology, 33: 167–176.

Bauchot M.L., Hureau J.C. & Quero J.C., 1990. Sparidae. Check-list of the fishes of the eastern tropical Atlantic (CLOFETA). JNICT, Lisbon; SEI, Paris; and UNESCO, Paris. Vol. 2: 790–812.

Brooks D.R. & Hoberg E.P., 2000. Triage for the biosphere: the need and rationale for taxonomic inventories and phylogenetic studies of parasites. Comparative Parasitology, 67: 1–25.

Bush A.O., Lafferty K.D., Lotz J.M. & Shostak A.W., 1997. Parasitology meets ecology on its own terms: Margolis et al. Revisited. Journal of Parasitology, 83: 575–583.

De Kinkelin P., 1971. Précis de pathologie des Poissons, Institut national de la recherche agronomique, Masson, 487 pp.

Descalaux C., 2003. Interactions hotes-parasites: diversité, mécanismes d'infestation et impact des trématodes digènes sur les coques *Cerastoderma edule* (Mollusques Bivalve) en milieu lagunaire. Thèse de Doctorat Université de Bordeaux, 247 pp.

Fanelli E., Badalamenti F., D'Anna, G., Pipitone C., Riginella E. & Azzurro E., 2011. Food partitioning and diet temporal variation in two coexisting sparids, *Pagellus erythrinus* and *Pagellus acarne*. Journal of Fish Biology, 78: 869–900. https://doi.org/10.1111/j.1095-8649.2011.02915.x.

Gibson D.I., Jones.A., & Bray R.A, 2002. Keys to the Trematoda. Vol. 1. CABI Publishing, London, 544 pp.

Harmelin-Vivien M.L., Kaim-Malka R.A., Ledoyer M. & Jacob-Abraham S.S., 1989. Food partitioning among scorpaenid fishes in Mediterranean seagrass beds. Journal of Fish Biology, 34: 715–734.

Holmes J.C., 1973. Site selection by parasitic helminths: interspecic interactions, site segregation, and their importance to the development of helminth communities. Canadian Journal of Zoology, 51: 333–347.

Holmes J.C., 1990. Competition, contacts and other factors restricting niches of parasitic Helminthes. Annales de Parasitologie Humaine et Comparée, 65: 69–72.

Holmes J.C. & Bartoli P., 1993. Spatio-temporalstructure of the communities of helminths in the digestive tract of *Sciaena umbra* L. 1758 (Teleostei). Parasitology, 106: 519–525.

Khan R.A. & Chandra C.V., 2006. Influence of climatic changes on the parasites of Atlantic cod *Gadus morhua* off coastal Labrador, Canada. Journal of Helminthology, 80: 193–197. https://doi.org/10.1079/JOH2006352

Kostadinova A. & Gibson D.I., 2009. New records of rarederogenids (Digenea: Hemiuroidea) from Mediterranean sparids, including the description of a new species of *Magnibursatus* Naidenova, 1969 and redescription of *Derogenes adriaticus* Nikolaeva, 1966. Systematic Parasitology, 74: 187–198. https://doi.org/10.1007/s11230-009-9214-6.

Marzoug D., Boutiba Z., Kostadinova A. & Pérezdel-Olmo A., 2012. Effects of fishing on parasitism in a sparid fish: contrasts between two areas of the Western Mediterranean. Parasitology International, 61: 414–420. https://doi.org/10.1016/j.parint.2012.02.002

Morand S., 1996. Biodiversity of parasites in relation with their life cycle. The Genesis and Maitenance of Biological Diversity, Oxford University Press, 243–260.

Pianka E.R., 1974. Evolutionary Ecology. Harper and Row, New York, 356 pp.

Poulin R., 1992. Determinants of host specificity in parasites of freshwater fishes. International Journal for Parasitology, 22: 753–758.

Poulin R., 2002. The evolution of monogenean diversity. International Journal of Parasitology, 37: 245–245.

Prévot G., 1974. Recherches sur le cycle biologique et l'écologie de quelques tréma- todes nouveaux parasites de *Larus argentatus michaellis* Naumann dans le midi de la France. Thèse Sciences, Aix-Marseille, 319 pp.

Price P.W. & Clancy K.M., 1983. Patterns in number of helminth parasite species in freshwater fishes. Journal of Parasitology, 69: 449–454.

Rohde k., 1979. A critical evaluation of intrinsic andextrinsic factors responsible for niche restriction inparasites. The American Naturalist, 114: 648–671.

Saad-Fares A. & Maillard C., 1990. Digenetic Trematodes of Lebanese coast fishes**:** the species complexes *Lepocreadium album* (Stossich, 1890) and *Lepocreadium pegorchis* (Stossich, 1900) Lepocreadiidae. Systematic Parasitologie, 17: 87–95.

Sánchez-García N., Raga J.A. & Montero F.E., 2014. Risk assessment for parasites in cultures of *Diplodus puntazzo* (Sparidae) in the Western Mediterranean: prospects of cross infection with *Sparus aurata*. Veterinary Parasitology, 204: 120–133. https://doi.org/10.1016/j.vetpar.2014.05.013.

Sánchez-García N., Ahuir-Baraja A., Raga J.A. & Montero F.E., 2013. Morphometric, molecular andecological analyses of the parasites of the sharpsnout sea bream *Diplodus puntazzo* Cetti (Sparidae) from the Spanish Mediterranean: implications for aquaculture. Journal of Helminthology, 89: 217–231. https://doi.org/10.1017/S0022149X13000813

Sasal P. & Thomas F., 2005. Parasite induced changes in host behavior and morphology. In: K. Rohde (Ed.), Marine Parasitology, pp. 259–264. CSIRO Publishing, Collingwood, 565 pp.

Sasal P., Morand S. & Guégan J.F., 1997. Parasite species richness for fish of the Mediterranean Sea. Marine Ecology Progress Series, 149: 61–71.

Sasal P., Niquil N. & Bartoli P., 1999. Community structure of digenean parasites of sparid and labrid fishes of the Mediterranean Sea: a new approach. Parasitology, 119: 635–648.

Sala E. & Ballesteros E., 1997. Partitioning of space and food resources by three fish genus *Diplodus* (Sparidae) in a Mediterranean rocky infralittoral ecosystem. Marine Ecology Progress Series, 152: 273–283.

Valtonen E.T., Holmes J.C. & Koskivaara M., 1997. Eutrophication, pollution and fragmentation: effects on parasite communities in roach (*Rutilus rutilus*) and perch (*Perca fluviatilis*) in four lakes in the Central Finland. Canadian Journal of Fisheries and Aquatic Sciences, 54: 572–585.

Williams H. & Jones A., 1994. Parasitic Worms of Fish. Taylor & Francis, 593 pp.

Yamaguti S., 1934 Studies on the helminth fauna of Japan. Part 2. Trematodes of fishes. Japanese Journal of Applied Entomology and Zoology, 6: 159–182.