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Ectoparasites of the blackspot seabream *Pagellus bogaraveo* (Teleostei: Sparidae) from Portuguese waters of the north-east Atlantic

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The ectoparasite community of the blackspot seabream, Pagellus bogaraveo*, was studied in different locations in Portuguese waters of the north-east Atlantic Ocean. This is the first study to focus on the ectoparasites of this commercially important sparid fish. Nine ectoparasite species were detected.* Gnathia *sp.,* Aega deshaysiana, A. antillensis, Rocinela danmoniensis *and* Argulus *sp. are reported for the first time on this host. Significant differences were detected among the sampling locations, with monogeneans being more prevalent in mainland waters, and crustaceans being more prevalent in the Atlantic islands of Madeira and Azores. Fish from Madeira showed significantly higher infection levels of all ectoparasites, especially crustaceans, and particularly high prevalence of* Hatschekia pagellibogneravei*. The potential impact of the species detected on captive fish is also discussed, since the blackspot seabream is a promising new species for marine aquaculture.*

Keywords: *Pagellus bogaraveo*, blackspot seabream, Portugal, north-east Atlantic, ectoparasites

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INTRODUCTION

The blackpot seabream, *Pagellus bogaraveo* (Brünnich, 1768) is a commercially important benthopelagic sparid fish that occurs in the north-east Atlantic as well as the Mediterranean Sea. Its parasitic fauna is insufficiently known, and there has never been a comprehensive study of its ectoparasites. There are some studies of specific parasite groups that report ectoparasite species detected in *P. bogaraveo*. The monogeneans *Lamellodiscus virgula* Euzet & Oliver, 1967, *Encotyllabe pagelli* van Beneden & Hesse, 1863, *Choricotyle chrysophryi* (van Beneden & Hesse, 1863) and *Choricotyle pagelli* Llewelyn, 1941 have been reported from blackspot seabream from north-east Atlantic waters (Llewellyn, 1941, 1956; Oliver, 1973; Hansson, 1998). Several copepod species have also been reported on *P. bogaraveo*, but mostly from the Mediterranean (Raibaut *et al.*, 1998); in the north-east Atlantic only three copepods have been detected parasitizing this fish, namely *Caligus centrodonti* Baird, 1850, *Hatschekia pagellibogneravei* (Hesse, 1878), and *Peniculus fistula* von Nordmann, 1832 (Scott & Scott, 1913; Gooding, 1957; Jones, 1985). The cymothoid isopod *Ceratothoa collaris* Schiödte & Meinert, 1883 has also been detected on this fish (Bariche & Trilles, 2008).

This study is the first attempt to describe the ectoparasite community of *P. bogaraveo* in the wild, and also to evaluate whether these parasites might become problematic in captivity, since this fish has recently started to be produced in aquaculture (Basurco *et al.*, 2011), and seems to be an excellent alternative to other commonly cultured sparids, such as *Sparus aurata*, due to its higher market value (Peleteiro *et al.*, 2000). Skin and gill parasites often have serious impact in cultured fish because, on the one hand, captive fish often experience higher stress levels than wild fish, rendering them more vulnerable to the negative effects of parasitism and, on the other hand, they are limited in the behavioural ways in which they might normally avoid the parasites that are present in the environment, or minimize their impact by seeking cleaner fish (Grutter, 2003). Skin parasites often cause lesions that might lead to secondary infections, especially of bacterial aetiology. Gill parasites, especially when present in large numbers, can cause severe damage to the gill and impair normal respiratory function, which may lead to the death of the host by hypoxia (Marino *et al.*, 2004). In addition, many ectoparasites feed on blood, and high intensities of infection may lead to anaemia and poor growth rates.

Another important aim of this study was to assess the differences in the ectoparasite communities of *P. bogaraveo* from different locations in the Portuguese waters, especially between mainland Portugal and the Atlantic islands of Madeira and the Azores. The fact that different locations were analysed, and also that sampling was carried out throughout the year, may have helped to capture a wide range of parasites that might not have been detected had the study been carried out in a single location or during a specific

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time of the year, and might help to achieve a more comprehensive perspective of the ectoparasites of *P. bogaraveo* in Atlantic waters.

MATERIALS AND METHODS

A total of 348 specimens of *Pagellus bogaraveo* caught in the Portuguese Exclusive Economic Zone were acquired from commercial catches between the years 2009 and 2011, from four mainland locations (42 from Matosinhos, 92 from Figueira da Foz, 42 from Peniche and 30 from Sagres) and the Atlantic islands of Madeira (56) and Azores (86) (Figure 1). Sampling was carried out during two seasonal periods (autumn/winter and spring/summer) in all locations except Sagres, where only spring/summer samples could be obtained. Fish were transported in ice to the laboratory and measured before being frozen in individual plastic bags. Fish mean length is presented in Table 1. After defrosting, each fish was analysed for the presence of ectoparasites. The tegument, mouth, nostrils and gill chambers were thoroughly observed. The gills were removed and placed in Petri dishes and each gill arch was separately observed under a stereomicroscope. All parasites were collected and preserved in 70% ethanol. Monogeneans were cleared and mounted in glycerol, observed in an optical microscope and identified according to the descriptions of Llewellyn (1941), Dawes (1947) and Oliver (1973). Identification of copepods followed Kabata (1979), Alexander (1983) and Boxshall (1986). Isopods were identified according to Sars (1899), Richardson (1905), Norman & Scott (1906) and Bruce (2004).

Prevalence and intensity of infection were determined according to Bush *et al.* (1997). Statistical analyses were carried out using IBM SPSS statistics software. Whenever possible, prevalence and intensity of parasite infection were compared among all 6 locations, and also between three regions (mainland, Madeira and Azores), using a Chi-square test for prevalence, and the non-parametric Kruskal–Wallis test for intensities, followed by multiple comparisons whenever significant differences were detected. For all tests, statistical significance was accepted when $P < 0.05$.

RESULTS

A total of nine ectoparasite species were detected in the 348 specimens of *Pagellus bogaraveo* examined: the monogeneans

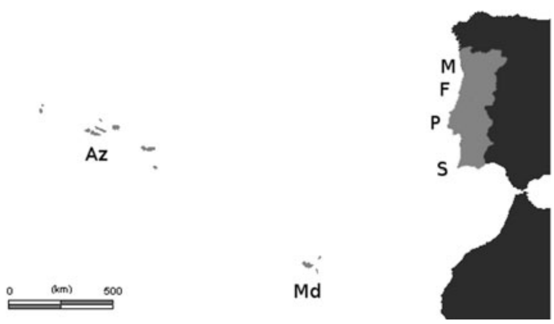

Fig. 1. Sampling locations on the Portuguese mainland coast: (M) Matosinhos; (F) Figueira da Foz; (P) Peniche; (S) Sagres; and Islands: (Md) Madeira; (Az) Azores.

Lamellodiscus virgula and *Choricotyle chrysophryi*; the copepods *Hatschekia pagellibogneravei* and *Peniculus fistula*; the isopods *Gnathia* sp. Leach, 1814 (praniza larvae), *Aega deshaysiana* (Milne Edwards, 1840), *Aega antillensis* Schiöedte & Meinert, 1879 and *Rocinela danmoniensis* Leach, 1818; and the branchiuran *Argulus* sp. Müller, 1785. Prevalence and intensity of infection for each species is presented in Tables 1 and 2, respectively.

Only 113 fish (32%) of all the specimens observed were infected with at least one ectoparasite species. Of these, the majority (81%) harboured only one species, whereas 15% had two parasite species and 4% three. No more than three species were detected per host.

Monogeneans were located exclusively on the gills. Prevalence of monogeneans was significantly different in the three regions, being higher in mainland samples. *Lamellodiscus virgula* was the only parasite species that occurred in all sampling locations, with a maximum prevalence in Sagres (30.0%). Intensity of infection was highly variable, but no significant differences were detected between locations. A maximum of 772 individuals were observed on a single fish. The polyopisthocotylean *C. chrysophryi* was detected in all mainland locations, but not in the islands. Prevalence was again highest in Sagres, but reached only 6.7%. Intensity of infection was always very low; no more than two specimens were ever detected in a single host.

The copepod *H. pagellibogneravei*, another gill parasite, presented the highest prevalence detected in this study: 96.4% in Madeira waters. This species also occurred in the Azores, albeit with a much lower prevalence (5.8%), but was absent from mainland waters. Intensity of infection was also significantly higher in Madeira. The copepod *P. fistula* was found attached to the caudal fin of only two fish, producing a dark colour lesion in the attachment site.

Praniza larvae of *Gnathia* sp. were detected in the mouth, oesophagus, gills, gill chamber, and on the tegument and fins of several fish from the islands and from one mainland location. Prevalence of this isopod was significantly higher in the islands. Mean intensity was not particularly high, but occasionally a single fish hosted more than 100 *Gnathia* sp. Three aegid isopods were detected for the first time in *P. bogaraveo*: *A. deshaysiana*, *A. antillensis* and *R. danmoniensis*. These isopods were usually detected on the tegument, most often underneath the pectoral fins, with the exception of *A. antillensis*, which was located on the gills, and infection levels were always low. A single specimen of *Argulus* sp. was also detected under a pectoral fin on a fish from Azorean waters.

Globally no significant differences were detected between autumn/winter and spring/summer except in the prevalence of *Gnathia* sp. (autumn/winter = 17.6% and spring/summer = 6.3%) and *H. pagellibogneravei* (autumn/winter = 25.2% and spring/summer = 10.1%), and intensity of *Gnathia* sp (mean intensity autumn/winter = 2.2 and spring/summer = 20.2).

Although nine ectoparasite species were detected, species richness never exceeded 5 at any sampling location. Fish from both islands had an ectoparasite community composed of 4 crustaceans and one monogenean species; while in mainland waters the ectoparasite community was composed of 3 crustaceans and 2 monogeneans. Overall, monogenean prevalence was higher in the mainland, whereas prevalence of crustaceans was higher in the islands. Within the three studied regions, prevalence and intensity of crustaceans and ectoparasites were significantly higher in Madeira.

Table 1. Prevalence (%) of parasite infection in *Pagellus bogaraveo* from locations on mainland Portugal (Matosinhos, Figueira da Foz, Peniche and Sagres) and Islands (Madeira and Azores). Number (N) and length (L) (mean ± standard deviation, in cm) of fish examined. Significant differences detected among locations and among regions (mainland, Madeira and Azores) by Chi-square test (similar letters indicate no significant differences).

Parasite species	Matosinhos N = 42 L = 32.0 ± 1.7	Figueira da Foz N = 92 L = 33.0 ± 1.8	Peniche N = 42 L = 37.4 ± 3.1	Sagres N = 30 L = 30.0 ± 0.7	Madeira N = 56 L = 31.0 ± 2.6	Azores N = 86 L = 34.9 ± 4.7	Total mainland N = 206 L = 33.2 ± 3.1	Overall N = 348 L = 33.3 ± 3.7	Significant differences
Lamellodiscus virgula	9.5	2.2	11.9	30.0	1.8	1.2	9.7	6.3	
					ab	a	b		3 reg: $P = 0.007$
Choricotyle chrysophryi	4.8	1.1	2.4	6.7	0.0	0.0	2.9	1.7	
TOTAL MONOGENEA	14.3	3.3	14.3	36.7	1.8	1.2	12.6	8.0	
					ab	a	b		3 reg: $P = 0.001$
Hatschekia pagellibogneravei	0.0	0.0	0.0	0.0	96.4	5.8	0.0	17.0	
	a	a	a	a	b	a			6 loc: $P = 0.000$
					c	b	a		3 reg: $P = 0.000$
Peniculus fistula	0.0	1.1	0.0	3.3	0.0	0.0	1.0	0.6	
Gnathia sp.	0.0	10.9	0.0	0.0	21.4	20.9	4.9	11.5	
					b	b	a		3 reg: $P = 0.000$
Aega deshaysiana	0.0	0.0	0.0	0.0	7.1	0.0	0.0	1.1	
Aega antillensis	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.3	
Rocinela danmoniensis	0.0	1.1	2.4	0.0	5.4	0.0	1.0	1.4	
Argulus sp.	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.3	
TOTAL CRUSTACEA	0.0	12.0	2.4	3.3	96.4	24.4	6.3	25.3	
	a	ab	a	ab	c	b			6 loc: $P = 0.000$
					c	b	a		3 reg: $P = 0.000$
TOTAL ECTOPARASITES	14.3	14.1	16.7	36.7	96.4	25.6	18.0	32.5	
	a	a	a	a	b	a			6 loc: $P = 0.000$
					b	a	a		3 reg: $P = 0.000$

P, probability level.

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Table 2. Intensity (median, mean ± standard deviation, (range)) of parasite infection in *Pagellus bogaraveo* from locations in mainland Portugal (Matosinhos, Figueira da Foz, Peniche and Sagres) and Islands (Madeira and Azores). Significant differences detected among locations and among regions (mainland, Madeira and Azores) by the Kruskal–Wallis test (similar letters indicate no significant differences).

Parasite species	Matosinhos	Figueira da Foz	Peniche	Sagres	Madeira	Azores	Total mainland	Overall	Significant differences
Lamellodiscus virgula	13.5 20.0 ± 24.0 (1–52)	1.5 1.5 ± 0.7 (1–2)	58.0 182.0 ± 331.3 (1–772)	11.0 17.3 ± 16.4 (1–47)	90.0 90.0 (90)	45.0 45.0 (45)	10.5 57.4 ± 169.7 (1–772)	12.5 58.4 ± 161.6 (1–772)	
Choricotyle chrysophryi	1 1.0 ± 0.0 (1)	1 1.0 (1)	1 1.0 (1)	1.5 1.5 ± 0.7 (1–2)	–	–	1.0 1.2 ± 0.4 (1–2)	1.0 1.2 ± 0.4 (1–2)	
TOTAL MONOGENEA	1.5 13.7 ± 21.0 (1–52)	1.0 1.3 ± 0.6 (1–2)	32.0 151.8 ± 305.4 (1–772)	10.0 14.5 ± 16.0 (1–47)	90.0 90.0 (90)	45.0 45.0 (45)	3.5 44.5 ± 149.9 (1–772)	5.0 46.1 ± 144.5 (1–772)	
Hatschekia pagellibogneravei	–	–	–	–	17.5 35.3 ± 63.2 (1–363)	4.0 4.2 ± 2.4 (1–7)	–	15.0 32.6 ± 61.1 (1–363)	
	–	–	–	–	b b	a a	–		2 loc: P=0.020 2 reg: P=0.020
Peniculus fistula	–	1.0 1.0 (1)	–	1.0 1.0 (1)	–	–	1.0 1.0 ± 0.0 (1)	1.0 1.0 ± 0.0 (1)	
Gnathia sp.	–	3.0 7.0 ± 10.2 (1–31)	–	–	1.0 2.3 ± 2.9 (1–11)	2.0 11.5 ± 30.9 (1–133)	3.0 7.0 ± 10.2 (1–31)	2.0 7.6 ± 21.4 (1–133)	
Aega deshaysiana	–	–	–	–	1.0 1.5 ± 1.0 (1–3)	–	–	1.0 1.5 ± 1.0 (1–3)	
Aega antillensis	–	–	–	–	–	1.0 1.0 (1)	–	1.0 1.0 (1)	
Rocinela danmoniensis	–	1.0 1.0 (1)	1.0 1.0 (1)	–	1.0 1.0 ± 0.0 (1)	–	1.0 1.0 ± 0.0 (1)	1.0 1.0 ± 0.0 (1)	
Argulus sp.	–	–	–	–	–	1.0 1.0 (1)	–	1.0 1.0 (1)	
TOTAL CRUSTACEA	–	2.0 6.5 ± 9.8 (1–31)	1.0 1.0 (1)	1.0 1.0 (1)	17.5 35.9 ± 63.2 (1–363)	4.0 11.0 ± 28.5 (1–133)	2.0 5.7 ± 9.2 (1–31)	8.0 25.5 ± 53.0 (1–363)	
	–	ab	abc	abc	C b	b a	a		6 loc: P=0.000 3 reg: P=0.000
TOTAL ECTOPARASITES	1.5 13.7 ± 21.0 (1–52)	2.0 5.8 ± 9.1 (1–31)	6.0 130.3 ± 284.6 (1–772)	10.0 14.5 ± 16.0 (1–47)	19.0 37.6 ± 63.9 (1–363)	4.0 12.5 ± 28.7 (1–133)	3.0 33.2 ± 126.2 (1–772)	8.0 31.3 ± 85.4 (1–772)	
	ab	a	ab	ab	b b	a a	a		6 loc: P=0.001 3 reg: P=0.000

P, probability level.

DISCUSSION

Parasite species detected

Until recently, two morphologically very similar species of diplectanid monogeneans were thought to occur in *Pagellus bogaraveo*, namely *Lamellodiscus obeliae* and *Lamellodiscus virgula*; however, analysis of their ribosomal DNA sequences has revealed differences of less than 1%, and they are therefore now considered a single species, *L. virgula* (Desdevises *et al.*, 2000). This monogenean occurred in fish from all locations studied, but it was more common in the mainland. Prevalence values were usually lower than those observed by Oliver (1973) on the Atlantic coast of France (30%) and by Kaouachi *et al.* (2010) in the Mediterranean (12–33%), on the same host. Although less pathogenic than other diplectanid species such as *Diplectanum* spp., *Lamellodiscus* spp. have been shown to cause damage to the gills, especially epithelial hyperplasia and microhaemorrhages (Sánchez-García *et al.*, 2011).

Choricotyle chrysophryi is a polyopisthocotylean that has previously been recorded in *P. bogaraveo* from both the north-east Atlantic (Llewellyn, 1941, 1956) and the Mediterranean (Kaouachi *et al.*, 2010). It is a relatively large monogenean, whose attachment organs function as suckers, allowing the parasite to move freely on the surface of the gills (Llewellyn, 1956). Although polyopisthocotylean parasites of fish feed on blood, they generally tend to be harmless to their hosts in wild fish (Kearn, 2005). That is probably the case for this species, since intensity of infection seems to be usually very low. Llewellyn (1941) detected no more than two parasites per host, as was also observed in the present study, whereas Kaouachi *et al.* (2010) found no more than one. Nonetheless, it is likely that higher parasite loads could occur in captive conditions, and large numbers of blood feeding parasites could potentially cause anaemia.

Hatschekia pagellibogneravei is a relatively common copepod that parasitizes several species of sparid fish, including *P. bogaraveo* (Raibaut *et al.*, 1998; Boualleg *et al.*, 2010b). It has often been reported from the Mediterranean (Raibaut *et al.*, 1998; Ternengo *et al.*, 2009; Boualleg *et al.*, 2010a, 2010b), and occasionally also from the north-east Atlantic (Jones, 1985). In this study it was only detected in the Atlantic islands, with a significantly higher prevalence in Madeira. Boualleg *et al.* (2010a) found a relatively high prevalence of this parasite on *Diplodus annularis* (L., 1758) from the Mediterranean (60%) but, to the best of our knowledge, a prevalence reaching almost 100% had never been detected on any host. Intensity of infection was also higher than the highest mean intensity previously reported, 11.4 on *Diplodus cervinus* (Lowe, 1838) (Boualleg *et al.*, 2010b). A mean abundance of 6.8 is the only parasitological index provided for *H. pagellibogneravei* on *P. bogaraveo* in the Mediterranean (Boualleg *et al.*, 2010b), so here we also determined this parameter and again, mean abundance of this species in Madeira was much higher (34.0 ± 62.4).

Gnathiid isopods are obligatory fish parasites during three juvenile stages of praniza larvae, feeding on fish blood, whereas the adult stages are free-living and do not feed (Hadfield *et al.*, 2009). Most studies of wild fish populations found no significant pathology associated with *Gnathia* sp. infection (Heupel & Bennett, 1999; Gene, 2007); however they may transmit blood parasites such as *Haemogregarina bigemina* Laveran & Mesnil, 1901 (see Davies *et al.*, 2004). Many wild fish seek cleaner fish very frequently (up to more than 100 times per day), which may help to minimize the impact of gnathiids (Grutter, 2003). However, in captive fish, these isopods can cause not only anaemia (Jones & Grutter, 2005), but also severe mechanical damage to the skin and especially the gills, which may in extreme cases lead to death by hypoxia (Marino *et al.*, 2004). Although the intensity detected in some fish in the present study was occasionally high (reaching 133 parasites in one host), mean intensity was generally moderate, and no lesions associated with this parasite were observed. It should however be noted that the stress imposed on fish by capture, as well as handling and transport, may influence the prevalence and intensity of infection by these parasites, as they can easily detach from the host. Praniza larvae of *Gnathia* sp. had never been detected in *P. bogaraveo*, but they have often been reported in various fish species captured in Portuguese waters (e.g. Davies *et al.*, 1994; Marques *et al.*, 2006; Sequeira *et al.*, 2010). Not only do gnathiids have low host specificity, but they also seem to show no particular preference for any site of attachment (Hadfield *et al.*, 2009). In this study they were detected in different locations on the skin and fins, as well as in the mouth, gill chamber, and on the gills, which coincides with findings by other authors (e.g. Grutter, 2003).

Aegidae are temporary parasites of fish (Bunkley-Williams & Williams, 1998). Some authors refer to these temporary associations as 'predation' (e.g. Novotny & Mahnken, 1971; Bruce, 2004); however, aegids seem to be associated with fish for longer periods of time than strictly necessary for feeding (Bunkley-Williams & Williams, 1998). Aegids can have a negative impact on fish by causing large wounds, stunting growth, and occasionally even killing young fish (Bunkley-Williams & Williams, 1998). The temporary character of the association and the ease with which they can detach from the host (Rokicki, 1985) can help to explain the low number of Aegidae detected. In fact, for most aegid species, very few hosts have been reported, yet it seems likely that they exhibit low specificity. Bruce (2004) mentions two sharks as hosts of *A. deshaysiana*, and Ramdane & Trilles (2008) have recently detected it on *Sardina pilchardus* (Walbaum, 1792). The only host reported for *A. antillensis* was a serranid fish (Bruce, 2004). For *R. danmoniensis* Sars (1899) mentions that it is generally found 'clinging to the skin of fishes of various kinds'. *Pagellus bogaraveo* is reported here for the first time as a suitable host for these three aegid species. Both *A. deshaysiana* and *R. danmoniensis* have been detected in the north-east Atlantic (Sars, 1899; Bruce, 2004), including in Madeiran waters, in the case of *A. deshaysiana*. On the other hand, the Portuguese mainland and Madeira extend the range of *R. danmoniensis* further south than was previously known. In the case of *A. antillensis*, the only previous records were from the north-west Atlantic, especially the Caribbean Sea and Gulf of Mexico (Bruce, 2004). However, the same author notes that the species is probably more widespread, and the present work extends its range of occurrence to the Azores, the westernmost archipelago of the north-east Atlantic.

Only two specimens of *P. fistula* were detected, both firmly attached to the caudal fin of their hosts. This was also the site of attachment reported by Gooding (1957). Only the post-metamorphose female is parasitic on fish, and exhibits a low host specificity (Boxshall, 1986). Attachment of this parasite

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involves a deep penetration of the tegument, and it seems likely that the resulting lesions might have a negative impact on fish health, particularly with higher intensities of infection.

Argulus sp. is a worldwide occurring branchiuran, commonly called fish lice. Several species are known to be highly pathogenic to cultured fish and, although there have been as yet no reports of *Argulus* sp. infections in marine aquaculture facilities, several marine species occur in the north-east Atlantic, and they could potentially have a severe negative impact on cultured fish (Schram *et al.*, 2005). There is currently some concern that *Argulus* sp. might start exhibiting higher growth rates in temperate regions due to climate warming (Hakalahti *et al.*, 2006). Here the blackspot seabream is reported for the first time as a suitable host for this crustacean.

Ectoparasite community

Although nine species of ectoparasites were detected in this study, species richness in any one location never exceeded 5 species. This is comparable to what has been reported for other sparid fish, such as *Boops boops* (L., 1758), *Dentex dentex* (L., 1758), *Diplodus vulgaris* (Geoffrow Saint-Hilaire, 1817) (all 6 ectoparasite species), and *Pagellus erythrinus* (L., 1758) (7 species) (González *et al.*, 2004; Pérez-del-Olmo *et al.*, 2007; Ternengo e*t al*., 2009). All of these species had only one or two monogeneans, as was also the case in the present study. Species richness of monogenean parasites of the genus *Lamellodiscus* is highly variable within the Sparidae, but in the larger species, such as *Sparus aurata* L., 1758, *Pagrus pagrus* (L., 1758) and *P. bogaraveo*, only one species usually occurs (Desdevises, 2006).

Copepod species richness is also highly variable, even within the genus *Pagellus*, with *Pagellus acarne* (Risso, 1827) being host to only two species and *P. erythrinus* to 13. *Pagellus bogaraveo* is somewhere in the middle, as seven copepod species have been reported from this fish (Raibaut *et al.*, 1998). In this study only two copepod species were detected, which is unexpectedly low, but one must bear in mind that most records of copepod parasites of *P. bogaraveo* that were not detected in the present study are from the Mediterranean Sea. However, these species (namely, *Alella pagelli* (Krøyer, 1863) and several *Caligus* spp.) are not unknown to occur in the north-east Atlantic (Kabata, 1992). No parasitological indices were found in the literature to assess whether these species are rare in the blackspot seabream, or whether they are more common in the Mediterranean than in the Atlantic.

In this study, monogeneans were more prevalent in Portuguese mainland waters. Several studies have shown that both monopisthocotylean and polyopisthocotylean monogeneans exhibit higher infection levels in polluted areas (see Pérez-del-Olmo *et al.*, 2007, and references therein). Since continental waters generally tend to be more polluted when compared to open oceanic waters, this seems a likely explanation for the higher prevalence of monogeneans in fish from Portuguese mainland waters.

Higher prevalence and intensity of ectoparasites, and crustaceans (i.e. all ectoparasites except monogeneans) in Madeira is a result that agrees with previous findings of increased abundance of ectoparasites of marine teleosts with decreased latitude (Rohde & Heap, 1998), and is related to differences in water temperature range. Rohde *et al.* (1995) found significant positive correlations between means of water temperature ranges (mean temperature during the coldest month to mean temperature during the warmest month) and intensity and abundance of ectoparasites, and abundance of copepods, specifically in benthopelagic fish. In this study, prevalence and intensity of ectoparasites, of crustaceans, and of the copepod *H. pagellibogneravei* were all significantly higher in Madeira, the southernmost location studied and the only one that is in a subtropical biogeographical region. In this area, the mean of the temperature range (data from the years 1981 to 2000) was 20.8°C, whereas in mainland Portugal it varied between 15.1°C in the northernmost location and 17.8°C on the southern coast, and in Angra do Heroísmo, Azores, it was 18°C (Carvalho & Soares, 2001).

In conclusion, nine ectoparasite species were detected on blackspot seabream from Portuguese waters, including two monogeneans and seven crustaceans, which is comparable to the ectoparasite communities of other sparid fish. *Gnathia* sp., *Aega deshaysiana*, *A. antillensis*, *Rocinela danmoniensis* and *Argulus* sp. were detected on this host for the first time. The ectoparasite community of *P. bogaraveo* varied significantly among locations, with the mainland samples showing higher prevalence of monogeneans. Madeira had significantly higher infection levels of ectoparasites, crustaceans, and the copepod *Hatschekia pagellibogneravei*, which might be due to biogeographical differences, as abundance of ectoparasites and copepods tends to increase in lower latitudes, especially in the case of benthopelagic fish.

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REFERENCES

Alexander P.D. (1983) *Peniculus haemuloni*, a new species of copepod (Siphonostomatoida: Pennelidae) parasitic on *Haemulon stendachneri* from Ubatuba, Brazil. *Bulletin of the British Museum (Natural History), Zoology* 45, 381–385.

Bariche M. and Trilles J.-P. (2008) *Ceratothoa collaris* (Isopoda: Cymothoidae) new to the eastern Mediterranean, with a redescription and comments on its distribution and host specificity. *Journal of the Marine Biological Association of the United Kingdom* 88, 85–93.

Basurco B., Lovatelli A. and García B. (2011) Current status of Sparidae aquaculture. In Pavlidis M.A. and Mylonas C.C. (eds) *Sparidae: biology and aquaculture of gilthead sea bream and other species.* Oxford, UK: Blackwell Publishing, pp. 1–50.

Boualleg C., Ferhati H., Kaouachi N., Bensouilah M. and Ternengo S. (2010a) The copepod parasite of the gills of four teleost fishes caught from the Gulf of Annaba (Algeria). *African Journal of Microbiology Research* 4, 801–807.

Boualleg C., Seridi M., Kaouachi N., Quiliquini Y. and Bensouillah M. (2010b) Les Copépodes parasites de poissons téléostéens du littoral Est-algérien. *Bulletin de l'Institut Scientifique, Rabat, section Sciences de la Vie* 32, 65–72.

Boxshall G.A. (1986) A new genus and two new species of Pennellidae (Copepoda: Siphonostomatoida) and an analysis of evolution within the family. *Systematic Parasitology* 8, 215–225.

Bruce N.L. (2004) Reassessment of the isopod crustacean *Aega deshaysiana* (Milne Edwards, 1840) (Cymothoidae: Aegidae): a world-wide complex of 21 species. *Zoological Journal of the Linnean Society of London* 142, 135–232.

Bunkley-Williams L. and Williams E.H. (1998) Isopods associated with fishes: a synopsis and corrections. *Journal of Parasitology* 84, 893–896.

Bush A.O., Lafferty K.D. and Shostak A.W. (1997) Parasitology meets ecology on its own terms: Margolis *et al*. revisited. *Journal of Parasitology* 83, 575–583.

Carvalho F. and Soares A. (2001) *A temperatura da água do mar em Portugal*. Instituto de Meteorologia, Ministério da Ciência e Tecnologia, Nota Técnica VAM2-2/2001, 56 pp.

Davies A.J., Eiras J.C. and Austin T.E. (1994) Investigations into the transmission of *Haemogregarina bigemina* Laveran & Mesnil, 1901 (Aplicomplexa: Adeleorina) between intertidal fishes in Portugal. *Journal of Fish Diseases* 17, 283–289.

Davies A.J., Smit N.J., Hayes P.M., Seddon A.M. and Wertheim D. (2004) *Haemogregarina bigemina* (Protozoa: Aplicomplexa: Adeleorina)—past, present and future. *Folia Parasitologica* 51, 99–108.

Dawes B. (1947) *The Trematoda of British fishes*. London: The Ray Society.

Desdevises Y. (2006) Determinants of parasite species richness on small taxonomical and geographical scales: *Lamellodiscus* monogeneans of northwestern Mediterranean sparid fish. *Journal of Helminthology* 80, 235–241.

Desdevises Y., Jovelin R., Jousson O. and Morand S. (2000) Comparison of ribosomal DNA sequences of *Lamellodiscus* spp. (Monogenea, Diplectanidae) parasitising *Pagellus* (Sparidae, Teleostei) in the North Mediterranean Sea: species divergence and coevolutionary interactions. *International Journal for Parasitology* 30, 741–746.

Gene E. (2007) Infestation status of gnathiid isopod juveniles parasitic on dusky grouper (*Epinephelus marginatus*) from the northeast Mediterranean Sea. *Parasitology Research* 101, 761–766.

González P., Sánchez M.I., Chirivella J., Carbonell E., Riera F. and Grau A. (2004) A preliminary study on gill metazoan parasites of *Dentex dentex* (Pisces: Sparidae) from the western Mediterranean Sea (Balearic Islands). *Journal of Applied Ichthyology* 20, 276–281.

Gooding R.U. (1957) On some copepoda from Plymouth, mainly associated with invertebrates, including three new species. *Journal of the Marine Biological Association of the United Kingdom* 36, 195–221.

Grutter A.S. (2003) Feeding ecology of the fish ectoparasite *Gnathia* sp. (Crustacea: Isopoda) from the Great Barrier Reef, and its implications for fish cleaning behaviour. *Marine Ecology Progress Series* 259, 295–302.

Hadfield K.A., Smit N.J. and Avenant-Oldewage A. (2009) Life cycle of the temporary fish parasite, *Gnathia pilosus* (Crustacea: Isopoda: Gnathiidae) from the east coast of South Africa. *Journal of the Marine Biological Association of the United Kingdom* 89, 1331–1339.

Hakalahti T., Karvonen A. and Valtonen E.T. (2006) Climate warming and disease risks in temperate regions—*Argulus coregoni* and *Diplostomum spathaceum* as case studies. *Journal of Helminthology* 80, 93–98.

Hansson H.G. (1998) *NEAT (North East Atlantic Taxa): South Scandinavian Marine Plathelminthes Check-List*. Available from http://www.tmbl.gu.se/libdb/taxon/neat_pdf/ NEAT*Plathelmint.pdf (accessed 30 November 2011).

Heupel M.R. and Bennett M.B. (1999) The occurrence, distribution and pathology associated with gnathiid isopod larvae infecting the epaulette shark, *Hemiscyllium oscellatum*. *International Journal for Parasitology* 29, 321–330.

Jones C.M. and Grutter A.S. (2005) Parasitic isopods (*Gnathia* sp.) reduce haematocrit in captive blackeye thicklip (Labridae) on the Great Barrier Reef. *Journal of Fish Biology* 66, 860–864.

Jones J.B. (1985) A revision of *Hatschekia* Poche, 1902 (Copepoda: Hatschekiidae), parasitic on marine fishes. *New Zealand Journal of Zoology* 12, 213–271.

Kabata Z. (1979) *Parasitic Copepoda of British fishes*. London: The Ray Society.

Kabata Z. (1992) *Copepods parasitic on fishes: keys and notes for the identification of the species*. Oegstgeest, The Netherlands, The Linnean Society of London and The Estuarine and Coastal Sciences Association [Synopses of the British Fauna (New Series), No. 47.]

Kaouachi N., Boualleg C., Bensouilah M. and Marchand B. (2010) Monogenean parasites in sparid fish (*Pagellus* genus) in eastern Algeria coastline. *African Journal of Microbiology Research* 4, 989–993.

Kearn G.C. (2005) *Leeches, lice and lampreys: a natural history of skin and gill parasites of fishes*. Dordrecht, The Netherlands: Springer.

Llewellyn J. (1941) A description of the anatomy of the monogenetic trematode *Choricotyle chrysophryi* van Beneden & Hesse. *Parasitology* 33, 397–405.

Llewellyn J. (1956) The host-specificity, micro-ecology, adhesive attitudes, and comparative morphology of some trematode gill parasites. *Journal of the Marine Biological Association of the United Kingdom* 35, 113–127.

Marino F., Giannetto S., Paradiso M.L., Bottari T., De Vico G. and Macrì B. (2004) Tissue damage and haematophagia due to praniza larvae (Isopoda: Gnathiidae) in some aquarium seawater teleosts. *Diseases of Aquatic Organisms* 59, 43–47.

Marques J.F., Teixeira C.M. and Cabral H.N. (2006) Differentiation of commercially important flatfish populations along the Portuguese coast: evidence from morphology and parasitology. *Fisheries Research* 81, 293–305.

Norman A.M. and Scott T. (1906) *The Crustacea of Devon and Cornwall*. London: William Wesley & Son.

Novotny A.J. and Mahnken C.V.W. (1971) Predation on juvenile Pacific salmon by a marine isopod *Rocinela belliceps pugettensis* (Crustacea: Isopoda). *Fishery Bulletin* 69, 699–701.

Oliver G. (1973) *Lamellodiscus obeliae* n. sp., une nouvelle espèce de diplectanidae (Monogenea, Monopisthocotylea) parasite de *Pagellus centrodontus* (Delaroche, 1809) (Pisces, Sparidae). *Zeitschrift für Parasitenkunde* 41, 103–108.

Peleteiro J.B., Olmedo M. and Alvarez-Blázquez B. (2000) Culture of *Pagellus bogaraveo*: present knowledge, problems and perspectives. *Cahiers Options Méditerranéennes* 47, 141–151.

Pérez-del-Olmo A., Raga J.A., Kostadinova A. and Fernández M. (2007) Parasite communities in *Boops boops* (L.) (Sparidae) after the *Prestige* oil-spill: detectable alterations. *Marine Pollution Bulletin* 54, 266–276.

Raibaut A., Combes C. and Benoit F. (1998) Analysis of the parasitic copepod species richness among Mediterranean fish. *Journal of Marine Systems* 15, 185–206.

Ramdane Z. and Trilles J.-P. (2008) Cymothoidae and Aegidae (Crustacea, Isopoda) from Algeria. *Acta Parasitologica* 53, 173–178.

Richardson H. (1905) Monograph on the isopods of North America. *Bulletin of the United States National Museum* 54, 1–727.

Rohde K., Hayward C. and Heap M. (1995) Aspects of the ecology of metazoan ectoparasites of marine fishes. *International Journal for Parasitology* 25, 945–970.

Rohde K. and Heap M. (1998) Latitudinal differences in species and community richness and in community structure of metazoan endo- and ectoparasites of marine teleost fish. *International Journal for Parasitology* 28, 461–474.

Rokicki J. (1985) Biology of adult Isopoda (Crustacea) parasitizing fishes of the North-West Africa shelf. *Acta Ichthyologica et Piscatoria* 15, 95–118.

Sánchez-García N., Padrós F., Raga J.A. and Montero F.E. (2011) Comparative study of the three attachment mechanisms of diplectanid monogeneans. *Aquaculture* 318, 290–299.

Sars G.O. (1899) *An account of the Crustacea of Norway, with short descriptions and figures of all the species. Volume 2. Isopoda.* Bergen, Norway: The Bergen Museum.

Schram T.A., Iversen L., Heuch P.A. and Sterud E. (2005) *Argulus* sp. (Crustacea: Branchiura) on cod, *Gadus morhua* from Finnmark, northern Norway. *Journal of the Marine Biological Association of the United Kingdom* 85, 81–86.

Scott T. and Scott A. (1913) *The British parasitic Copepoda. Volume I. Copepoda parasitic on fishes.* London: The Ray Society.

Sequeira V., Gordo L.S., Neves A., Paiva R.B., Cabral H.N. and Marques J.F. (2010) Macroparasites as biological tags for stock identification of the bluemouth, *Helicolenus dactylopterus* (Delaroche, 1809) in Portuguese waters. *Fisheries Research* 106, 321–328.

and

Ternengo S., Levron C., Mouillot D. and Marchand B. (2009) Site influence in parasite distribution from fishes of the Bonifacio Strait Marine Reserve (Corsica Island, Mediterranean Sea). *Parasitology Research* *104*, 1279–1287.

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