Metazoan ectoparasites of two teleost fish, *Boops boops* (L.) and *Mullus barbatus barbatus* L. from Algerian coast: diversity, parasitological index and impact of parasitism

by

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Abstract. – A total of 664 *Boops Boops* (Linnaeus, 1758) and 823 *Mullus barbatus barbatus* Linnaeus, 1758 from the east coast of Algeria were examined to study their parasitofauna. We collected eleven parasitic species (two monogeneans, three copepods, five isopods and one Branchiura) from *B. boops*, and four parasitic species (two copepods and two isopods) from *M. barbatus barbatus*. Five species were reported for the first time in Algeria. The site of attachment on the host and the degree of specificity varied according to the parasite species while the infestation rate changed according to the month and the host size. The parasitism did not show a significant negative impact on the biological parameters of the fish host.

Résumé. – Ectoparasites métazoaires de deux espèces de téléostéens, *Boops Boops* (L.) et *Mullus barbatus barbatus* L., des côtes d'Algérie : diversité, taux d'infestation et impact du parasitisme.

Au total, 664 *Boops Boops* (Linnaeus, 1758) et 823 *Mullus barbatus barbatus* Linnaeus, 1758 capturés le long du littoral Est de l'Algérie ont été examinés afin d'étudier leur parasitofaune. Sur *B. boops*, nous avons récolté 11 espèces d'ectoparasites (deux monogènes, trois copépodes, cinq isopodes et un Branchioura), et quatre espèces sur *M. barbatus barbatus* (deux copépodes et deux isopodes). Parmi les 14 ectoparasites identifiés, cinq ont été récoltés pour la première fois en Algérie. Le site d'attache sur l'hôte et le degré de spécificité étaient différents selon les espèces de parasites. Le taux d'infestation variait selon le mois et la taille de l'hôte. Le parasitisme n'a induit aucun impact négatif significatif sur les paramètres biologiques des poissons hôtes.

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Parasitism can induce stress to aquatic organisms (Lemly and Esch, 1984) and exerts a strong control of the host population dynamic, inducing great economic losses (Mann, 1952; Kabata, 1955, 1958; Anderson and May, 1979; Bragoni *et al*., 1983; Cassier *et al*., 1998). The development and maintenance of the parasite and the immune reaction of host result in a physiological cost for the host (Combes, 2001).

The presence of parasites can affect survival, physiology, behaviour and fitness of its host (Lester and Roubal, 1995; Trilles and Hipeau-Jacquotte, 1996, 2012; Barber *et al*., 2000; Combes, 2001; Östlund-Nilsson *et al*., 2005). Reduced condition index and growth (Romestand and Trilles, 1979; Adlard and Lester, 1994; Johnson and Dick, 2001; Collyer and Stockwell, 2004), impaired reproduction and a reduced lifespan (Adlard and Lester, 1994) have been observed, but other studies reported no effect of parasitism (Weinstein and Heck, 1977; Herrera-Cubilla, 1985; Hajji *et al*., 1994).

Despite the potential importance of parasitism in marine ecology (Zander *et al*., 2002; Lafferty *et al*., 2006) its effects on biological performance and populations dynamic of fish are rarely assessed. Moreover, there is usually no emphasis on the links between fish health, stock assessment and management of marine fisheries (Lloret *et al*., 2012).

Mullus barbatus barbatus (Mullidae) and *Boops boops* (Sparidae) are economically important species of the Mediterranean. In Algeria, *M. barbatus barbatus* and *B. boops* are caught by trawlers at around 2000 and 5000 tonnes per year, respectively. No studies have been performed on the host/parasite relationships and the effect of parasitism on fish biology. The aim of this survey was to determine the parasitofauna of the two fish species and to get insight into the effect of parasites on their biological performances.

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MATERIAL AND METHODS

The study was conducted in the east coast of Algeria. A total of 664 *B. boops* and 823 *M. barbatus barbatus* were sampled between 2007 and 2008 from the fishing port of Béjaïa (east coast of Algeria). The length in cm (total length, standard length and fork length), weight in g (total and eviscerate weight) were measured and sex determined for each fish. The body, fins, buccal cavity, gill cavities, gills, and muscle were examined for the presence of parasite using a dissecting stereomicroscope. Parasites were fixed in ethanol 70%. Prevalence, mean abundance and mean intensity were calculated according to Margolis *et al*. (1982) and Bush *et al*. (1997).

All collected parasites were considered (cumulative effect on hosts) to analyse the impact of parasitism on the biological performances of the host. Three biological parameters were compared between unparasitized and parasitized specimens: the size/weight relationship ($Wt = a. Lt^{b}$, a: constant, b: coefficient of allometry), the Fulton's condition factor K ($K = (W)/Lt^{b}$, b: coefficient of allometry considered equal to 3) and the growth rate using the model of Von Bertalanffy (1938). Growth parameters were identified through the Software Fishparm (Prager *et al*., 1989). Age was determined by otolithometry (Jones, 1992; Panfili *et al*., 2002; Mahé *et al*., 2012). Analysis of one-way ANOVA (followed by post-hoc Tukey tests) and covariance (ANCOVA) were performed using the statistical software XLSTAT 2012. Parasitologic indexes were compared according to the months and sizes by the Chi-square test (χ^2) using the statistical software MINITAB 13. 31 version.

RESULTS

Parasitofauna and dynamics of infestation

A total of 1487 specimens belonging to different size classes were examined (Fig. 1). Fifteen ectoparasitic species

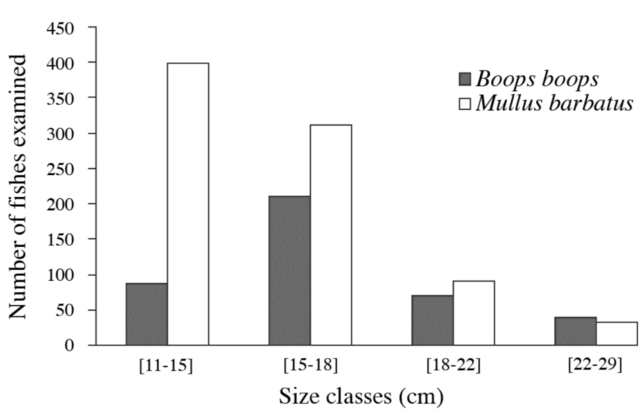

Figure 1. - Number of examined specimens per size classes for *Boops boops* and *Mullus barbatus barbatus* from Béjaïa, Algeria.

Table I. - Monthly variation of parasitologic indexes per parasite species. P%: prevalence; A: mean abundance; Im: mean intensity; M: mean; Min: minimum; Max: maximum; SD: standard deviation; n: number of examined fishes.

Hosts/ Parasites species	Epidemiological data	Months											
		January	February	March	April	May	June	July	August	September	October	November	December
Boops boops	n	90	105	66	98	80	30	30	30	30	30	44	31
	(M±SD)	17.3 ± 1.97	18.2 ± 3.8	21.6 ± 4.0	16.8 ± 2.5	17.2 ± 2.7	16.8 ± 1.2	15.8 ± 1.8	16.6 ± 4.4	18.4 ± 2.3	18.1 ± 2.7	17.8 ± 2.4	18.87 ± 2.95
Cyclocotyla bellones	P%	0	0.95	0	2.04	1.25	0	0	0	0	0	2.273	0
	A	0	0.019	0	0.02	0.025	0	0	0	0	0	0.023	0
	Im (Min-Max)	0	2 (1-2)	0	1	2 (1-2)	0	0	0	0	0	1	0
Microcotyle erythrini	P%	0	6.06	8.16	3.75	6.67	6.67	6.67	6.67	0	0	3.226	16.13
	A	0	0.06	0.13	0.10	0.07	0.07	0.10	0.10	0	0	0.032	0.16
	Im (Min-Max)	0	1	1.625 (1-4)	2.67 (1-4)	1	1	1.5 (1-2)	1.5 (1-2)	0	0	1	1
Hatschekia pagellibogneravei	P%	0	0	0	0	0	0	0	0	0	0	0	3.23
	A	0	0	0	0	0	0	0	0	0	0	0	0.06
	Im (Min-Max)	0	0	0	0	0	0	0	0	0	0	0	2
Naobranchia cygniformis	P%	7.78	10.48	1.52	6.12	1.25	10.00	0	0	0	0	4.55	9.68
	A	0.12	0.10	0.02	0,07	0.03	0.27	0	0	0	0	0.05	0.16
	Im (Min-Max)	1.57 (1-2)	1	1	1.17 (1-2)	2	2.67 (1-4)	0	0	0	0	1	1.67 (1-3)
Lernaeolophus sultanus	P%	0	0	0	0	1.25	0	0	0	0	10	0	0
	A	0	0	0	0	0.025	0	0	0	0	0.04	0	0
	Im (Min-Max)	0	0	0	0	1	0	0	0	0	1	0	0
Anilocra frontalis	P%	2.22	0	0	0	0	0	0	0	0	0	0	0
	A	0.02	0	0	0	0	0	0	0	0	0	0	0
	Im (Min-Max)	1	0	0	0	0	0	0	0	0	0	0	0

Table I. - Continued.

Hosts/ Parasites species	Epidemiological data	Months											
		January	February	March	April	May	June	July	August	September	October	November	December
Ceratothoa oestroides	P%	1.11	2.86	6.06	2.04	3.75	3.33	3.33	3.33	0	0	0	0
	A	0.01	0.03	0.08	0.02	0.04	0.03	0.03	0.03	0	0	0	0
	Im (Min-Max)	1	1	1.25 (1-2)	1	1	1	1	1	0	0	0	0
Ceratothoa oxyrrhynchaena	P%	0	0	0	0	3.75	0	0	0	0	0	0	0
	A	0	0	0	0	0.04	0	0	0	0	0	0	0
	Im (Min-Max)	0	0	0	0	1	0	0	0	0	0	0	0
Ceratothoa parallela	P%	4.44	7.62	3.03	7.14	6.25	3.33	0	0	0	0	11.36	6.45
	A	0.04	0.11	0.03	0.08	0.10	0.03	0	0	0	0	0.11	0.06
	Im (Min-Max)	1	1.5 (1-2)	1	1.14 (1-2)	1.6 (1-2)	1	0	0	0	0	1	1
Emetha audouini	P%	1.11	0	0	0	0	0	0	0	0	0	0	0
	A	0.01	0	0	0	0	0	0	0	0	0	0	0
	Im (Min-Max)	1	0	0	0	0	0	0	0	0	0	0	0
Argulus vittatus	P%	5.56	1.90	1.52	0	2.50	0	0	0	0	0	4.55	3.23
	A	0.06	0.02	0.02	0	0.03	0	0	0	0	0	0.05	0.03
	Im (Min-Max)	1	1	1	0	1	0	0	0	0	0	1	1
Mullus barbatus barbatus	n			101	263	92	183	86	66	32			
	(M ± SD)			14.1 ± 2.1	14.7 ± 1.6	16.6 ± 1.8	13.8 ± 2.2	17.7 ± 2.5	17.2 ± 1.6	16.1 ± 1.3			
Hatschekia mulli	P%	0	0	3.96	4.94	9.78	10.38	15.12	25,76	6.25	0	0	0
	A	0	0	0.05	0.06	0.21	0.14	0,88	0,52	0.09	0	0	0
	Im (Min-Max)	0	0	1.25 (1-2)	1.15 (1-2)	2.11 (1-3)	1.32 (1-5)	5.85 (1-2)	2 (1-6)	1.5 (1-2)	0	0	0
Caligus uranoscopi	P%	0	0	0	0	3.26		0	0	0	0	0	0
	A	0	0	0	0	0.03		0	0	0	0	0	0
	Im (Min-Max)	0	0	0	0	1.5 (1-2)		0	0	0	0	0	0
Anilocra frontalis	P%	0	0	0	0	1.09	1.09	0	0	0	0	0	0
	A	0	0	0	0	0.01	0.02	0	0	0	0	0	0
	Im (Min-Max)	0	0	0	0	1	1.5 (1-2)	0	0	0	0	0	0
Gnathia sp.	P%	0	0	0	1.52	3.26	3.28	2.33	3.03	0	0	0	0
	A	0	0	0	0.02	0.07	0.04	0.03	0.05	0	0	0	0
	Im (Min-Max)	0	0	0	1.5 (1-2)	2 (1-4)	1.17 (1-2)	1.5 (1-2)	1.5 (1-2)	0	0	0	0

were identified on *B. boops* (11) and *M. barbatus barbatus* (4) and only one (*Argulus vittatus*) by the two species (Tab. I). Among these parasites, five species, namely *Hatschekia pagellibogneravei* (Hesse, 1879), *Argulus vittatus* (Rafinesque-Smaltz, 1814), *Caligus uranoscopi* Vaissière, 1955 (Copepoda), *Cyclocotyla bellones* Otto, 1823 and *Microcotyle erythrini* van Beneden & Hesse, 1863, were reported for the first time in Algerian coast. *A. vittatus* and *H. pagellibogneravei* are new ectoparasites for *B. boops*. *C. uranoscopi* was collected only on *M. barbatus barbatus*. The parasites were found in the branchial cavity and on the skin. Oixenic, stenoxenic and euryxenic parasitic specificities were identified.

Monthly variations in the rate of infestation (*B. boops*: $\chi^2 = 39.128$; p = 0.014 and *M. barbatus barbatus*: $\chi^2 = 27.850$; p = 0.000) (Fig. 2A, C) and differences of infestation among fish size classes were observed (*B. boops*: $\chi^2 = 14.890$; p = 0.021 and *M. barbatus barbatus*: $\chi^2 = 18.811$; p = 0.004) (Fig. 2B, D). In *B. boops*, the highest parasitic rates were observed in spring (p = 25% and 1 to 4 parasite specimens per infested fish) and lowest rates from the late summer to the beginning of autumn (p close to 10%) (Fig. 2A). Largest and smallest *B. boops* were much more parasitized (Fig. 2B). In *M. barbatus barbatus* the infestation rate showed a gradual increase from March to August (Fig. 2C) (Maximum p% = 27%) and specimens belonging to the size classes 16 to 21 cm showed the highest parasitism prevalence and intensity (22% to 30% and 2 to 6 parasites specimens per infested fish) (Fig. 2D).

Parasitism and biological performance relationships

Length/weight relationship and growth

No significant difference was found in the length-weight relationships and growth rate between unparasitized and parasitized specimens of the two host species (Tabs II, III). The only signifi-

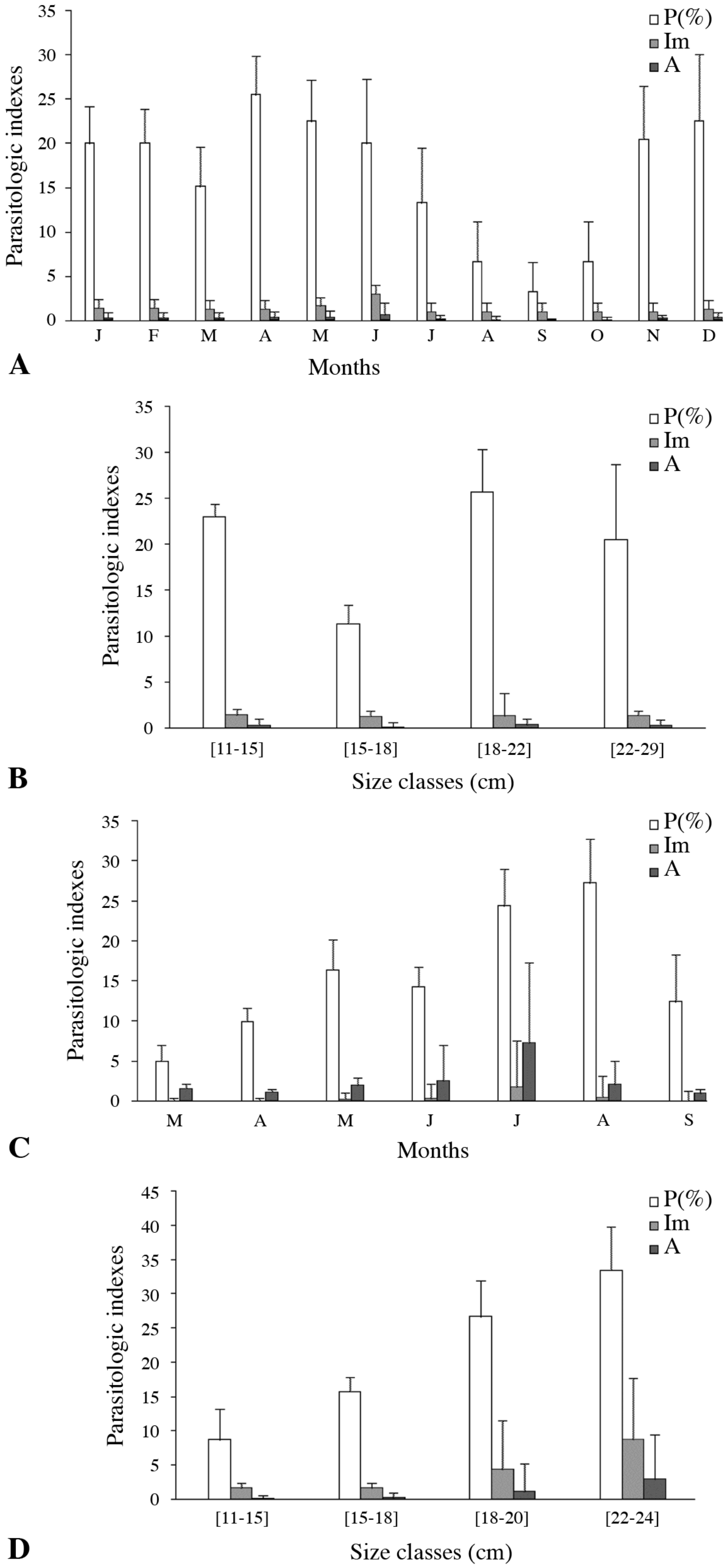

Figure 2. - Variation of the parasitologic indexes according to the month and the size classes of *B. boops* (**A, B**) and *M. barbatus barbatus* (**C**, **D**). P (%): prevalence; Im: mean intensity; A: mean abundance.

cant difference was observed between males and females of *M. barbatus barbatus* (length/weight relationship: ANCOVA, p = 0.004; growth, ANCOVA, p = 0.000) (Tabs II, III).

Condition index K

Only two significant differences in the Fulton K condition index were recorded between males and females of *M. barbatus barbatus* (ANOVA, p = 0.00) and between unparasitized and parasitized females of *B. boops* (ANOVA, p = 0.04) (Tab. IV).

DISCUSSION

In the present study, a total of 14 ectoparasitic species, including 12 species of Crustacea, were collected from the Algerian *B. boops* and *M. barbatus barbatus*. Among the 11 ectoparasites collected from *B. boops*, six species were already reported for *B. boops* from French and / or Tunisian Mediterranean coasts (Renaud *et al.*, 1980; Anato *et al.*, 1991): two Isopoda [*Ceratothoa oestroides* (Risso, 1826) and *C. parallela* (Otto, 1828)], two Copepoda [*Naobranchia cygniformis* Hesse, 1863 and *Lernaeolophus sultanus* (Milne Edwards, 1840)] and two Monogenea [*C. bellones* and *M. erythrini*]. Three species, *Anilocra physodes* (L., 1758), *Peniculus fistula* Rudolphi, 1880 and *Pseudaxine trachuri* Parona & Perugia, 1890 were collected only in French and/or Tunisian coasts. These three parasites were not recorded on Algerian *B. boops* and are probably restricted to these two regions.

Five species (*C. oestroides*, *C. parallela*, *N. cygniformis*, *C. bellones* and *M. erythrini*) parasitize *B. boops* in the Southern and Northern Mediterranean. In the Eastern coast of Algeria, *M. erythrini* was already collected from *Pagellus* sp. (Sparidae) by Kouachi *et al.* (2010).

Other species [*Anilocra frontalis* Milne Edwards, 1840, *C. oxyrrhynchaena* Koelbel, 1878, *Emetha audouini* (Milne Edwards, 1840), *H. pagellibogneravei*, *L. sultanus*, *P. trachuri* and *A. vittatus*] were so far only collected from *B. boops* in Algerian and / or Tunisian waters. *H. pagellibogneravei*, *C. bellones* and *A. vittatus* are reported for the first time for Algerian *B. boops,* and *M. erythrini* is newly recorded on Algerian *B. boops*. The richness in species parasitizing *B. boops* is thus higher in Algerian coast than in French and Tunisian coasts.

The ectoparasitic fauna of *M. barbatus barbatus* includes four species of Crustacea that were already reported for the Mediterranean Sea (Dollfus, 1946,

Table II. - Length-weight relationships of parasitized and unparasitized *B. boops* and *M. barbatus barbatus* according to sex. **: significant difference $p < 0.05$.

Species	Examined specimen categories	$Y = aX^b$	R^2	P
M. barbatus barbatus	Female	$Y = 0.0068X^{3.1593}$	$R^2 = 0.93$	0.004**
	Male	$Y = 0.0039X^{3.3479}$	$R^2 = 0.94$	
	Unparasitized specimens	$Y = 0.0042X^{3.3268}$	$R^2 = 0.96$	0.847
	Parasitized specimens	$Y = 0.0039X^{3.3479}$	$R^2 = 0.96$	
B. boops	Female	$Y = 0.015X^{2.776}$	$R^2 = 0.95$	0.902
	Male	$Y = 0.013X^{2.816}$	$R^2 = 0.91$	
	Unparasitized specimens	$Y = 0.013X^{2.827}$	$R^2 = 0.94$	0.890
	Parasitized specimens	$Y = 0.015X^{2.778}$	$R^2 = 0.93$	

Table III. - Growth rate variation of *M. barbatus barbatus* and *B. boops* according to sex and in parasitized and unparasitized specimens. **: significant difference $p < 0.05$.

Species	Examined specimen categories	Model of Von Bertalanffy (1938) $L\infty (1 – \exp(–k \times (t – t0))$	P
M. barbatus barbatus	Females	$Lt = 227 (1 – \exp(–0.49 \times (t + 0.87))$	0.000**
	Males	$Lt = 212 (1 – \exp(–0.34 \times (t + 1.54))$	
	Unparasitized females	$Lt = 223 (1 – \exp(–0.84 \times (t + 0.86))$	0.206
	Parasitized females	$Lt = 217 (1 – \exp(–0.46 \times (t + 1.24))$	
B. boops	Females	$Lt = 275 (1– \exp(–0.28 \times (t + 1.2))$	0.898
	Males	$Lt = 270 (1 – \exp(–0.24 \times (t + 1.53))$	
	Unparasitized females	$Lt = 275 (1 – \exp(–0.22 \times (t + 1.7))$	0.898
	Parasitized females	$Lt = 277 (1 – \exp(–0.24 \times (t + 1.53))$	

Table IV. - Variation of condition K coefficient ($g.cm^{-3}$) of *M. barbatus barbatus* and *B. boops* according to sex and in parasitized and unparasitized specimens. SD: standard deviation; K: condition index; N: number; P: probability; **: significant difference.

Species	Examined specimen categories	N	K ± SD ($g.cm^{-3}$)	F	P
M. barbatus barbatus	Males	332	0.97 ± 0.12	83.38	0.00**
	Females	474	1.07 ± 0.11		
	Unparasitized specimens	675	1.03 ± 0.13	0.43	0.51
	Parasitized specimens	131	1.04 ± 0.10		
	Unparasitized females	381	1.07 ± 0.12	0.14	0.70
	Parasitized females	93	1.06 ± 0.10		
	Unparasitized males	294	0.97 ± 0.12	0.45	0.50
	Parasitized males	38	0.99 ± 0.09		
B. boops	Males	381	0.81 ± 0.16	2.17	0.14
	Females	508	0.82 ± 0.11		
	Unparasitized specimens	665	0.82 ± 0.11	1.04	0.31
	Parasitized specimens	224	0.81 ± 0.19		
	Unparasitized females	383	0.83 ± 0.12	4.43	0.04**
	Parasitized females	125	0.80 ± 0.08		
	Unparasitized males	282	0.80 ± 0.09	0.13	0.71
	Parasitized males	99	0.82 ± 0.29		

1948; Le Pommelet *et al*., 1997; Raibaut *et al*., 1998; Brahim *et al*., 2009). However, *C. uranoscopi* was only collected on *M. barbatus barbatus* from the Algerian coasts. Therefore, on the two studied fish species, five species of parasites were reported here for the first time in Algeria.

Infestation rates of *B. boops* and *M. barbatus barbatus* varied both monthly and during fish ontogeny. The highest infestation rates were observed in July and August when sea temperature is elevated. Temperature and salinity are important factors affecting the parasite loads in coastal and estuarine waters. It was reported that the highest infestation is due to the increasing reproduction rate of parasites during warm seasons (Cressey, 1983). During the summer, Bragoni *et al*. (1983) observed high mortalities of cultured sea bass *Dicentrarchus labrax* infested by *Nerocila orbignyi* (Isopoda; Cymothoidae). In spring and summer, the large concentrations of potential hosts increase the chance of contact with parasites and therefore the opportunity of fish infestation. Fish age (size) is also an important factor controlling the infestation rate (Cressey and Collette, 1970; Diamant *et al*., 1999). Both the fish body surface available for fixation of parasite larvae and the amount of filtered water that can carry parasites increase with growth enhance active infestation. Moreover, parasites are able to develop adaptive strategies in response to increasing host size (Sorci *et al*., 1997; Morand and Sorci, 1998). According to these authors, parasites select large sized hosts in order to access to rich nutrient resources and space. This is why increasing host size induces active competition between different infestation forms of parasites (larvae).

In the present study, we observed no significant differences in the growth rate, the length-weight relationship and the condition index between parasitized and unparasitized specimens of *B. boops* and *M. barbatus barbatus*. A significant difference in the Fulton K condition index was only recorded between unparasitized and parasitized females of *B. boops*. The same results (absence of parasitism effects) were reported by Herrera-Cubilla (1985) and Hajji *et al*. (1994). Romestand and Trilles (1979) did not find direct influence of parasites on length-weight relationships of cultured *D. labrax* (Linnaeus, 1758) but a slight decrease in weight of parasitized specimens. Johnson *et al*. (2004) reported that several copepod species affect significantly growth, fertility and survival of their cultured hosts. Sadzikowski and Wallace (1974) and Romestand and Trilles (1979) also observed that some Cymothoidae attached in the buccal cavity and on the body surface exert a significant effect on the growth of their wild hosts. Bragoni *et al*. (1983) reported a decreasing condition of the cultured *D. labrax* infested by the cymothoid *Nerocila orbignyi* (Guerin-Meneville, 1832). In cases of heavy infestations, the Gnathiidae are also able to induce deleterious effects on teleosts and elasmobranchs (Cressey, 1983). In wild fishes, as in the case of *M. barbatus barbatus* and *B. boops* studied here, there are no such obvious effects of parasitism, unlike on cultured fishes that suffer from several factors (more stress, confinement and lowered immunization) reducing considerably their physiological potential.

However, even in natural conditions, the reproduction period, during which fish energy is dedicated to reproductive activity and the warm season, when the increase of temperature leads to the proliferation of parasites may enhance fish parasitism. Thereafter these two periods may impair fish growth and/or condition. In the Gulf of Béjaïa, some environmental factors (temperature, salinity, available nutrients, good water quality, etc.) are likely enabling the normal development of *B. boops* and *M. barbatus barbatus*, even in the presence of parasites. Besides, Euzet and Combes (1980) reported that the host/parasite relationships are balanced, the parasite and its host constituting a biological entity. The host adapts to the presence of parasites by developing strategies to overcome the energy losses. The lack of difference in growth and size-weight relationships between parasitized and unparasitized fish specimens observed here could be explained by a higher food intake by parasitized specimens as suggested for cardinal fish *Cheilodipterus quinquelineatus* Cuvier, 1828 (Östlund-Nilson *et al.,* 2005).

Finally, we have observed no effect of parasitism on the biological performances and/or the health of Algerian *B. boops* and *M. barbatus barbatus*. Only the condition index of *B. boops* was slightly impacted. For the two studied fish species, the obtained results might differ according to their geographic distribution. In many localities, parasitism and fish diseases are generally induced by human activities. Knowing that bloodsucking ectoparasites are potential vectors for several bacteria and viruses, prophylaxis must be conducted in order to prevent the speed of infective forms in wild and cultured fish stocks. The links between fish health, stock assessment and management of marine fisheries are therefore important to consider.

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