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PARASITISM OF *GOBIUS BUCCHICHII* STEINDACHNER, 1870 (TELEOSTEI, GOBIIDAE) IN PROTECTED AND UNPROTECTED MARINE ENVIRONMENTS

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ABSTRACT: We collected 396 *Gobius bucchichii*, Steindachner, 1870 (Teleostei, Gobiidae) in and around the marine reserve of Cerbère-Banyuls, in the southeast of France, between March and July 1994. Five species of adult parasites were found: one acanthocephalan, *Acanthocephaloides propinquus* Dujardin, 1845 (Acanthocephala, Arhythmacanthidae); one nematode, *Cucullanus* sp. (Nematoda, Cucullanidae); and three species of digenetic trematodes, *Helicometra* sp. (Digenea, Opecœlidae), *Derogenes* sp. (Digenea, Hemiuridae) and *Deretrema scorpaenicola* Bartoli, 1990 (Digenea, Zoogonidae). Fishes collected in a protected area were on average, larger, older, had a higher percentage of regenerated scales, and harbored more parasites.

Key words: Gobius bucchichii, marine reserve, parasites, fish.

INTRODUCTION

Preserving biodiversity is one of the main aims of ecological studies in order to protect ecosystems against direct or indirect human pressure (Barbault and Hochberg, 1992). Thus, the establishment of protected areas or sanctuaries has increased over the last 20 yr, not only to avoid a greater disturbance but also to reestablish, in time, the original equilibrium. Scientists have emphasized the important role of marine sanctuaries in coastal fisheries management through spillover (Roberts and Polunin, 1991) and larval export (Rowley, 1994), and on communities and population structures of wild fishes (Polunin and Roberts, 1993). Benefits of protection are generally more important for endangered species and spear-fishing target species, which may increase in their biomass and densities with protection (Francour, 1994).

Modifications affecting the population structure of fishes may favor the circulation of parasites although data are very scarce. Moreover, it is now currently accepted that parasites of fish can regulate their host population (Dobson and May, 1986), modify host behavior (Dobson, 1988; Combes, 1991), reduce host fecundity (Sindermann, 1986) and growth (Kennedy, 1977), decrease energetic resources (Faliex and Morand, 1994), and decrease longevity of hosts (Sindermann, 1986).

Our goals were to determine the prevalence, abundance, and mean intensity (Margolis et al., 1982) of parasites among a fish species (*Gobius bucchichii*, Steindachner, 1870; Teleostei, Gobiidae) inside and outside a marine reserve. We also hoped to determine the changes in the population structure of this fish within the Cerbère-Banyuls Marine Reserve in the southeast of France. Several factors, such as length, age, condition factor and rate of regenerated scales, were compared between parasitized and unparasitized fishes in order to evaluate the impact of parasitism within the context of biological conservation.

MATERIAL AND METHODS

We collected 396 fishes in five monthly samples between March and July 1994 in and around the 650-ha Cerbère-Banyuls Marine Reserve (42°28′N, 03°10′E). Samples were done simultaneously in three areas presenting different levels of protection to fish: an unprotected zone (U), a partially protected zone (P) where spear-fishing was forbidden, and a totally protected zone (T) where only scientific activities were allowed (Fig. 1). The sampling substrate consisted of small rocks surrounded by sand. All fishes were collected at a maximum depth of 3 m. Specimens were captured by

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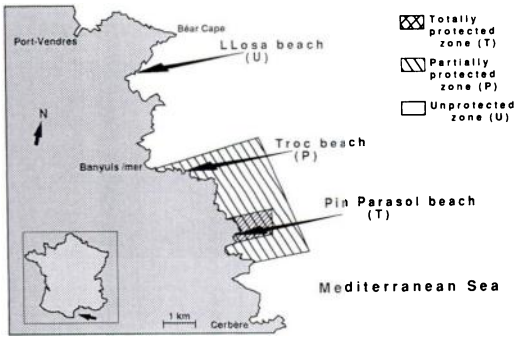


FIGURE 1. Location of the three sampling sites with different protection levels, unprotected zone (U), partially protected zone (P) and totally protected zone (T), in the region of the Marine Reserve of Cerbère-Banyuls, southeastern France.

hand netting using a solution of 20% quinaldine (Sigma Chemical, Saint Louis, Missouri, USA) mixed with 80% acetone.

Total body lengths (Lt) and total weights (Wt) of fishes were measured to the nearest millimeter and centigram, respectively. A condition factor was calculated as $K = (Wt \times 100)/Lt^a$ (with Wt in grams and Lt in centimeters) (Bolger and Connolly, 1989). The values of the exponent (a) were issued for each sex and each sampling station from the simple regression between logarithmic values of total length and total body weight.

To determine age and the percentage of regenerated scales of *G. bucchichii,* 20 to 40 scales were removed from under the pectoral fin and washed in a solution of 10% sodium hypochlorite in distilled water. They were then rinsed in freshwater. Annuli were clear enough to determine age of the fish (Sasal et al., 1996), even though it is currently established that gobiid scales are not suitable for estimating age (Miller, 1961). Age-0 fish were defined as less than 1-yr old fish (no annulus), age-1 fish were more than 1 but less than 2-yr old (1 annulus), and so on.

Fishes were dissected immediatly after collection and adult macro-parasites were removed alive from the gills and digestive tract. Parasites were fixed in Bouin's solution (Martoja and Martoja-Pierson, 1967) and stained in Grenacher's borax carmine (Langeron, 1949). Nematodes were identified using the key proposed by Chabaud (1975). Acanthocephalans were identified using the key of Golvan (1969). Digenetic trematodes were identified with the key and synopsis of Yamaguti (1971).

Percentage of regenerated scales (% R.S.) was transformed in arcsin $(\%\ R.S.)^{1/2}$. The analysis of variance (ANOVA) and *t*-test between the stations were performed on transformed values of parasites (Ln (number of parasite + 1)) in order to look at abundance differences between the populations (Zar, 1984). A Z-test was done to compare prevalence of infections (Zar, 1984). In order to evaluate the impact of parasitism on the host population in relation to protection, biological data of fishes were analyzed in relation to parasitism and protection using the same methods, considering separately parasitized and unparasitized fishes.

RESULTS

Five species of adult macro-parasites were collected from *G. bucchichii*: one acanthocephalan, *Acanthocephaloides propinquus* Dujardin, 1845 (Acanthocephala, Arhythmacanthidae), one nematode, *Cucullanus* sp. (Nematoda, Cucullanidae) and three digenetic trematodes, *Helicometra* sp. (Digenea, Opecœlidae), *Derogenes* sp. (Digenea, Hemiuridae), and *Deretrema scorpaenicola* Bartoli, 1990 (Digenea, Zoogonidae) (Table 1). Most species were found in the intestine, but *Derogenes* sp. and *D. scorpaenicola* occurred in the gall bladder. Only female nematodes were encountered, preventing specific determination. Voucher specimens are deposited in the Muséum National d'Histoires Naturelles of Paris, France, for the parasites (Accession numbers 492 HF-Tg 110 for *D. scorpaenicola,* 493 HF-Tg 111 for *Derogenes* sp., 494 HF-Tg 112 and 495 HF-Tg 113 for *Helicometra* sp., 496 HF-H66 for the acanthocephalan, and 497 HF-N683 for the nematode) and for the host (Accession numbers MNHN 1996-127).

Helicometra sp. was the most abundant parasite in *G. bucchichii.* Prevalence and abundance were both higher in protected areas (T and P) compared to the unprotected zone (U) (U versus P, $P < 0.01$; U versus T, $P < 0.01$). The two gall-bladder digeneans were less abundant than *Helicometra* sp.. Abundance and prevalence for *Derogenes* sp. did not differ significantly between stations. In contrast, abundance for *D. scorpaenicola* decreased in protected areas and a significant difference was detected between the unprotected and the totally protected areas ($P < 0.01$).

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TABLE 1. Prevalence (%), abundance, and mean intensity of parasites of *Gobius bucchichii* in and out of the Cerbère-Banyuls Marine Reserve and comparison of abundance (ANOVA and pair comparison *t*-test) and prevalence (Z-test).

Species		U[a] (n = 150)	P (n = 122)	T (n = 124)	Abundance	Prevalence
Helicometra sp.	Prevalence	20	53.3	41.1	U < P[b]	U < P[b]
	Abundance	0.31	1.47	1.13	U < T[b]	U × T[b]
	Mean intensity	1.53	2.75	2.75	P–T[d]	P–T[d]
	Range	1–5	1–15	1–12		
Derogenes sp.	Prevalence	4	4.9	6.5	U–P[d]	U–P[d]
	Abundance	0.05	0.06	0.07	U–T[d]	U–T[d]
	Mean intensity	1.33	1.17	1.13	P–T[d]	P–T[d]
	Range	1–3	1–2	1–2		
Deretrema scorpaenicola	Prevalence	9.3	3.3	1.6	U–P[d]	U–P[d]
	Abundance	0.1	0.05	0.02	U > T[b]	U–T[d]
	Mean intensity	1.07	1.50	1	P–T[d]	P–T[d]
	Range	1–2	1–3	1		
Acanthocephaloides propinquus	Prevalence	0	0.8	4.9		U–P[d]
	Abundance	0	0.01	0.07	U–P[d]	U–T[d]
	Mean intensity	0	1	1.5	U < T[b]	P–T[d]
	Range	0	1	1–4	P < T[c]	
Cucullanus sp.	Prevalence	2.7	0.8	3.2		U–P[d]
	Abundance	0.03	0.01	0.04	U–P[d]	U–T[d]
	Mean intensity	1	1	1.25	U–T[d]	P–T[d]
	Range	1	1	1–2	P–T[d]	

[a] U = Unprotected zone; P = Partially protected zone; T = Totally protected zone.
[b] Significantly ($P < 0.01$) different.
[c] Significantly ($P < 0.05$) different.
[d] Not significantly ($P > 0.05$) different.

However, no significant differences were detected for prevalence.

Acanthocephaloides propinquus was found in protected areas only. This species was significantly ($P < 0.05$) more abundant in the totally protected area (T) than in the other sites. Values of prevalence were not significantly different between the three stations.

Cucullanus sp. (Nematoda) was present at all the three stations. No significant differences were found in abundance or prevalence between the three sites.

Mean length of fishes was significantly higher in the totally protected area compared to the unprotected and the partially protected areas ($P < 0.01$). Fishes were significantly older in totally and partially protected sites than in the unprotected area, and the values of the condition factor were significantly higher in the totally protected area compared to unprotected and partially protected sites ($P < 0.01$); the percentage of regenerated scales (% R S) was significantly ($P < 0.05$) higher in totally protected site compared to the unprotected one (Table 2).

Parasitized fishes were larger than unparasitized ones ($P < 0.01$) (Table 3). Unparasitized fishes were larger in the totally protected site compared to the unprotected site ($P < 0.01$) and parasitized ones were larger in the totally protected site compared to the partially protected one ($P < 0.01$) (Table 4). Parasitized fishes were older than unparasitized ones ($P < 0.05$), but no significant differences were found between stations for either parasitized or unparasitized fishes.

There condition factor did not differ significantly between parasitized and unparasitized fishes. However, the mean value

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TABLE 2. Total-length, age, condition factor (K) and percentage of regenerated scales (% RS) of *Gobius bucchichii* in the three different stations. Tests for regenerated scales were done on transformed values.

	Number of fish studied	Total length (mm) $\bar{x} \pm SD$	Age (yr) $\bar{x} \pm SD$	K (10^{-3} g/cm^3) $\bar{x} \pm SD$	% RS $\bar{x} \pm SD$
Unprotected Zone (U)	150	75.8 ± 15.0	2.7 ± 1.1	8.13 ± 1.06	60.8 ± 24.7
Partially protected zone (P)	122	76.5 ± 15.2	3.2 ± 1.3	8.15 ± 0.75	65.2 ± 21.6
Totally protected zone (T)	124	82.7 ± 15.5	3.2 ± 1.3	8.64 ± 1.58	67.6 ± 20.3
Spatial comparison	396	U–P[a] U < T[c] P < T[c]	U < P[b] U < T[c] P–T[a]	U–P[a] U < T[c] P < T[c]	U–P[a] U < T[b] P–T[a]

[a] No significant difference ($P > 0.05$).
[b] Significant difference ($P < 0.05$).
[c] Significant difference ($P < 0.01$).

of the condition factor was significantly higher for parasitized fishes in the totally protected site compared to other stations. Furthermore, unparasitized fishes had a significantly higher mean condition factor in the totally protected site than those in the partially protected site ($P < 0.05$).

The percentage of regenerated scales was significantly lower in unparasitized fishes than in parasitized ones ($P < 0.01$). When values of regenerated scales were controlled for age of fishes, this difference was significant only for fishes less than 3 yr old ($P < 0.05$) and not for older fishes. A significant difference was evident between the unprotected site and the totally protected site for unparasitized fishes ($P < 0.01$), while no spatial differences were found for parasitized fishes.

DISCUSSION

To our knowledge, this is the first time that changes in the parasitofauna in relation to the population structure of a host were investigated in areas presenting different levels of protection to a fish species. Based on comparisons of the parasitofauna, we observed three major findings. First, there was a higher level of parasite species richness at higher levels of protection. This was supported by the presence of the acanthocephalan, *Ancanthocephaloides propinquus,* only in the reserve. Acanthocephalans have heteroxenous life cycles and use crustaceans as intermediate hosts (Buron and Golvan, 1986). The presence of this parasite in the reserve probably was linked to the presence of the appropriate intermediate hosts, but no data are available. *Ancanthocephaloides propinquus* has a large definitive host range; Buron (1986) listed more than 40 fish species as hosts of this parasite. Thus its life cycle could be favored in a reserve because of higher densities of potential definitive hosts such as *Diplodus annularis* (Dufour et al., 1995).

Second, there was a change in parasite

TABLE 3. Total length, the age, the condition factor (K) and the percentage of regenerated scales (% RS) for parasitized and unparasitized fishes.

	Number of fish studied	Total length (mm) $\bar{x} \pm SD$	Age (yr.) $\bar{x} \pm SD$	K (10^{-3} g/cm^3) $\bar{x} \pm SD$	% RS $\bar{x} \pm SD$
Parasitized	215	80.5 ± 14.2	3.2 ± 1.1	8.28 ± 1.23	68.4 ± 19.7
Unparasitized	181	75.4 ± 16.4[a]	2.8 ± 1.3[b]	8.32 ± 1.16	59.9 ± 24.6[a]

[a] Significant ($P < 0.01$) difference from parasitized fish.
[b] Significant ($P < 0.05$) difference from parasitized fish.

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TABLE 4. Spatial variations for the mean values of the total length, the age, the condition factor (K) and the percentage of regenerated scales (% RS) in the three different stations for parasitized and unparasitized fishes.

		Number of fish studied	Total length (mm) ± SD	Age (yr.) ± SD	K (10^{-3} g/cm^3) ± SD	% RS ± SD
Unprotected zone (U)	Parasitized	70	79.8 ± 13.1	2.9 ± 0.9	7.98 ± 1.06	70.7 ± 20.2
	Unparasitized	80	72.3 ± 15.7	2.6 ± 1.2	8.26 ± 1.04	53.7 ± 25.4
Partially protected zone (P)	Parasitized	76	77.6 ± 14.7	3.4 ± 1.3	8.19 ± 0.82	67.4 ± 20.3
	Unparasitized	46	74.7 ± 15.9	2.9 ± 1.3	8.09 ± 0.63	61.0 ± 23.6
Total protected zone (T)	Parasitized	69	84.5 ± 14.3	3.4 ± 1.2	8.68 ± 1.61	67.4 ± 18.9
	Unparasitized	55	80.6 ± 16.7	3.1 ± 1.3	8.59 ± 1.57	67.9 ± 22.1
Spatial comparison	Parasitized	215	U–P[a]	U–P[a]	U–P[a]	U–P[a]
			U–T[a]	U–T[a]	U < T[c]	U–T[a]
			P < T[c]	P–T[a]	P < T[b]	P–T[a]
	Unparasitized	181	U–P[a]	U–P[a]	U–P[a]	U–P[a]
			U < T[b]	U–T[a]	U–T[a]	U < T[c]
			P–T[a]	P–T[a]	P < T[b]	P–T[a]

[a] No significant difference ($P > 0.05$).
[b] Significant difference ($P < 0.05$).
[c] Significant difference ($P < 0.01$).

infection between different stations at different levels of protection. Prevalence or abundance of *Helicometra* sp. and *A. propinquus* increased in relation to the level of protection. The higher abundance of *Helicometra* sp. with protection could be connected to a very wide host range; Reversat et al. (1991), listed 50 hosts species in the Mediterranean Sea. It also could connected to an increase of the densities of potential hosts in protected areas; Dufour et al. (1995) observed an increase in densities of potential hosts, such as *Coris julis, Labrus merula, Symphodus ocellatus* and *S. tinca* in protected sites.

On the contrary, *D. scorpaenicola* has lower abundance in protected areas. This species has a rather narrow host range, five species according to Bartoli and Bray (1990). *Gobius bucchichii* is considered to be an occasional host based on its very low prevalence. The significant differences in values of abundance observed between unprotected zone and totally protected zone may be connected with the decrease in numbers of the type host (*Scorpaena porcus*) and other usual hosts in the totally protected area. Three of four potential host species (*Scorpaena porcus, Serranus cabrilla* and *Serranus scriba*) described by Bartoli and Bray (1990) have lower mean densities in protected areas (Bell, 1983; Dufour et al., 1995). The fourth species (*Labrus merula*) whose density was higher in the reserve, appeared to be an occasional host (Bartoli and Bray, 1990) and may not play an important role in the transmission dynamics of this trematode.

Third, prevalence and abundance of *Derogenes* sp. and *Cucullanus* sp. did not change in different stations. Unfortunately, no data are available on the life cycles of these parasites.

The increase of parasite burden with respect to protection may have been related to an increase in the biomass and densities of hosts in marine reserves. However, some species of parasites showed unchanged or decreasing values of abundance in protected areas highlighting the importance of parasite life-history traits.

Increases in the mean length and age of the *G. bucchichii* populations structure (Sasal et al., 1996) were considered in order to evaluate the impact of the protection on this unfished species. This is the first known report that an unfished species of fish was larger, lived longer, had a higher mean condition factor, and had a higher rate of regenerated scales in a protected

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area. Thus, even in an unfished species, there are some benefits to the protection of marine reserves.

Parasitized fishes were larger and older than unparasitized ones. This was consistent with the positive correlation between length (Saad-Fares and Combes, 1992) or age (Buchmann, 1989), and parasite burden.

Based on the lack of differences in mean values of the condition factor between infected and uninfected fishes, we believe that there was an absence of adult parasite-induced negative effects on this host. Occasionally, adult parasites produce direct negative effects on their hosts; however, such effects are usually induced by larval stages of parasites (Faliex and Morand, 1994).

Infected fishes had a higher percentage of regenerated scales compared to uninfected ones. This difference was essentially significant for young fishes but not significant for older fishes; this was due to the cumulative effect of regenerated scales during the fish life. Moreover, parasitized fishes were larger than unparasitized ones and the percentage of regenerated scales was positively correlated with the length of the fishes ($R^2 = 0.42$, $P < 0.01$). Thus, the higher rate of regenerated scales in infected fishes could have been the result of the age effect, and the parasites may have had a synergetic action by increasing stress (Sire, 1982) and physiological changes (Aoyama, 1957); these things could have affected the rate of regenerated scales on young fishes.

In conclusion, we found no clear negative impact of adult parasites on populations of *G. bucchichii,* either out of the protected area or in the reserve where parasite burden was on average higher. We found a modification of the parasite community and we related it to the modification of the whole fish community in the protected area (Dufour et al., 1995). However each species of parasite had different responses in relation to the level of protection. Host range was hypothesized as the main factor affecting parasite abundance. We hypothesize that parasites with a large range of definitive hosts may have higher levels of abundance and intensity because of the protection; they would encounter more potential intermediate hosts in protected areas. Furthermore, parasites with narrow specificity would not be specially favored in the protected areas when their host densities were not affected.

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