Iranian Journal of Fisheries Sciences 6(2)33-58 2007

Impact of two parasitic trematodes, *Meiogymnophallus minutus* and *Himasthla* spp., on the growth of cockle, *Cerastoderma edule*

A. Javanshir[1*] ; S. J. Seyfabadi[2] ; G. Bachelet[3] and J. Feghhi[1]

arashjavanshir@hotmail.com

1- Natural Resources Faculty, University of Tehran, Karaj, Iran

2- Faculty of Natural Resources and Marine Biology, Tarbiat Modarres University, Noor, Iran

3- Station Zoologique d`Arcachon, France

Received: May 2004 Accepted: November 2006

Abstract: The impact of two principal parasitic digenetic trematodes, *Meiogymnophallus minutus* and *Himasthla* spp., on the growth (weight and length) of the cockle, *Cerastoderma edule,* in Arcachon Bay (France) was studied. The experiment was conducted in the land-based mesocosms. The velocity of infestation with both trematodes was far more rapid during summer in the cockles already parasitized with these trematodes (0.35 to 0.45 metacercariae day^{-1}) than those of healthy ones (approximately 0.01 metacercariae day^{-1}). The parasitism had also an effect on the growth rates of cockles. During 190 days of the experiment, the daily growth speed varied from 0.001mm.day^{-1} to 0.021mm.day^{-1}. On average, the growth was slightly more important in healthy cockles after the start of experiments (0.014mm.day^{-1}) than those initially infested cockles (0.011mm.day^{-1}). The experiment also showed that infestation of hosts with trematodes could perhaps disturb their immunity system, as the intensification with trematode parasites had been favored by already infested cockles.

Keywords: Mesocosm, *Cerastoderma edule*, parasitism, Digenea, growth, Host parasite interactions

---

* **Corresponding author**

Introduction

Parasites are one of the omnipresent, often invisible, components of animal populations. They can constitute an important quantity of the biomass of host individuals, modify the consumption of oxygen (Javanshir, 2001a), energy reserves (Javanshir, 2001b) and the metabolism of their host (Lauckner, 1983). They can modify the proportion of individuals of the host-population, participate in the reproduction (Deltreil & His, 1970; Taskinen & Valtonen, 1995), decrease the egg production of the host (Taskinen & Valtonen, 1995), and also allocate some nutrition for growth (Taskinen & Valtonen, 1995). Some parasites can increase the mortality of their host-population (Jonsson & André, 1992). The parasitic infestation in marine bivalve can induce a reaction to survival of their host, which is always dependent on the intensity of infestation (Bartoli, 1973). The reduction of the density of a population due to parasites has been demonstrated in laboratory, showing that infested preys can affect healthy predators (Hulscher, 1982).

Parasitism has often been neglected in studies of population dynamics of marine invertebrate; traditionally, competition and predation or seasonal variations of the hydro-climate have been admitted as the major determinants of this population dynamics (Navarro *et al.*, 1989; Vincent *et al.*, 1989; Montaudouin & Bachelet, 1995). Even in studies on marine organisms physiology, the factor of parasitism has often been neglected (Smaal, 1998). Several in situ experiments or theories suggest, never-theless, that parasitism is an important factor and can have a notable influence on the dynamics of populations (Minchella & Scott, 1991; Sousa, 1991; Javanshir, 2001a & b).

The edible cockle, *Cerastoderma edule* (L.), has been chosen for several years as a model species for studies on population dynamics carried out in the Oceanography Laboratory of Arcachon, in the framework of the national programs (GLOBEC-FRANCE/Programme National de Developpement et de Recrutement) as well as Programme National de l'Environnement Côtier). These studies have been aimed to explain the effect of such environmental factors as competition, population density, latitude and predation on *C. edule* inter-annual recruitment factors as reproduction (Madani, 1989; Guillou *et al.*, 1990,1992), Growth

(Madani, 1989; Ducrotoy *et al.*, 1991; Montaudouin, 1995, 1996; Montaudouin & Bachelet, 1995,1996), mortality (Madani, 1989; Ducrotoy *et al.*, 1991; Guillou *et al.*, 1992; Montaudouin, 1995), inter and intra-specific competition (Bachelet *et al.*, 1992 a,b; Montaudouin, 1995; Montaudouin & Bachelet, 1996), predation (Montaudouin, 1995) and hydrodynamic on juvenile dispersion (Montaudouin & Bachelet, 1995&1996).

The influence of the factor parasitism on populations of bivalves of the Arcachon Basin has, nevertheless, been little studied. The presence of the digenetic trematode, *Labratrema minimus,* in cockles of the Arcachon Basin and its castration effect was reported by Deltreil & His (1970). Other studies have demonstrated the parasitism as one of the mechanisms that affect the recruitment of the cockles (Kisielewski, 1998; Jensen *et al.*, 1999).

The first objective of this experiment was to determine the time and intensity the cockles were infested with trematodes; this was accomplished by placing healthy cockles (non-infested) at sites where cockles were "naturally" highly infested and follow the rate of infestation and, simultaneously, compared with the native infested cockle.

The second objective of this *in situ* mesocosm experiment was to evaluate the effect of the parasitic infestation on the cockles' growth (linear and weight-related).

Materials and Methods

The experiment was carried out in mesocosm environments from Oct.1996 to Apr.1997 on an intertidal site in the North Arguin islet, Arcachon bay, southwest of France. Three parameters were taken into account:

1) The infestation status by the metacercariae of *Himasthla* spp. and *Meiogymnophallus minutus* (the most frequent Digenea on the shore of Arguin site). Despite prevalent infestation by these two parasites (at metacercariae stage) at Arguin site, they were totally absent on other sites of the Arcachon bay (Javanshir, 1999).

2) The density of cockles that can exert influence on the individual's growth (Bachelet *et al.*, 1992 a,b). For this purpose, two experimental adult densities of

400 and 1200 ind.m^{-2} were taken into consideration; this was based on the natural population range reported in the earlier works. The average cockle density on the Arguin site was 171 ind.m^{-2}, therefore, clearly inferior to experimental densities. The former was, however, similar to the natural densities estimated by Madani (1989): 483 ind.m^{-2} of size >17mm on the Péreire site or maximal experimental densities used by Bachelet *et al.* (1992 a,b: 1257 ind.m^{-2}) and Montaudouin (1995: 1440 ind.m^{-2}).

3) The initial size of cockles; to take into account the influence of the initial size on the growth and infestation rate during our experiments. For this purpose, two length groups were selected based on the size range present during autumn 1996: individuals < 25mm and individuals > 25mm.

In Sep.1996, sixteen mesocosms (cages) of 50x50x20cm dimensions constituted of a metalic frame of 6 mm diameter and plastic net-walls of 5x5mm mesh size were installed parallel to the shore in the intertidal zone of the Arguin islet. Each mesocosm penetrated 5cm in the sediment. Based on our three concerned parameters and their backgrounds, *viz* health, initial size and density (per 0.25m^2 of the experimental mesocosm), the followings were derived:

- Healthy cockles [S] or parasitized [P],
- Cockles of size < 25mm [l] or > 25mm [L],
- Cockles in low density (100 by mesocosm [d], or in high density (300 by mesocosm [D]),

Based on the above parameters, the following eight combinations (treatments) in 2 replications were designated:

Pdl = parasited cockles, in low density and small size,
PdL = parasited cockles, in low density and large size,
PDl = parasited cockles, in high density and small size,
PDL = parasited cockles, in high density and large size,
Sdl = healthy cockles, in low density and small size,
SdL = healthy cockles, in low density and large size,
SDl= healthy cockles, in high density and small size,
SDL = healthy cockles, in high density and large size

These eight treatments (in 2 replicates) were randomly distributed into 16 designated mesocosm (pens) (Fig. 1).

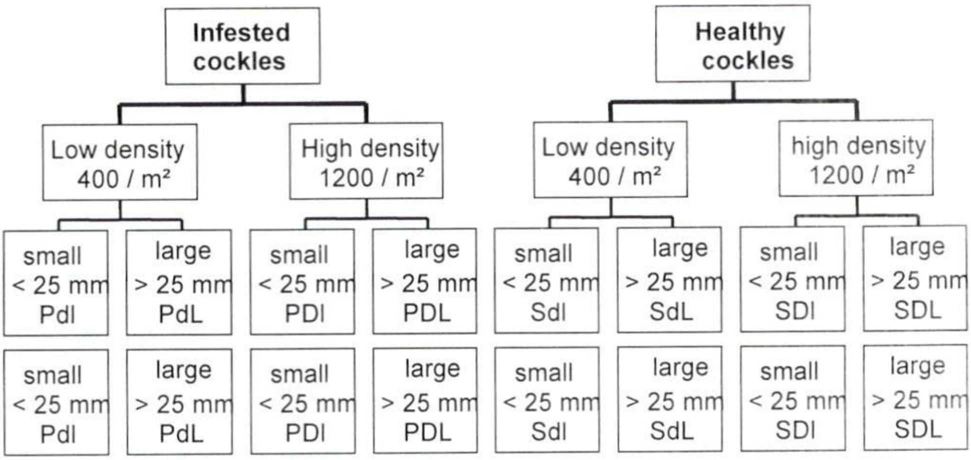

Figure 1: Arrangement of Mesocosm enclosures containing three experimental treatments (two conditions of parasitism, two conditions of density and two conditions of cockle size), of the Banc d'Arguin site.

The experiment was commenced on Oct. 2, 1996 and had been planned to be carried out for one complete year, but the displacement of sand hills and burial of several mesocosms during strong storms in the spring of the next year motivated its stop in April 1997.

Sampling was performed once in every two months in which 15 cockles were randomly removed from each mesocosm and transferred to the laboratory for analysis. In order to keep the density of the mesocosms constant, the picked samples were immediately replaced with equal number of infested cockles from Arguin site (infested at 99% of the population). In order to avoid picking the replaced samples in the next sampling times, they were marked with nail varnish. During each sampling, mesocosms were cleaned of seaweeds and other biofoulers/debris clogging the net-walls. The length and weight (dry flesh) of the picked up samples in the laboratory were measured and their parasites were specifically determined and counted.

Statistical analysis

The effect of each experimental treatment at each sampling time was compared by means of analysis of variance (software Statistica 5), using three independent factors (parasite status, density and size) and four dependent variables: the intensity of infestation by *Himasthla* spp., the intensity of infestation by *Meiogymnophallus minutus*, the dry flesh weight and the size of cockles.

Results

Interaction of the experimental factors on the size evolution of cockles (Fig. 2, Table 1):

The factor "initial size" had always had a highly significant effect ($P<0.001$) on the size evolution of cockles; the groups with large initial size (L) maintained higher size at each sampling throughout the course of experiment.

The factor "density" remained without any influence ($P>0.05$) on the size evolution of cockles until the third sampling time (T_3). From T_0 to T_2, no significant difference in the average size of cockles between high (D) and low (d) densities was found [in T_0, the average size of high density (D) was 26.92mm and that of low density (d) was 27.09mm; in T_1, D was 27.26mm and that of d was 27.56mm; in T_2, D was 28.87mm and that of d was 28.65mm]. In T_3, however, a significant difference ($P<0.001$) in the average size of cockles between high density (D) (30. 06mm) and low density (d) (28. 84mm) was observed, indicating the larger size was achieved in the higher density.

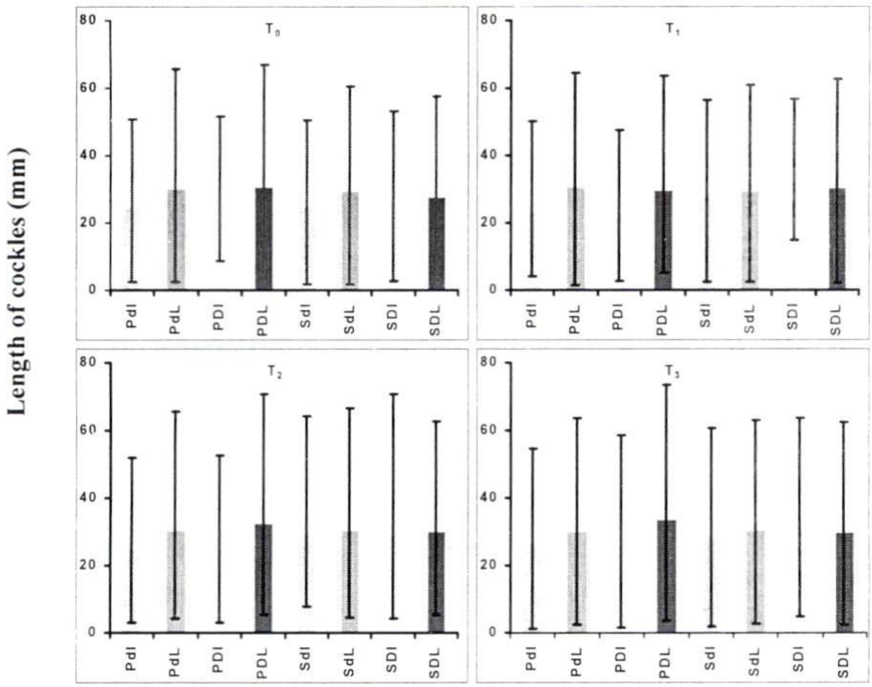

Figure 2: Evolution of the cockle size in different treatments from T_0 to T_3. Barrs show the minimum and the maximum of these values.

Table 1: Analysis of variance showing the interaction of the three experimental factors "parasitism," "density," and "size" on the size of cockles, during four sampling times (T_0 to T_3). Numbers of degrees of freedom for each source of variation is 1; for the error: 232 from T_0 to T_2, 185 in T_3.

Sampling time	Source of variation	F	p
T_0	Parasitism	2.952	0.087
	Density	0.558	0.455
	Size	358.165	< 0.001***
	Parasitism x density	1.994	0.159
	Parasitism x size	40.412	< 0.001***
	Density x size	3.038	0.082
	Parasitism x density x size	18.011	< 0.001***
T_1	Parasitism	61.414	< 0.001***
	Density	1.370	0.242
	Size	359.395	< 0.001***
	Parasitism x density	2.970	0.086
	Parasitism x size	80.547	< 0.001***
	Density x size	0.889	0.346
	Parasitism x density x size	3.316	0.069
T_2	Parasitism	16.169	< 0.001***
	Density	0.572	0.450
	Size	131.180	< 0.001***
	Parasitism x density	6.161	0.013*
	Parasitism x size	63.675	< 0.001***
	Density x size	3.479	0.063
	Parasitism x density x size	1.027	0.311
T_3	Parasitism	0.139	0.709
	Density	19.686	< 0.001***
	Size	90.448	< 0.001***
	Parasitism x density	12.456	< 0.001***
	Parasitism x size	52.875	< 0.001***
	Density x size	0.788	0.375
	Parasitism x density x size	14.381	< 0.001***

The factor "parasitism" did not greatly affect ($P>0.05$) the average size in T_0 [the average sizes of parasitized (P) and healthy (S) cockles were 27.21 mm and 26.81 mm, respectively]. In T_1, however, the size growth in parasitized cockles (26.40 mm) was significantly lower ($P<0.001$) than the healthy ones (28.41 mm); in T_2, too, the size growth in parasitized cockles (28.12mm) was significantly lower ($P<0.001$) than the healthy ones (29.40mm); in T_3, however, no difference in size between parasitized cockles (29.40mm) and healthy ones (29.50mm) was found.

During 190 days of the experiment, the daily growth speed varied from 0.001mm.day^{-1} (treatment PdL) to 0.021mm.day^{-1} (treatment SDl) (Fig. 3). On average, the growth has been slightly more important in healthy cockles after the start of experiment (0.014mm.day^{-1}) than that in initially infested cockles (0.011mm.day^{-1}).

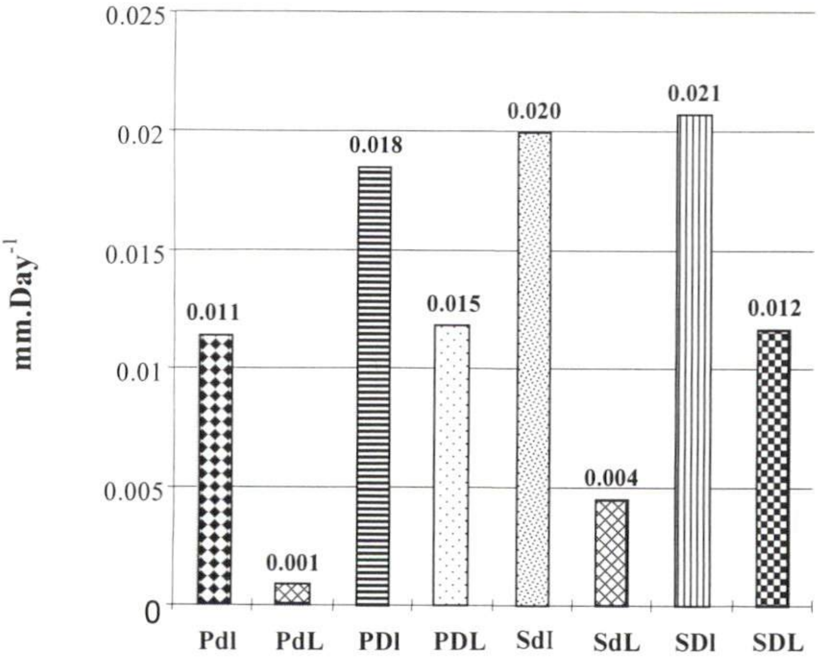

Figure 3: Growth rate (per day) of cockles in different treatments during the whole period of experiments.

Interaction of the experimental factors on the cockles' weight evolution (Fig. 4, Table 2):

Similar to the size evolution, the average weight in T_0, too, was not greatly affected (P>0.05) by the factor "parasitism"[the average weight of parasitized (P) and healthy (S) cockles were 0.28g and 0.29g, respectively]. In later sampling times, however, significant differences between weight of parasitized and healthy cockles were observed; in T_1 the average weight of parasitized and healthy cockles were 0.20g and 0.22g (P<0.05), respectively; in T_2, the average weight of parasitized and healthy cockles were 0.27g and 0.35g, and those for T_3 were 0.28g and 0.46g (P<0.001), respectively.

As for the factor "density", the weight was always superior in the low density (d) than the high density (D) treatments, except for not being statistically meaningful in T_0 and T_2 [D=0.28g, d=0.29g and D=0.31g, d=0.32g (P>0.05), respectively]. In T_1, the average weight in low and high density treatments were 0.19g & 0.23g (P<0.01), and those for T_3 were 0.33g & 0.41g (P<0.001), respectively.

Finally, the factor "initial size" had a highly significant effect (P<0.001 or P<0.01) on the weight at all sampling times. In other words, the cockles of the greater size were logically those of the larger initial size.

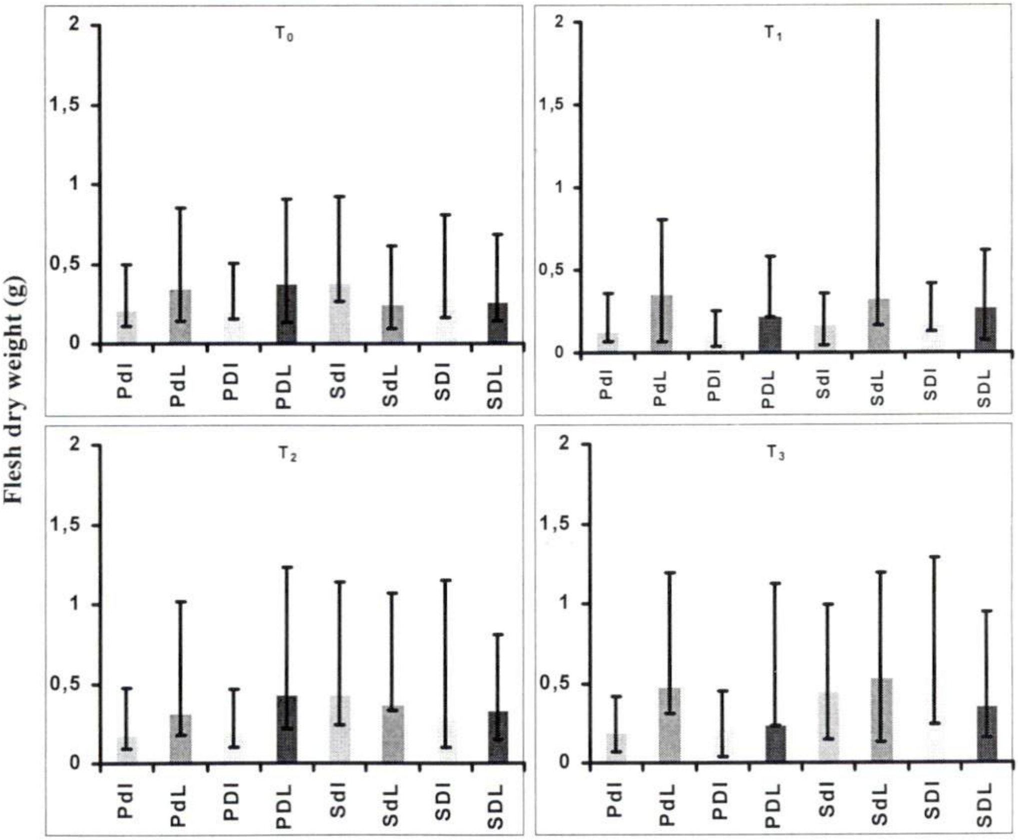

Figure 4: Development of dry weights (g) of cockles in different treatments from T_0 to T_3. Barres shows minimum and maximum of the value.

Table 2: Analysis of variance showing the interaction of the three experimental factors "parasitism," "density," and "size" on the weight of cockles, during four sampling times (T_0 to T_3). Numbers of degrees of freedom for each source of variation: 1; for the error: 232 of T_0 to T_2, 185 in T_3.

Sampling time	Source of variation	F	p
	Parasitism	2.081	0.150
	Density	0.942	0.332
	Size	13.575	< 0.001***
T_0	Parasitism x density	3.555	0.060
	Parasitism x size	138.767	< 0.001***
	Density x size	7.715	0.005**
	Parasitism x density x size	1.906	0.168
	Parasitism	4.641	0.032*
	Density	8.727	0.003**
	Size	88.139	< 0.001***
T_1	Parasitism x density	2.911	0.089
	Parasitism x size	2.486	0.116
	Density x size	8.972	0.003**
	Parasitism x density x size	0.470	0.493
	Parasitism	30.148	< 0.001***
	Density	0.475	0.491
	Size	39.479	< 0.001***
T_2	Parasitism x density	29.126	< 0.001***
	Parasitism x size	52.638	< 0.001***
	Density x size	11.843	< 0.001***
	Parasitism x density x size	0.002	0.957
	Parasitism	109.364	< 0.001***
	Density	20.566	< 0.001***
	Size	11.027	0.001**
T_3	Parasitism x density	2.685	0.102
	Parasitism x size	31.702	< 0.001***
	Density x size	52.095	< 0.001***
	Parasitism x density x size	0.014	0.904

Interaction of the experimental factors on the cockles' infestation intensity with *Himasthla* spp. (Fig. 5, Table 3):

The number of *Himasthla* cysts always remained higher in the initially parasitized cockles (P) than the initially healthy ones (S), except in the last sampling time (T_3). In T_0, the average number of *Himasthla* cysts in parasitized cockles (6.87) was greatly superior ($P<0.001$) to the healthy ones (0); this difference between parasitized (11.80) & healthy cockles (3.17) in T_1 and 11.72 & 3.25 in T_2 remained high ($P<0.001$), but no significant difference ($P>0.05$) in the parasite intensity between the initially parasitized (8.69) and healthy (7.40) individuals was found in the last sampling period (T_3).

The factor "density" did not significantly ($P>0.05$) affect the parasite intensity in T_0). In the later sampling periods, however, the "density" factor exhibited significant effects on the parasite intensity, that the cockles in high density were more parasitized ($p<0.001$) than those in low density. In T_1, the average number of *Himasthla* cysts in high & low density individuals were 9.41 & 5.56, respectively; this number in T_2 were 9.24 & 5.74, and those for T_3 were 11.00 & 5.09, respectively.

The effect of "initial size" factor was very obvious ($P<0.001$) in T_0 to $T_{2,}$ for the cockles of greater size containing a higher number of *Himasthla*t cysts than the smaller ones. In $T_{0,}$ the average number of *Himasthla*t cysts in the larger (L) & smaller (l) individuals were 5.19 & 1.68, respectively; in T_1, these numbers were 12.43 & 2.53, and those for T_2 were 11.56 & 3.41, respectively. The "initial size" effect on parasite intensity in T3 was significant, however at ($P<0.\ 05$), being 9.19 & 6.90 for larger and smaller individuals, respectively.

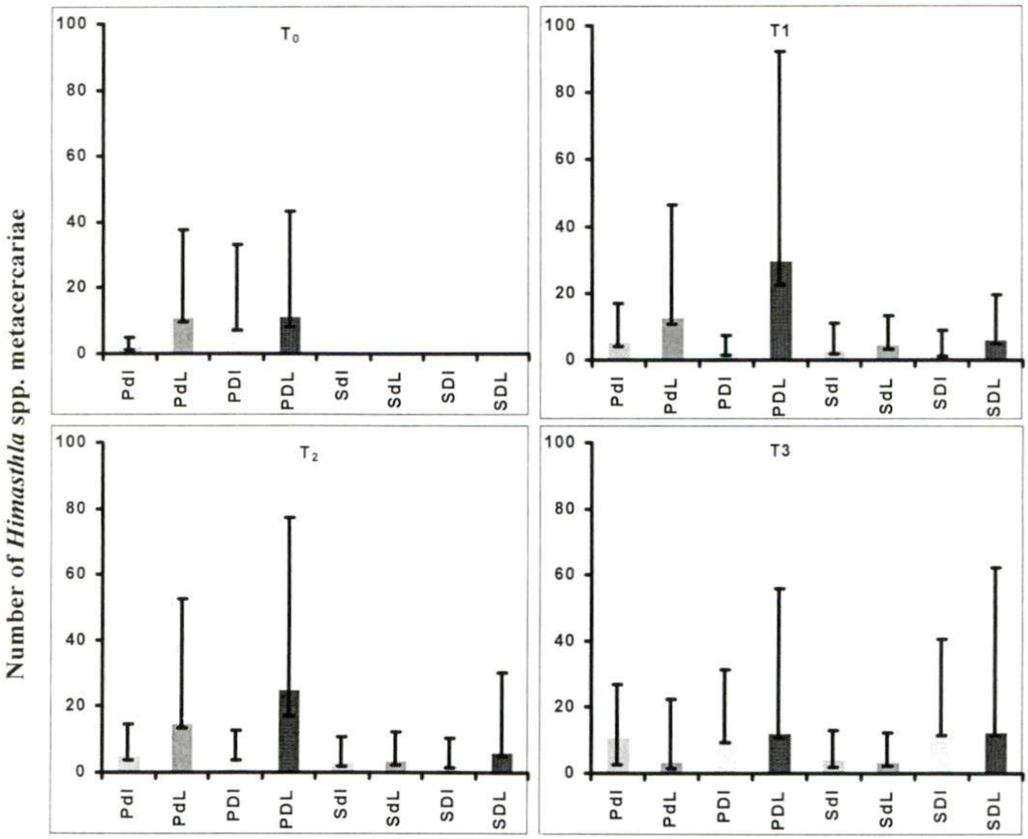

Figure 5: Development of infestation intensity by cysts of *Himasthla* spp. from T_0 to T_3. Barrs show minimum and maximum of the value.

Table 3: Analysis of variance showing the interaction of the three experimental factors "parasitism," "density," and "size" on the intensity of infestation by *Himasthla* spp., during four sampling times (T_0 to T_3). Numbers of degrees of liberty for each source of variation: 1; for the error: 232 of T_0 to T_2, 185 in T_3.

Sampling time	Source of variation	F	p
T_0	Parasitism	160.519	< 0.001***
	Density	2.656	0.104
	Size	42.101	< 0.001***
	Parasitism x density	2.656	0.104
	Parasitism x size	42.101	< 0.001***
	Density x size	4.633	0.032*
	Parasitism x density x size	4.633	0.032*
T_1	Parasitism	110.221	< 0.001***
	Density	21.919	< 0.001***
	Size	144.936	< 0.001***
	Parasitism x density	13.756	< 0.001***
	Parasitism x size	73.847	< 0.001***
	Density x size	39.730	< 0.001***
	Parasitism x density x size	24.656	< 0.001***
T_2	Parasitism	106.871	< 0.001***
	Density	18.263	< 0.001***
	Size	99.029	< 0.001***
	Parasitism x density	8.350	0.004**
	Parasitism x size	63.313	< 0.001***
	Density x size	20.965	< 0.001***
	Parasitism x density x size	9.194	0.002**
T_3	Parasitism	1.374	0.242
	Density	28.534	< 0.001***
	Size	4.258	0.040*
	Parasitism x density	2.631	0.106
	Parasitism x size	1.595	0.208
	Density x size	4.244	0.040*
	Parasitism x density x size	4.182	0.042*

Interaction of the experimental factors on the cockles' infestation intensity with *Meiogymnophallus minutus* (Fig. 6, Table 4):

The factor "density" had a significant effect on the intensity of infestation with *M. minutus* at T_1 and T_2. Contrary to what was observed for *Himasthla* spp., these were the cockles of low density treatment that had been the most infested; in T_1, the average number of metacercariae of *M. minutus* in cockles of high density was 36.95, while in low density was 49.29 ($P<0.01$); in T_2, the average number of metacercariae of *M. minutus* in cockles of high density was 44.24 and in low density was 58.31 ($P<0.001$). This factor "density" did not, however, have significant effect ($P>0.05$) in T_0 and T_3.

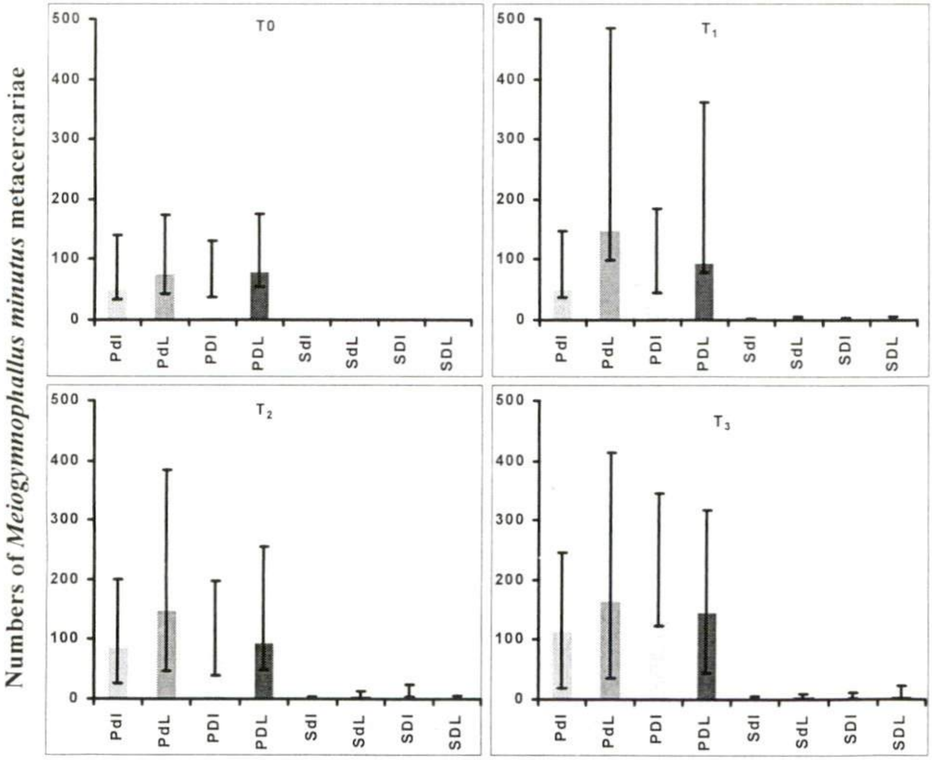

Figure 6: Evolution of infestation intensity by *Meiogymnophallus minutus* from T_0 to T_3. Barrs show minimum and maximum of the value.

Table 4: Analysis of variance showing the interaction of the three experimental factors "parasitism," "density," and "size" on infestation intensity by *Meiogymnophallus minutus*, during four sampling times (T_0 to T_3). Numbers of freedom degree for each source of variation: 1; for error: 232 from T_0 to T_2, 185 at T_3.

Sampling time	Source of variation	F	p
T_0	Parasitism	1322.561	< 0.001***
	Density	0.055	0.814
	Size	71.929	< 0.001***
	Parasitism x density	0.055	0.814
	Parasitism x size	71.929	< 0.001***
	Density x size	0.220	0.639
	Parasitism x density x size	0.220	0.639
T_1	Parasitism	386.136	< 0.001***
	Density	8.027	0.005**
	Size	62.011	< 0.001***
	Parasitism x density	8.126	0.004**
	Parasitism x size	62.044	< 0.001***
	Density x size	11.975	< 0.001***
	Parasitism x density x size	11.414	< 0.001***
T_2	Parasitism	1755.807	< 0.001***
	Density	34.060	< 0.001***
	Size	56.694	< 0.001***
	Parasitism x density	34.799	< 0.001***
	Parasitism x size	60.008	< 0.001***
	Density x size	34.470	< 0.001***
	Parasitism x density x size	25.810	< 0.001***
T_3	Parasitism	2334.274	< 0.001***
	Density	0.024	0.877
	Size	31.962	< 0.001***
	Parasitism x density	0.019	0.889
	Parasitism x size	29.744	< 0.001***
	Density x size	11.340	< 0.001***
	Parasitism x density x size	10.716	0.001**

The intensity of infestation by *M. minutus* has been constantly more raised at cockles of great size ($P<0.001$) and at those initially infested ($P<0.001$).

The intensity of infestation by the metacercariae of *M. minutus*, always high and rising at initially parasitized cockles (overtake of 62.84 metacercariae per individual in T_0 to 139.03 in T_3), has remained remarkably low at healthy cockles (from 0 in T_0 to 1.90 in T_3). The velocity of infestation with this trematodes has thus far more rapid during summer at cockles already parasitized (0.35 to 0.45 metacercariae.day^{-1} according to the treatment) than that of

Discussion

Interaction of the experimental factors on the growth (size & weight) of cockles:

The cockles of initially large size groups (L) maintained their size superiority over the ones of initially small size groups (l) throughout the experiment (Fig. 2 & Table 1). The same superiority in the dry weight of cockles' flesh was also observed (Fig. 4 & Table 2).

A negative effect of the high densities of cockles on the individual weight was somewhat observed during each sampling (Fig. 4 & Table 2). In other words, higher density (D) brought about lower individual weight, which could be traced to intra-specific competition for the food. A similar effect of density on the cockles' individual size was also observed. The obvious influence of density on individual weight has already been studied in cockles (Montaudouin, 1996) and other filter-feeding bivalves (Peterson & Andre, 1980; Peterson & Black, 1987). The influence of density in our experience, however, was not as conspicuous as the earlier mentioned studies; no significant difference in the average size of cockles between high (D) and low (d) densities was found until the third sampling period, but a significant difference ($P<0.001$) between high density (D) (30.06mm) and low density (d) (28.84mm) was observed in the third sampling period, indicating an inverse result from the earlier ones in that the larger size was achieved in the higher density. These surprising results could be explained by an unsimultaneity in the linear growth (size & weight). The short duration of the experiment, less favorable growth circumstances, and the weakness of individuals sampled from cages could have partially contributed here to this ambiguity of density effect on size. On the other hand, it is necessary to underline that some authors (Kamermans *et al.*, 1992) have shown no significant effect of density on the cockle's linear growth.

Our experiment has, further, shown that parasitism by *Himasthla* spp. and *Meiogymnophallus minutus* had a negative effect on cockle's linear growth. Similar results have also been observed on the cockles infested with various trematodes (Sannia *et al.*, 1978; Bowers, 1969) as well as other bivalves (Bartoli, 1973, 1976; Taskinen & Valtonen, 1995).

Interaction of the experimental factors on the cockles' infestation intensity with *Himasthla* spp.:

The intensity of infestation of initially infested cockles with *Himasthla* spp. was significantly greater than those of initially healthy ones until the third sampling period, and then this difference became non-significant in the third sampling period (Fig. 5, Table 3). This means that there has been a "correction", of the intensity cockle's infestation by the absence of parasites in healthy cockles during the experiment.

The intensity of infestation was significantly greater in the group of cockles in high density than the ones in low density, indicating cockles in high density were more prone to infestation with *Himasthla* spp. than the ones in low density. This effect appears unexpected if the infestation of cockles by the cercaria is considered as a passive phenomenon. Personal observations on the artificial infestation of cockles with the cercaria of *Himasthla* spp. have shown that this phenomenon can be strengthened by the high ventilation exerted by dense populations.

Finally, the infestation intensity with *Himasthla* spp. was higher in the "large" cockles than the "small" ones until the third sampling period. According to Montaudouin *et al.* (1998) and Wegeberg *et al.* (1999), the infestation with the cercaria is a function of the filtration; the entry of the cercaria in cockles could have, therefore, been higher by the strong filtration exerted by the large cockles than the relatively lower filtration rate of the small ones.

Interaction of the experimental factors on the cockles' infestation intensity with *Meiogymnophallus minutus*:

As in the case of *Himasthla* spp., the intensity of infestation with *M. minutus* of initially infested cockles was significantly greater than those of initially healthy ones (Fig. 6, Table 4). Unlike the preceding case, the difference between treatments throughout the sampling periods was obvious, and proved a gradual increase in the course of experiment. It, therefore, appeared as if the intensification with *M. minutus* of cockles had been favored by the presence of the parasite, while in healthy cockles some defensive mechanisms had prevented the infestation with this trematode. The speed of infestation at infested cockles had, thus, been more rapid than those of healthy ones. That can be linked to the fact that some parasites mimic the internal defense system of their host against the external body entry, so as to facilitate the infestation (Bayne, 1991; Loker, 1994). Less rapid than in the case of *Himasthla* spp., the evolution of the prevalence shown however a constant progression, reaching an average value of 72 % at healthy cockles in fine of experience.

As for the host size, its effect was more conspicuous on the infestation intensity with *M. minutus*, than with *Himasthla* spp. In other words, the intensity of infestation with *M. minutus* had always been significantly more important in cockles of "large" size than those of "small" ones throughout the course of experiment.

The effect of host density on the infestation intensity with *M. minutus* proved differently from that of *Himasthla* spp. In other words, the cockles in low density were more prone to infestation with *M. minutus.* This result seems to be more logical if one admits that when the density of host is raised, the pool of parasites distributed on the population of the host is therefore diluted.

References

Bachelet, G. ; Desprez, M. ; Ducrotoy, J.P. ; Guillou, J. ; Labourg, P.J. ; Rybarczyk H. ; Sauriau, P.G. ; Elkaïm, B. and Glémarec, M. , 1992a. Rôle de la compétition intraspécifique dans la régulation du recrutement chez la coque, *Cerastoderma edule* (L.). Ann. Inst. Océanogr., Paris, France. **68:**75-87.

Bachelet, G. ; Guillou, J. and Labourg, P.J. , 1992b. Adult-larval and juvenile interactions in the suspension-feeding bivalve, *Cerastoderma edule*: field observations and experiments. *In*: Colombo G., Ferrari I., Ceccherelli V.U. & Rossi R. (Eds). Marine Eutrophication and Population Dynamics, Olsen & Olsen, Fredensborg. pp.175-182.

Bartoli, P. , 1973. La pénétration et l'installation des cercaires de *Gymnophallus fossarum* P. Bartoli, 1965 (Digenea, Gymnophallidae) chez *Cardium glaucum* Bruguière. Bull. Mus. Hist. Nat., Paris, 3ème sér. **117**, Zoologie. Vol. 91, pp.319-334.

Bartoli, P. , 1976. Modification de la croissance et du comportement de *Venerupis aurea* parasité par *Gymnophallus fossarum* P. Bartoli, 1965 (Trematoda, Digenea). *Haliotis*. **7**:23-28.

Bayne, C.J. , 1991. Invertebrate host immune mechanisms and parasite escapes. *In: Parasite-Host Associations*. Toft C.A., Aeschlimann A. & Bolis L. (Eds). Oxford University Press. pp.298-315.

Bowers, E.A. , 1969. *Cercaria bucephalopsis haimeana* (Lacaze-Duthiers, 1854) (Digenea: Bucephalidae) in the cockle, *Cardium edule* L. in South Wales. J. Nat. Hist. **3:**409-422.

Deltreil, J.P. and His, E. , 1970. Sur la présence d'une cercaire de trématode chez *Cardium edule* L. dans le bassin d'Arcachon. Rev. Trav. Inst. Pêches marit. **34:** 225-232.

Ducrotoy, J.P. ; Rybarczyk, H. ; Souprayen, J. ; Bachelet, G. ; Beukema, J.J. ; Desprez, M. ; Dörjes, J. ; Essink, K. ; Guillou, J. ; Michaelis, H. ; Sylvand, B. ; Wilson, J.G. ; Elkaïm, B. and Ibanez, F. , 1991. A comparison of the population dynamics of the cockle (*Cerastoderma edule*, L.) in North-Western Europe. *In* : Elliott M. & Ducrotoy J. P. (Eds). Estuaries and coasts: spatial and temporal intercomparisons. Olsen & Olsen, Fredensborg. pp.173-184.

Guillou, J. ; Bachelet, G. ; Desprez, M. ; Ducrotoy, J.P. ; Madani, I. ; Rybarczyk, H. ; Sauriau, P.G. ; Sylvand, B. ; Elkaim, B. and Glémarec, M. , 1990. Les modalités de la reproduction de la coque (*Cerastoderma edule*) sur le littoral Français de la Manche et de l'Atlantique. Aquat. Living Resour. **3**:29-41.

Guillou, J. ; Bachelet, G. and Glémarec, M. , 1992. Influence des fluctuations de température sur la reproduction et le recrutement de la coque *Cerastoderma edule* (L.). Ann. Inst. Océanogr., Paris, France. **68:**65-74.

Hulscher, J.B. , 1982. The oystercatcher, *Haematopus ostralegus,* as a predator of the bivalve, *Macoma balthica*, in the Dutch Wadden Sea. Ardea. **70:**89-152.

Javanshir, A. , 1999. Effets de quelques parasites (Digenea) sur la dynamique des populations et la physiologie respiratoire de la coque, *Cerastoderma edule* (Mollusque Bivalve) dans le basin d'Arcachon. Thèse de doctorat de l'Université Paris, France. Vol. 6, 102P.

Javanshir, A. , 2001a. Influence of infestation by *Labratrema minimus* (Bucephalidae: Digenea) on oxygen consumption of edible cockle *Cerastoderma edule* (Mollusca: Bivalvia in Laboratory conditions. Iranian Journal of Fisheries Sciences. **3**(1)39-45.

Javanshir, A. , 2001b. Influence of *Labratrema minimus* (Trematoda: Digenea) on filtration rate performance of edible cockle, *Cerastoderma edule,* in the extreme temperature and salinity conditions (an invitro experiment*)*. Iranian Journal of Fisheries Sciences. **3**(2)73-94.

Jensen, K.T. ; Fernandez Castro, N. and Bachelet, G. , 1999. Infectivity of *Himasthla* spp. (Trematoda) in cockle (*Cerastoderma edule*) spat. J. Mar. Biol. Ass. U.K. **79:**265-27.

Jonsson, P.R. and André, C. , 1992. Mass mortality of the bivalve, *Cerastoderma edule*, on the Swedish west coast caused by infestation with the digenean trematode, *Cercaria cerastodermae* I. Ophelia. **36:**151-157.

Kamermans, P. ; van der Veer, H.W. ; Karczmarski, L. and Doeglas, G.W. , 1992. Competition in deposit- and suspension-feeding bivalves: experiments in controlled outdoor environnements. J. Exp. Mar. Biol. Ecol. **162**:113-135.

Kisielewski, I. , 1998. Caractéristiques de l'infestation de trois Mollusques bivalves par des trématodes, dans le bassin d'Arcachon. Mémoire de D.E.S. Sciences Naturelles, Université Bordeaux 1, 31P.

Lauckner, G. , 1983. Diseases of Mollusca: Bivalvia – Agents: Trematoda. *In* : Diseases of marine animals, Vol. II, Introduction, Bivalvia to Scaphopoda. Kinne O. (ed.) Biologische Anstalt Helgoland, Hamburg, Germany. pp.732-762.

Loker, E.S. , 1994. On being a parasite in an invertebrate host: a short survival course. J. Parasitol. **80:**728-747.

Madani, I. , 1989. Dynamique des populations et processus de recrutement chez quatre espèces de bivalves appartenant aux genres *Abra* et *Cerastoderma*, dans le bassin d'Arcachon. Thèse de Doctorat, Université de Bordeaux I, 152P.

Minchella, D.J. and Scott, M.E. , 1991. Parasitism: a cryptic determinant of animal community structure. Trends in Ecology and Evolution. **6:**250-254.

Montaudouin X. de , 1995. Etude expérimentale de l'impact de facteurs biotiques et abiotiques sur le recrutement, la croissance et la survie des coques, *Cerastoderma edule* (Mollusque-Bivalve). Thèse de Doctorat, Université Bordeaux I, 304P.

Montaudouin X. de , 1996. Factors involved in growth plasticity of cockles, *Cerastoderma edule* (L.), identified by field survey and transplant experiments. J. Sea Res. **36:**251-265.

Montaudouin X. de and Bachelet, G. , 1995. Mesoscale variability of cockle, *Cerastoderma edule*, growth: evidence of tidal level effects from field survey and transplant experiments. *In*: 30th European Marine Biology Symposium, Southampton, UK.18-22 September 1995, Book of Abstracts, 11P.

Montaudouin X. de and Bachelet, G. , 1996. Experimental evidence of complex interactions between biotic and abiotic factors in the dynamics of an intertidal population of the bivalve, *Cerastoderma edule*. Oceanol. Acta. **19:**449-463.

Montaudouin X. de, ; Wegeberg, A.M. ; Jensen, K.T. and Sauriau P.G. , 1998. Infection characteristics of *Himasthla elongata* cercariae in cockles as a function of water current. Diseases of Aquatic Organisms. **34:**63-7.

Navarro, E. ; Iglesias, J.I.P. and Larranaga, A. , 1989. Interannual variation in the reproductive cycle and biochemical composition of the cockle, *Cerastoderma edule*, from Mundaca Estuary (Biscay, North Spain). Mar. Biol. **101:**503-511.

Peterson, C.H. and Andre, S.V. , 1980. An experimental analysis of interspecific competition among marine filter feeders in a soft-sediment environment. Ecology. **61:**129-139.

Peterson, C.H. and Black, R. , 1987. Resource depletion by suspension feeders on tidal flats: influence of local density and tidal elevation. Limnol. Oceanogr. **32:**143-166

Sannia, A. ; James, B.L. and Bowers, E.A. , 1978. The occurrence of *Cercaria cerastodermae* I (Digenea: Monorchiidae) in populations of *Cerastoderma edule* (L.) from the commercial beds of the Lower Thames estuary. *Z. Parasitenkd.* **56:**1-11.

Smaal, A.C. , 1998. Food supply and demand of bivalve suspension feeders in a tidal system. Thesis of doctorat, University of Groningen. 237P.

Sousa, W.P. , 1991. Can models of soft-sediment community structure be complete without parasites? Amer. Zool. **31:**821-830.

Taskinen, J. and Valtonen, E.T. , 1995. Age, size and sex specific infection of *Anodonta piscinalis* (Bivalvia: Unionidae) with *Rhipidocotyle fennica* (Digenea: Bucephalidae) and its influence on host reproduction. Can. J. Zool. **73:**887-897.

Vincent, B. ; Joly, D. and Brasseur, C. , 1989. Effets de la densité sur la croissance du bivalve *Macoma balthica* (L.) en zone intertidale. J. Exp. Mar. Biol. Ecol. **126:**154-162.

Wegeberg, A.M. ; de Montaudouin, X. and Jensen, K.T. , 1999. Effect of intermediate host size (*Cerastoderma edule*) on infectivity of cercariae of three *Himasthla* species (Echinostomatidae, Trematoda). J. Exp. Mar. Biol. Ecol. **238:**259-269.