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FOULING ORGANISMS ON *PERNA PERNA* MUSSELS: IS IT WORTH REMOVING THEM?

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ABSTRACT

Perna perna mussel spat were suspended from ropes on a long-line cultivation, at Coqueiro´s Beach, Anchieta, South-eastern Brazil, in order to quantify the fouling community structure and its effects on growth and biomass of mussels**.** Half of the ropes had the fouling removed monthly, half had the fouling left until the end of the experiment. Monthly samples of thirty mussels from each group were measured and their biomass determined. The fouling organisms were identified, quantified and their biomass evaluated on a monthly basis. After ten months, mussels on the cleaned treatment were significantly larger and heavier (ANOVA*;* $P < 0.05$; Bonferroni: unfouled > fouled), showing that fouling reduced mussel development. The most abundant epibiont organisms in terms of biomass were the algae *Polysiphonia subtilissima* (29%) and *Ulva rigida* (10.3%), followed by the bryozoans *Bugula neritina* (13.6%) and *Perna perna* spat (10.6%). Over 97 taxa and 42,646 individuals were identified, crustaceans being the most abundant group, predominantly one amphipod *Cheiriphotis megacheles* (12,980 ind.). Species abundance was positively correlated with algal biomass, revealing the influence of algae on vagile fauna, which provide both food and shelter. The benefits of fouling removal are discussed because the majority of species are important feeding items to fishes and yet, the costs of its fouling control added to the associated mussel spat loss make this fouling removal of questionable value.

RESUMO

Sementes de *Perna perna* foram colocadas em cordas suspensas em long-line na Praia do Coqueiro, Anchieta, ES, objetivando-se determinar a estrutura da comunidade de incrustantes e seu efeito sobre o desenvolvimento dos mexilhões. Metade das cordas teve os incrustantes removidos mensalmente, na outra metade eles foram deixados até o final do experimento. Mensalmente, 30 mexilhões de cada grupo foram retirados e medidos e a biomassa aferida. Os incrustantes foram identificados, quantificados e a biomassa de cada taxon determinada. Após 10 meses de cultivo, os mexilhões sem incrustantes eram significativamente maiores e mais pesados (ANOVA*;* $P < 0,05$; Bonferroni: sem incrustantes > com incrustantes), demonstrando que os incrustantes interferiram negativamente no desenvolvimento dos mexilhões. Os incrustantes mais abundantes em termos de biomassa foram as algas *Polysiphonia subtilissima* (29%) e *Ulva rigida* (10,3%), seguidas pelos briozoários *Bugula neritina* (13,6%) e sementes de *Perna perna* (10,6%). Foram registrados 97 taxa e 42.646 indivíduos, sendo Crustacea o grupo mais abundante, principalmente o anfípodo *Cheiriphotis megacheles* (12.980 ind.). A abundância de indivíduos foi positivamente correlacionada com a biomassa de algas, revelando a influência das algas na fauna vágil, provendo abrigo e alimentação. Os benefícios da remoção dos incrustantes são discutidos, uma vez que a maioria dos incrustantes são importantes como itens alimentares para os peixes; além disso, os custos desta remoção somados à perda de sementes de mexilhões, tornam a remoção desta comunidade de incrustantes questionável.

Descriptors: Mussel farming, *Perna perna,* Fouling communities, Anchieta – Espírito Santo.
Descritores: Maricultura, Mexilhão, Criação, Incrustações marinhas, Organismos, Anchieta (ES).

INTRODUCTION

Mussel cultures form complex structures, that attract fouling organisms and their associated fauna. These epibionts can negatively affect mussel development, as well as other bivalves, due to competition for space and food. Fouling organisms can cover the shells and obstruct filtration, or even cause the mussels to fall off the culture ropes due to the weight increase, resulting in decreased productivity (Arakawa, 1990; Enright, 1993; Freitas, 1997; Marques, 1998).

Sponges and tunicates can be the main fouling organisms on cultivated *Perna perna* mussels, and when present in large quantities, they can seriously harm the cultivation, even causing the death of mussels, decreasing productivity (Marques & Pereira, 1988).

In Brazil, studies of the effect of fouling communities on mussel cultivation revealed, in some cases, a negative effect of these organisms, as in Espírito Santo state (Garcia-Prado, 2000), while other authors such as Monteiro & Silva (1995) at Guanabara Bay/RJ and Metri *et al.* (2002) in Itapocorói/SC, found that fouling organisms did not affect mussel growth.

The interference of the fouling community can be minimized through its growth control, which can be done by different methods, such as manual cleaning, high-pressure spraying, immersion in hot or fresh water, or even exposure to air and sun, one of the most usual techniques (Enright *et al.*, 1983).

This study determined the structure of the fouling community on *P. perna* mussels cultivated at Praia do Coqueiro, Anchieta district, ES, and also evaluated the effect of fouling on mussel growth.

MATERIALS AND METHODS

Study Area

The study farm is located at Coqueiro's Beach, Anchieta (20°48'50"S; 40°39'40"W), South-eastern Brazil, adjacent to the Benevente River estuary, an important source of nutrient input (Fig. 1). The farming of the brown mussel *Perna perna* has been carried out since 1998, with approximately 100 long-lines with an estimated production of 24 ton per annum. Salinity is usually higher than 30‰ but lower values (minimum 10‰) have been registered during rainy months, i.e. January. The annual water temperature ranges from 23.7 to 27.5ºC; dissolved oxygen values of 3.33 to 6.52 mg. L^{-1}, food concentration in the water column in the form of chlorophyll *a* ranges from 0.1 to 5.1 µg.L^{-1} and particulate organic matter from 0.6 to 3.9 mg.L^{-1}. The average depth is 3 m and tidal currents may reach up to 25 cm.s^{-1} in winter, and 35 cm.s^{-1} in summer, predominantly in a south-westerly direction.

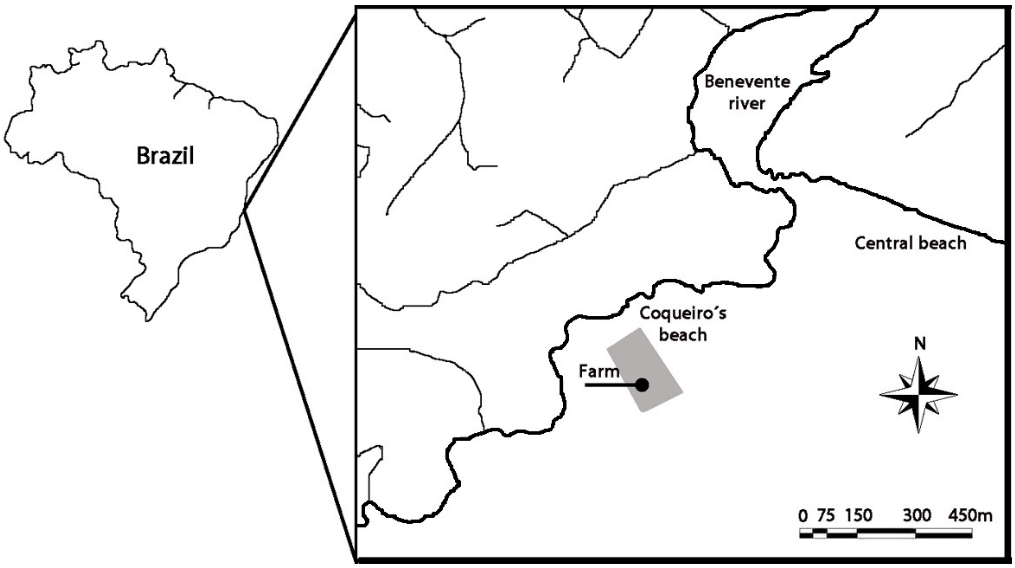

Fig. 1. Geographic location of Coqueiro´s Beach, with the mussel farming area.

Experimental Treatments

In May 2002, spat of *P. perna* mussels with an average length of 35.1 mm (±3.3), were collected at rocky shore on Coqueiro´s beach, and all the fouling organisms were removed. Seventeen ropes (50 cm long) were mounted according to the French method and suspended in long-lines; eight of them had the fouling removed manually with a brush once a month; the remaining nine ropes did not receive any treatment. The study ran for 10 months.

Thirty mussels of each treatment (fouled x unfouled) were sampled monthly and measured for length, height and width using a Vernier caliper. The mussel total weight, the weight of the wet meat and weight of dry meat (after drying in an oven 60ºC for 24 h) were also recorded. The condition index (CI) was obtained by the formula: CI = (dry weight of the meat / dry weight of the shell) x 100 (according to Lucas & Beninger, 1985).

Mussel growth was analyzed through linear regression between biometric data and cultivation time. The effect of the fouling community on the size and biomass of mussels was analyzed through ANOVA. The difference between the presence and absence of fouling organisms was tested by the Bonferroni test *a posteriori*.

A rope of fouled mussels was sampled monthly, with the purpose of studying the fouling community attached or living among the mussel shells. When pulled out, the rope was put into a plastic bag and taken to the laboratory, where the fouling species were quantified and identified to the lowest taxonomic level possible, weighed (wet weight per taxon) on an analytical scale and then preserved in 70% ethanol. In September, due to technical constraints, sampling was not done.

RESULTS

Mussel development

After 10 months of culture, mussels with and without fouling reached mean dimensions of, respectively, 72.2 mm (± 5.3) and 77.6 mm (±5.2) in length, 35.2 mm (±2.6) and 35.4 mm (±2,0**)** in height, and 25.3 mm (±2.2) and 26.4 mm (±2.5) in width **(**Fig. 2A-C**).** The average biomass of fouled and unfouled mussels were respectively 32.91g (±6.3) and 34.76g (±6.51) for total weight with valve; 9.82g (±1.94) and 11.52g (±2.37) for fresh weight without valve and 2.86 g (±0.73) and 2.92 g (±0.82) for dry weight **(**Fig. 3A-C**)**. The mean Condition Index was 22 (±3.27) for unfouled mussels and 20 (±3.5) for fouled ones (Fig. 3D). The regression lines were significant ($P < 0.01$). All these biometric variables were significantly different between fouled and unfouled mussels, excepting the Condition Index (Table 1). *A posteriori* Bonferroni tests for fouling factor revealed that mussels without fouling were bigger and heavier than fouled ones (Table 1).

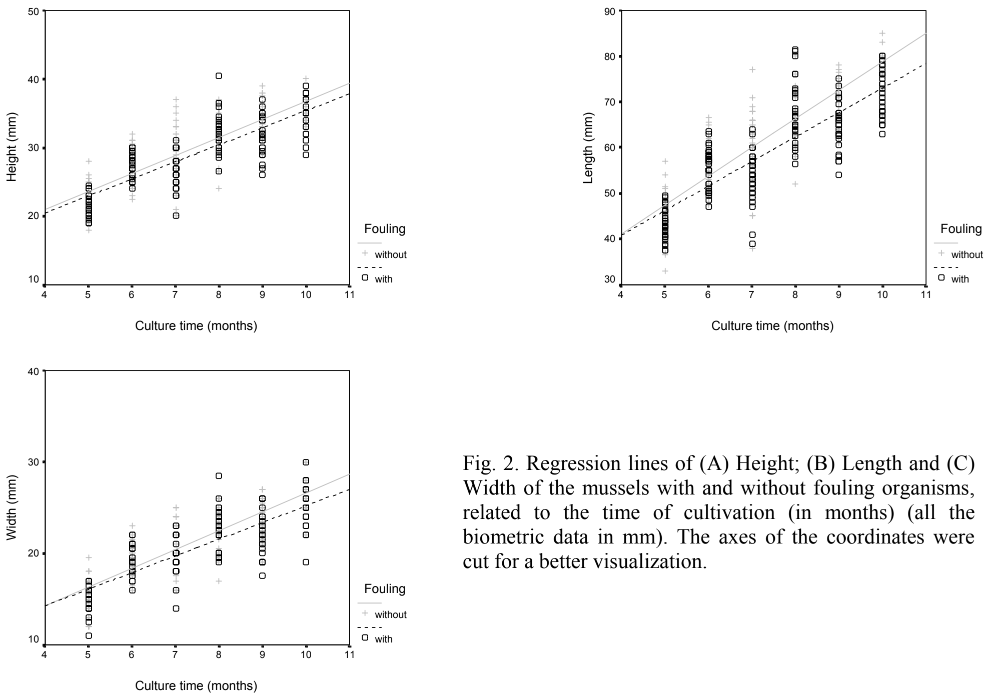

Fig. 2. Regression lines of (A) Height; (B) Length and (C) Width of the mussels with and without fouling organisms, related to the time of cultivation (in months) (all the biometric data in mm). The axes of the coordinates were cut for a better visualization.

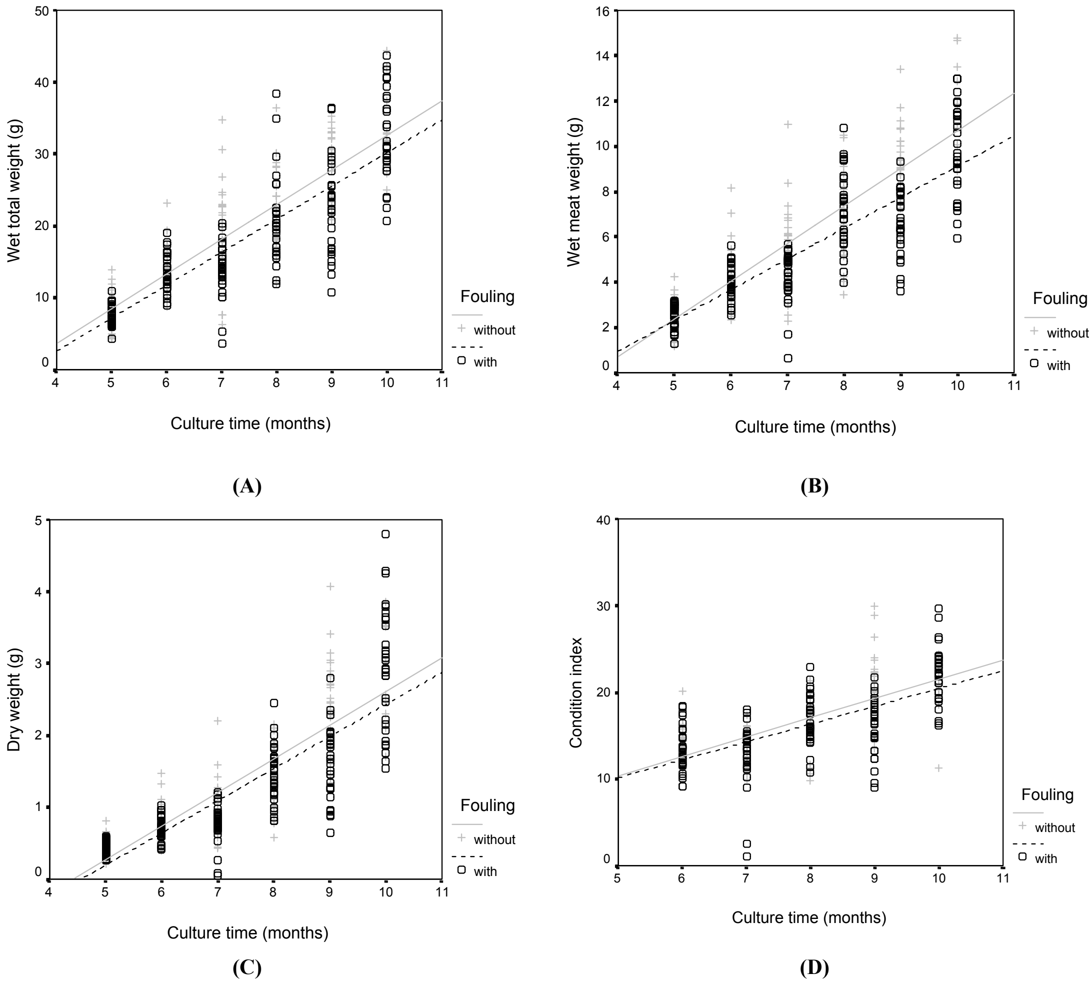

Fig. 3. Regression lines of biomass of the mussels with and without fouling organisms related to the time of cultivation (in months). (A) Total weigh (g); (B) Flesh weigh (g); (C) Dry weight (g) and (D) Condition Index. The axes of the coordinates were cut for a better visualization.

Table 1. Results of ANOVA and Bonferroni Test for the biometric variables of mussels in relation to presence or absence of fouling organisms after 10 months of cultivation.

	Factor	***F***	d.f.	*P*-value	Bonferroni Test
thickness	Fouling	11.72	1	< 0.001	S > C
length	Fouling	28.84	1	< 0.001	S > C
height	Fouling	7.64	1	< 0.05	S > C
Total weight	Fouling	14.13	1	< 0.001	S > C
Fresh weight	Fouling	30.05	1	< 0.001	S > C
Meat dry weight	Fouling	9.41	1	< 0.05	S > C
Condition Index	Fouling	1.94	1	NS	-

NS: not significant; S: without fouling organisms; C: with fouling

Fouling Community

We found 97 taxa associated with the mussel ropes, being 26 Polychaeta, 20 Crustacea, 20 Mollusca, 14 Algae, 4 Bryozoa and 13 belonging to other groups (Table 2). These organisms covered mussel shells or were found among them. The biomass of the fouling community varied between 20.91g and 66.52 g; higher values observed in December and February and smaller ones in October and January. The largest percentage of this biomass was constituted by the algae *Polysiphonia subtilissima* and *Ulva rigida*, as well as by the bryozoa *Bugula neritina* and spat of *Perna perna*, with great variations during the study: February was characterized by the great abundance of *P. subtilissima*, while November was marked by the great occurrence of *Balanus* sp. and *P. perna.* Although the spat of *P. perna* have been numerically more abundant in August, the biomass was low due to the small size of the individuals (Table 2).

Discussion

Mussel Growth

The mussels without fouling reached the commercial size (around 70 mm) in 9 months of cultivation, while those with fouling took 10 months to reach the same size (Fig. 2B). Garcia-Prado (2000), also studying *Perna perna* mussels at the same farm, from September/1999 to April/2000, obtained the commercial size within 7 months, with mussel spat smaller than ours. In both cases, fouling community increased the time for farmed mussel to reach the commercial size. Enright *et al.* (1983), Dittiman & Robles (1991), Enright *et al.* (1993), Flimlin Jr. & Mathis Jr. (1993), Claereboudt *et al.* (1994), Lodeiros & Himmelman (1996), Taylor *et al.* (1997), Cigarría *et al.* (1998) also observed that fouling had reduced the weight and/or size of cultivated bivalves. However, Monteiro & Silva (1995) and Metri *et al.* (2002), using different treatments for elimination of the fouling, did not observe significant variations in the length of the mussels with or without fouling; Freitas (1997) observed a small decrease in the size and weight of the mussels without fouling (compared to those with them), probably due to the treatment to eliminate fouling (aerial exposure).

Mussels are filter feeding organisms that remove food particles such as microscopic algae, bacteria and seston from the water (Marques, 1998). Many of the fouling organisms also feed by filtration, competing against the mussels for food. However, the competition happens mainly for space for attachment, because fouling covers the shells, preventing the bivalves from opening their valves (Arakawa, 1990; Lesser *et al.*, 1992; Lodeiros & Himmelman, 1996). The great amount of these organisms can reduce the water flow for the bivalves, causing a decrease in the amount of food and oxygen (Arakawa, 1990; Claereboudt *et al.*, 1994).

Variations in the time of cultivation to obtain the commercial size of mussels were also observed by Freitas (1997) and Marques *et al.* (1998) who reported that they were due to the fact that the cultivations had been initiated in different seasons, or alternatively, according to Lauzon-Guay *et al. 2005* they may be due to the density and the cultivated individuals' initial size.

Fouling Community

Mussel ropes may host a highly diverse associated community, mainly algae, bryozoans and barnacles, that harbours small epibionts such as polychaetes, amphipods, small crabs and gastropods, among other groups. The fouling organisms with higher biomass were the algae *Polysiphonia subtilissima* and *Ulva rigida*, the bryozoan *Bugula neritina* and seeds of *P. perna*. Garcia-Prado (2000) also found algae to be the main fouling organisms in the same farming area, but the most important species were *Ulva fasciata*, *Hypnea musciformis* and *Cladophora vagabunda.* He suggested that this was due to nutrients discharged by the Benevente River, favoring the proliferation of opportunistic organisms such as these species.

These fouling communities differed from the one observed at Florianópolis, SC by Freitas (1997) where barnacles *Balanus* sp. and oysters *Crassostrea* sp. and *Ostrea* sp., anemones and algae, such as *P. subtilissima* were the most conspicuous fouling on the mussels cultivated there. Monteiro & Silva (1995) found the ascidian *Styela plicata* to be the dominant species on *P. perna* cultivated at Guanabara Bay, together with algae, several bryozoan species (*B. neritina* among them), hydrozoans and barnacles. Metri *et al.* (2002) found mainly hydrozoans, tunicates and sponges forming the fouling community in the mussel farms at Penha-SC. The occurrence of *P. subtilissima* and *B. neritina* as fouling over short intervals of approximately one month, was also recorded in Guanabara Bay by Silva (1980) and Zalmon *et al.* (1993), that observed *B. neritina* to be one of the main species covering wood panels. These variations in the fouling communities, over mussels or other substrata, are probably due to differences on the time of submersion, on the patterns of recruitment and biogeographic differences, besides temporary variations in the pattern of settlement of the fouling species and the stochastic nature of the establishment as well as on the mortality of many species with planktonic larvae (Silva, 1980; Sutherland, 1990; Anderson & Underwood, 1994).

Table 2. Biomass (g) of the main fouling species present in the mussel ropes during the months of cultivation and their cumulative percentage (%).

Taxa	Jul/02	Aug/02	Oct/02	Nov/02	Dec/02	Jan/03	Feb/03	Mar/03	Total	%
Polysiphonia subtlissima	19.8	11.9	1.8	0	18.4	3.3	36	8.5	**99.6**	**29.1**
Bugula neritina	17.6	11.2	5.6	0	1.7	0.8	5.4	4.1	**46.5**	**42.7**
Perna perna	0	2.5	2.5	15.8	1	13.7	0.8	0.1	**36.4**	**53.3**
Ulva rigida	6.5	4.3	1.3	0.5	14.3	0.1	5.7	2.5	**35.0**	**63.6**
Caprella sp.1	2.5	6	0.9	0.5	9.1	0.6	2.3	0.9	**22.6**	**70.2**
Caprella sp.2	0.9	2.8	0.3	0	6.5	0.4	2.2	1.2	**14.3**	**74.4**
Balanus sp.	0	0	0.9	12	0	0	0.3	0	**13.2**	**78.3**
Cheiriphotis megacheles	1.5	2.1	0.2	0.6	2	0.1	2	0.6	**8.9**	**80.8**
Hypnea musciformis	1.6	2.4	0.7	0	2.3	0	0.4	0.3	**7.7**	**83.1**
Crassostrea sp.	0	0.8	1.1	0	3.2	0	0.2	1.8	**6.9**	**85.1**
Corophium acutum	1.5	0.8	0.3	0.1	0.2	0.1	0.3	0.2	**5.4**	**86.7**
Elasmopus pectenicrus	0.5	1.2	0.1	0.6	0.6	0.1	0.3	1.6	**4.8**	**88.1**
Bugula sp.	0.9	0	1.8	0.1	0.2	0.1	0.7	1	**4.8**	**89.5**
Caprella sp.3	0.1	0	0	0.7	1.3	0.1	1.4	0.8	**4.5**	**90.8**
Cladophora vagabunda	1	0	0	0.5	1.6	0	0.6	0.5	**4.0**	**92.0**
Ostrea equestris	0.3	0.7	1.7	0	0.5	0	0	0.2	**3.4**	**93.0**
Ampitoidae	0.7	1	0	0	0	0	0	0.5	**2,2**	**93.6**
Enteromorpha flexuosa	0	0	0	0	0.3	0.1	0.5	0.9	**1.8**	**94.1**
Pachygrapsus transversus	0	0.6	0.1	0	0.9	0	0	0	**1.6**	**94.6**
Halosydnella sp.	0.2	1.1	0	0.2	0	0	0	0	**1.6**	**95.0**
Eunice sp.	0	0.5	0.2	0	0	0.5	0	0.4	**1.6**	**95.5**
Hiatella arctica	0.1	0.1	0.7	0.1	0.5	0.1	0.1	0	**1.5**	**96.0**
Panopeus austrobesus	0	0.2	1.1	0	0	0	0	0	**1.2**	**96.3**
Other organisms	1.1	2.2	0.5	0.5	2.2	0.9	2.7	2.6	**12.6**	**100.0**
Total (g)	56.7	52.3	21.6	32.1	66.4	20.8	61.8	28.5	**342.2**	

Thus, the reduction in development verified in the fouled mussels can be attributed to the presence of fouling growing on their shells, which probably affected the mussels negatively by disturbing their filtration. However, the cost of fouling removal is high (about 20% of the market value of the product, according to Enright, 1993). The reduction caused by them, as much in size as in the mussels weight was relatively low (5.4 mm in the mussel final length and 1.7g in the weight of the meat). Consequently, removal of the fouling would not be cost-effective unless the reduction in profits caused by fouling was greater than the costs of the fouling removal. Besides, scraping to remove fouling may increase the risk of losing mussels, particularly recently-settled spat, resulting in a decrease of profit to the mussel farmers.

It should also be considered that this fouling community may form attractive microhabitats for a great number of species with a commercial value (fish, shrimps and lobsters) (Souza-Conceição *et al.*, 2003; Morrisey *et al.*, 2006), providing food and shelter against predators, and potentially affording an increase in the amount of fauna with commercial value, which could generate further source of income for mussel-farmers (Marques, 1998). Overall, the profits from taking the fouling off may not overtake the profits of their advantages as fish attractors.

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