BOLETIM DO INSTITUTO DE PESCA
ISSN 1678-2305 online version
Scientific Note

MARICULTURE IMPACTS ON THE BENTHONIC ICTHYOFAUNA OF ITAGUÁ BAY, UBATUBA, SOUTHEAST BRAZIL

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Received: February 27, 2019
Approved: August 29, 2019

ABSTRACT

Due to the decline of fishing stocks, aquaculture has been expanding throughout the world. Taking into account the possibility of conflicts of aquacultural activities in areas of environmental protection, this study aims at assessing the effects of mariculture upon the local ichthyofauna of Itaguá Bay in Ubatuba, São Paulo state, Brazil, which is within a marine protection area. In order to do so, the fish community was analyzed in areas with mussels and macroalgae farms and in areas without any maricultural activities. After six months of sampling efforts, 230 individuals were captured from 19 different species and 15 families. There was no difference in catchability, richness, diversity, and evenness among the areas. Nevertheless, the species composition was distinct in areas where mussels were farmed. These areas have presented twice as much fish biomass than the others. Based on these results, we can observe that the environmental alterations caused by mussel farming, are sources of habitat complexity, hence able to enrich the marine fauna of the region. Thus, we conclude that mariculture, specifically mussel farming, has a positive impact on ichthyofauna, contributing to biodiversity maintenance in protected areas.

Key words: environmental protection area; covo; *Kappaphycus alvarezii*; mariculture; *Perna perna.*

IMPACTOS DA MARICULTURA SOBRE A ICTIOFAUNA BENTÔNICA DA BAÍA DO ITAGUÁ, UBATUBA, SUDESTE DO BRASIL

RESUMO

Com o declínio dos estoques pesqueiros a aquicultura vem se desenvolvendo em todo o mundo. Considerando os possíveis conflitos existentes entre atividades produtivas e áreas de preservação ambiental, este estudo teve como objetivo avaliar o efeito da maricultura sobre a ictiofauna local da Baía do Itaguá em Ubatuba, estado de São Paulo, Brasil, que está dentro da Área de Proteção Ambiental Marinha Litoral Norte. Para isto a comunidade de peixes foi avaliada em áreas com cultivo de mexilhões, macroalgas marinhas e áreas sem atividade de maricultura. Após seis meses de coleta foram capturados 230 indivíduos, de 19 espécies e 15 famílias. Não houve diferença na capturabilidade, riqueza, diversidade e equitabilidade entre as áreas. Entretanto, a composição das espécies da área com mexilhões foi distinta das demais. A área com mexilhões também apresentou quase o dobro de biomassa de peixes que o obtido nas demais áreas. Com base em nossos resultados podemos observar que a alteração ambiental gerada pelo cultivo de mexilhões é uma fonte de complexidade de habitat capaz de agregar a fauna marinha da região. Dessa forma, concluímos que a maricultura, em especial a mitilicultura, exerce um impacto positivo sobre a ictiofauna, podendo contribuir para a manutenção da biodiversidade nas áreas de preservação ambiental.

Palavras-chave: área proteção ambiental; covo; *Kappaphycus alvarezii*; maricultura; *Perna perna.*

INTRODUCTION

Mariculture is the branch of aquaculture that cultivates marine species. In Brazil, this activity is represented by the farming of shrimps, bivalve mollusks, fish and macroalgae. In 2014, world production of fish reached the mark of 108 million tons and mariculture was responsible for 24% of such total (FAO, 2016). The prospect is that by 2050 world aquaculture will triplicate its production to meet the demands for fish (Rocha and Rodrigues, 2015). The Brazilian aquaculture plan intends to produce 2 million tons by 2020, 25% of it being marine organisms (Brasil, 2015).

The main product of Brazilian mariculture is the shrimp *Litopenaeus vannamei* (Boone, 1931). The northeast region is the biggest producer, reaching up to 70 thousand tons annually (IBGE, 2015). The production of bivalves comes in second place; the main species cultivated is the mussel *Perna perna* (Limnaeus, 1758). The South region is responsible for 98% of the national production, led by the state of Santa Catarina that exceeded 20 thousand tons in 2015 (Andrade, 2016). The production of mussels represents a key alternative to coastal communities that have been affected by the lack of perspectives of traditional fishing, thus migrating to mariculture as the main source of income (Ferreira and Magalhães, 2004). Besides, *P. perna* has a key ecological role structuring several communities within rocky shores (Freitas and Velastin, 2010).

The least representative activities in Brazilian mariculture are pisciculture and algae culture (the farming of macroalgae), both of which have a negligible production within the national scenario (IBGE, 2015; Pereira and Rocha, 2015; Sanches and Kuhnen, 2016). Despite its irrelevance in Brazil, algaculture has been consolidated worldwide as a significant economic activity. Leading the world ranking of most produced macroalgae is the *Kappaphycus alvarezii* (Doty), farmed mostly for the extraction of carrageenan (FAO, 2016). The carrageenan is a hydrocolloid that has been widely used in industries as a gelling and thickening agent as well as for its pharmaceutical and cosmetic applications (Yong et al., 2015). This species was introduced into Brazil in the 1990s (Paula et al., 2002) and it is the only macroalgae commercially farmed in the country.

The state of São Paulo has ideal geographic and environmental characteristics to the development of mariculture, especially macroalgae and mussel farming. Nevertheless, its entire coast has been declared as an area of environmental protection (decree nº 53.525/2008) since 2008. The area of marine environmental protection (Área *de Proteção Ambiental Marinha Litoral Norte*) was created with the goal of protecting, arranging, assuring and disciplining the use of natural resources, through the ordering of the activities as to promote sustainable development of the region (Brasil, 2008). Considering the growth of mariculture, it is necessary to associate the development of the sector with environmental concerns. For example, monitoring efforts to assess the possible positive and/or negative impacts on the local communities (Tureck and Oliveira, 2003; Castelar et al., 2009).

Fish traps are used by artisanal fishers as fishing gear in places where other fishing modalities are impeded or limited. The advantage of this type of fishing modality is the possibility of keeping fish alive and in the case of capturing species of low commercial value or size below the permitted minimum this fishing gear allows the release of such specimens back to nature, resulting in a sustainability aspect to the use of this fishing gear (Sanches and Sebastiani, 2009). A different purpose for fish traps was proposed by Kushlan (1981) who suggested the possibility of using traps to estimate populations, evaluating the spatial distribution and relative abundance of species. The use of this fishing gear as a fauna sampler has also been used in estuarine (Carvalho and Couto, 2011) and freshwater (Teixeira and Couto, 2012) environments. One advantage of traps is that it can act without damaging the animals, unlike other fishing gear, resulting in lower suffering (Bernardes et al., 2005).

The literature has already confirmed the impact of mariculture enterprises, notably mussel cultivation, on the structure of the macrobenthic community (Barbieri et al., 2014; Costa and Nalesso, 2006). Therefore, the use of coffins would favour the investigation of benthic ichthyofauna associated with the crops. Traps also provide shelter for fish, thus the less structured the environment, the greater the trap's efficiency (Robichaud et al. 2000). This observation explains, for example, the choices of fishermen from Paraty (Rio de Janeiro state), who dives searching for areas to set the traps in the sand rather than on rocks (Sanches and Sebastiani, 2009).

The intrinsic restrictions to protected areas create socio-environmental conflicts and, consequently, challenges to the management of the area (Fontes and Guerra, 2016). The growth of mariculture requires an assessment of the possible impacts on the ecosystem in which it is inserted. Therefore, the present study aims at evaluating the effect of mariculture on the local ichthyofauna. As our case study, the farms of the mussel *P. perna* and the macroalgae *K. alvarezii* in Itaguá Bay (Ubatuba, São Paulo, Brazil) were analyzed. Considering the size of the analyzed farms, our hypothesis is that any of the cultivated species will negative affect the local icthyofauna.

MATERIALS AND METHODS

Study area

The study was conducted in Itaguá Bay, in the municipality of Ubatuba, north coast of São Paulo state, Brazil. Itaguá bay has a total area of 8 km^2; it is divided into 5 sandy beaches delimited by rocky shores and four streams, which drain into the bay (Mantelatto and Fransozo, 1999). It presents mean salinity of 35 (varying between 29 and 39) and water temperature ranging from 19º to 29ºC (Mantelatto and Fransozo, 1999). Predominant winds are East and Southeast, which can modify water circulation (Castro Filho et al., 1987). Depth varies from 10 to 15m in the more external areas of the bay whereas internal areas are notably shallower (Mahiques, 1995).

Capture methodology

In order to evaluate the effects of mariculture on the composition of ichthyofauna three distinct points were sampled: i) control area, with no presence of any maricultural activity (23º27.139'S; 045º02.881'W); ii) area with macroalgae farming (*K. alvarezii*, 23°27.118'S; 045°02.852'W); and, iii) area with mussel farming (*P. perna*, 23°26.917'S; 045º02.521'W). Sample points were relatively close among themselves and the control area was located between both farming areas (approximately 800m apart from each) (Figure 1).

In order to capture the fish (license Sisbio nº 33022-2), artisanal traps commonly known in Portuguese as *covo* were used. This kind of trap has a heart-shaped format with a single funnel-shaped opening through which the fish enters and cannot leave. One of

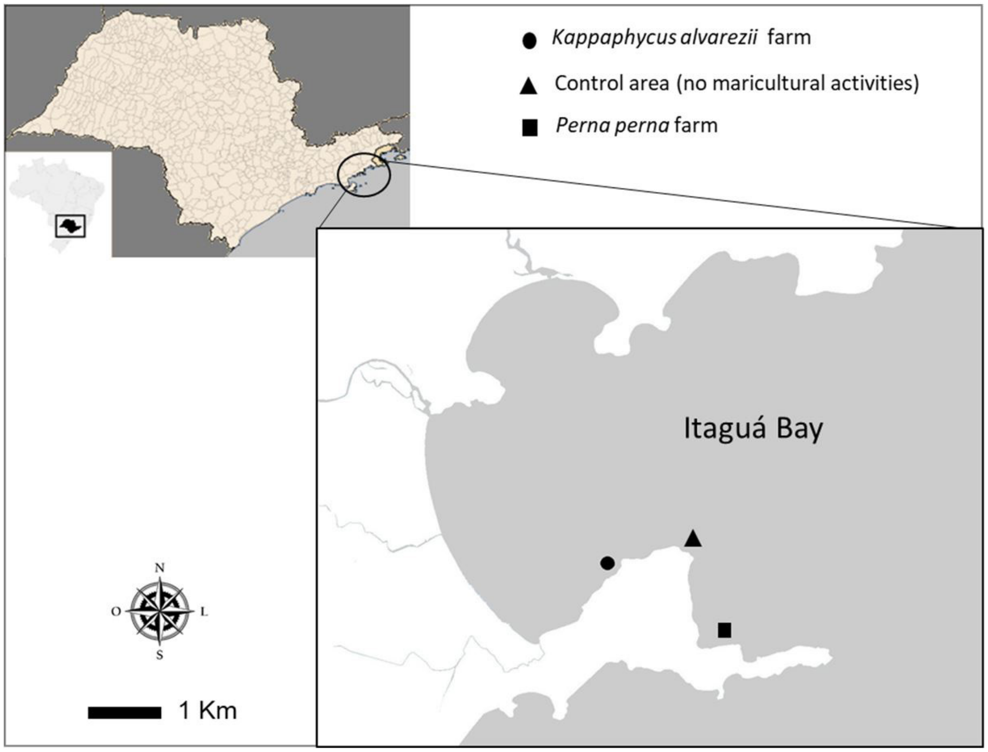

Figure 1. Itaguá Bay (Ubatuba, São Paulo state, Brazil) location map highlighting sampled areas.

the main advantages of this gadget is the possibility of keeping the captured fishes alive, allowing to return them to the ocean once the analysis is completed (Sanches and Sebastiani, 2009). The trap can be manufactured with several materials; in this study, it was built with 3/8 iron rods frame covered with a plastic mesh with 50mm opening and opposite nods. Its dimensions were 80cm long, 40cm wide and 35cm high, which totals 200lts of internal volume. Traps were placed six meters deep without baits.

From March to October, sixty capture expeditions were conducted, with the average interval of 4 days between samplings. In order to capture the fish, the traps were submerged for 24 h and no kind of bait was used to lure the fish in. Captured species were identified based on the description and identification keys proposed by Figueiredo and Menezes (2000) as well as comparing them to specimens from the ichthyological collection of the USP Zoology Museum. In order to avoid recapture, fish captured during the trial period were taken to the Marine pisciculture lab of the Fishing Institute. The fish were kept in 3000 L tanks with a filtering and water recirculation systems. After the trial period, all captured fishes were released to their respective capture locations.

Statistical analysis

For each of the three sampled areas, the following was calculated: a) the catch per effort unit (CPUE) according to the formula: CPUE = g t^{-1}, in which g represents the total catch weight (in grams) and t is the trap submersion interval (in hours); b) Fish diversity, estimated according to Simpsons' diversity index [1-∑(Ni*(Ni-1)/(N*(N-1) in which N corresponds to the number of species]; c) evenness, using Pielou's index [H/Log(S); in which H stands for Shannon-Weiner's index (-∑pi*Lnpi; pi representing the relative abundances of each species) and S is the number of species] (Magurran, 2004); d) the estimate species richness, using Margalef's index (Colwell et. al, 2004). Variance analysis was used to compare CPUE, richness, diversity, and evenness of the three areas (Gotelli and Ellison, 2011).

Community composition was compared according to the analysis of similarities (ANOSIM) based on Bray-Curtis similarity index (Clarke and Warwick, 2001). The similarity percentage analysis (SIMPER) was used to identify which species are more representative in each area, as well as those that contribute to the dissimilarity between the communities of each sampled area (Clarke and Warwick, 2001).

RESULTS

At the end of the 60 campaigns, 230 individuals belonging to 19 species and 15 different families were captured (Tables 1, 2, 3; Figure 2). The most captured species was the Grunt *Haemulon steindachneri* (Jordan and Gilbert, 1882), captured 120 times. Considering that the Grunt had a disproportional catchability in relation to all the other species in all three areas, in order to analyze similarity in the ichthyofauna composition, such species was excluded from the SIMPER and ANOSIM analysis.

Most species were registered only once (37%). Species that occurred in all three areas were the Chere-chere Grunt

Table 1. Description of sampled species in the control areas and in the areas with algae and mussels farms (Families: Ariidae, Batrachoididae, Haemulidae, Labridae and Blenidae – see other families in tables 2 and 3).

	Control Area	Farms present in the sampled area	
		Macroalgae	Mussels
ARIIDAE			
Sea Catfish *Cathorops spixii* (Agassiz, 1829)			
Captures (%)	0	0	2 (2)
Weight (g)	0	0	282.9-426.2 (354.6±101.3)
Length (cm)	0	0	30.5 - 33.0 (31.8±1.8)
BATRACHOIDIDAE			
Toadfish *Porichthys porosissimus* (Cuvier, 1829)			
Captures (%)	0	1 (1)	0
Weight (g)	0	306.1	0
Length (cm)	0	29.5	0
HAEMULIDAE			
Chere-Chere Grunt *Haemulon steindachneri* (Jordan and Gilbert, 1882)			
Captures (%)	30 (59)	61 (65)	29 (34)
Weight (g)	11.5 - 230.0 (78.2±43.4)	8.5 - 394.5 (30.1±51.5)	7.5 - 230.7 (110.3±77.5)
Length (cm)	9.0 - 21.1 (16.3±3.2)	7.9 - 30.0 (11.5±3.4)	8.1 - 24.6 (17.8±5.4)
Black Grunt *Haemulon bonariense* Cuvier, 1830			
Captures (%)	5 (10)	8 (9)	3 (4)
Weight (g)	23.2 - 88.3 (43.8±26.7)	17.9 - 47.3 (33.5±10.4)	26.2 - 161.9 (109.8±73.2)
Length (cm)	11.5 - 18.5 (14.0±2.8)	10.7 - 15.0 (13.2±1.5)	11.2 - 22.6 (18.6±6.4)
LABRIDAE			
Blackear Wrasse *Halichoeres poeyi* (Steindachner, 1867)			
Captures (%)	0	0	4 (5)
Weight (g)	0	0	12.6 - 145.9 (82.7±57.9)
Length (cm)	0	0	9.3 - 21.5 (16.9±5.4)
BLENIDAE			
Seaweed Blenny *Parablennius marmoreus* (Poey, 1876)			
Captures (%)	0	0	1 (1)
Weight (g)	0	0	16.7
Length (cm)	0	0	11.4

Capture values represent the number of captured individuals. Values in brackets represent the percentual relative abundance in relation to the total individuals captured in the sampled area. The values for weight and length represent minimum value – maximum value (mean ± DP).

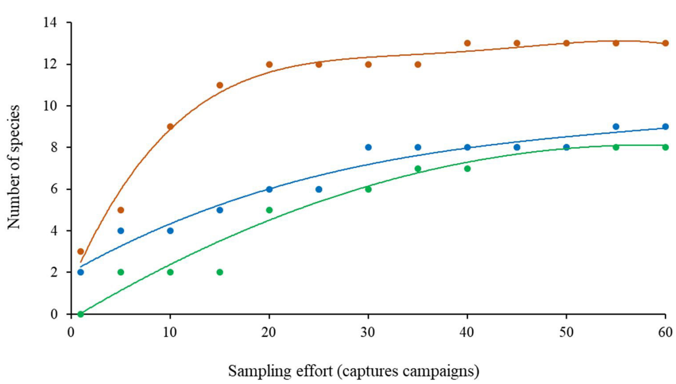

Figure 2. The cumulative curve of the sampled species in areas with mussel farming (orange), with macroalgae farming (green), with no maricultural activity (blue).

H. steindachneri, the Black Grunt *Haemulon bonariense* (Cuvier, 1830), the Smooth-cheek Scorpionfish (Mees and Hildebrand, 1928), and the Planehead Filefish *Stephanolepis hispidus* (Linnaeus, 1766). Nevertheless, most species were registered in only one of the sampled areas (58%).

Although there was no significant difference in catchability, richness, diversity or evenness between the areas with or without maricultural activities (Table 4), the ichthyofauna composition of the area with mussel farms was distinct (Global R=0.16; p=0.001). The three species were responsible for 95% of similarity between sampled areas were the Smooth-cheek Scorpionfish *Scorpaena isthmensis* (54%), the Planehead Filefish *Stephanolepis hispidus* (32%) and the Spotted Goatfish *Pseudupeneus maculatus* (9%). There was no significant difference in the ichthyofauna composition of the areas with macroalgae farms and without maricultural

Table 2. Description of sampled species in the control areas and in the areas with algae and mussels farms (Families: Lutjanidae, Monacanthidae, Mullidae, Ogcocephalidae and Pomacentridae – see other families in tables 1 and 3).

	Control Area	Farms present in the sampled area	
		Macroalgae	Mussels
LUTJANIDAE			
Mutton Snapper *Lutjanus analis* (Cuvier, 1828)			
Captures (%)	2 (4)	0	0
Weight (g)	183.7 - 246.5 (215.1±44.4)	0	0
Length (cm)	24.0 - 27.0 (25.5±2.1)	0	0
Lane Snapper *Lutjanus synagris* (Linnaeus, 1758)			
Captures (%)	5 (10)	6 (6)	0
Weight (g)	28.1 - 282.4 (81.1±112.5)	36.4 - 492.9 (128.3±179.9)	0
Length (cm)	12.0 - 27.5 (15.4±6.7)	12.7 - 32.5 (17.9±7.3)	0
MONACANTHIDAE			
Planehead Filefish *Stephanolepis hispidus* (Linnaeus, 1766)			
Captures (%)	1 (2)	3 (3)	12 (14)
Weight (g)	64.3	13.2 - 38.1 (54.6±42.4)	6.3 - 262.7 (92.7±94.4)
Length (cm)	15.0	9.0 - 16.5 (13.3±3.8)	7.0 - 23.5 (14.7±6.2)
MULLIDAE			
Spotted Goatfish *Pseudupeneus maculatus* (Bloch, 1793)			
Captures (%)	0	0	9 (11)
Weight (g)	0	0	42.0 - 233.3 (106.8±62.9)
Length (cm)	0	0	14.9 - 26.3 (19.5±3.9)
OGCOCEPHALIDAE			
Seadevil *Ogcocephalus vespertilio* (Linnaeus, 1758)			
Captures (%)	0	0	1 (1)
Weight (g)	0	0	228.7
Length (cm)	0	0	24.0
POMACENTRIDAE			
Indo-pacific Sergeant *Abudefduf saxatilis* (Linnaeus, 1758)			
Captures (%)	0	6 (6)	2 (2)
Weight (g)	0	13.5 - 149.9 (70.8±62.3)	6.1 - 7.1 (6.6±0.7)
Length (cm)	0	8.8 - 18.2 (13.2±4.3)	6.5 - 7.8 (7.2±0.9)

Capture values represent the number of captured individuals. Values in brackets represent the percentual relative abundance in relation to the total individuals captured in the sampled area. The values for weight and length represent minimum value – maximum value (mean ± DP).

activities. Species responsible for the similarities between these areas were the Lane Snapper *Lutjanus synagis* and the Black Grunt *Haemulon bonariense*. The area with mussel farms presented nearly the double of cumulative biomass (7.5 Kg) than the other areas (without mariculture = 3.7 Kg; with macroalgae = 4.5 Kg). No significant difference in average size was observed in the fishes of the three areas.

DISCUSSION

Based on our results we can observe that the mariculture in the Itaguá Bay region has not caused any negative impact on the richness and diversity of the local marine fish community. The farming of macroalgae presented very similar results to those registered in areas without maricultural activities.

On the other hand, the species composition in the area with mussels farms was distinct and with bigger biomass. Our results indicate that macroalgae farming has no negative impacts on the local fish community, meanwhile, mussels farming can act as a tool to aggregate ichthyofauna.

The abundance pattern observed to the three species in the sampled areas followed the tendencies of most biological communities, in which few species are abundant and many are rare (Magurran and Henderson, 2003). The most abundant species in the three areas have low commercial value as a common characteristic (*H. steindachneri, H. bonariense, S. isthmensis, S. hispidus*). One of the first signs of fishing overexploitation is the low catchability of

Table 3. Description of sampled species in the control areas and in the areas with algae and mussels farms (Families: Scaridae, Sciaenidae, Serranidae, Sparidae and Synanceiidae – see other families in tables 1 and 2).

	Control Area	Farms present in the sampled area	
		Macroalgae	Mussels
SCARIDAE			
Emerald Parrotfish *Nicholsina usta* (Valenciennes, 1840)			
Captures (%)	0	0	1 (1)
Weight (g)	0	0	75.3
Length (cm)	0	0	16.5
SCIAENIDAE			
High-hat *Pareques acuminatus* (Bloch e Schneider, 1801)			
Captures (%)	0	0	1 (1)
Weight (g)	0	0	29.4
Length (cm)	0	0	13.0
SERRANIDAE			
Sand Perch *Diplectrum formosum* (Linnaeus, 1766)			
Captures (%)	5 (10)	0	3 (4)
Weight (g)	23.4 - 108.6 (46.2±35.2)	0	9.6 - 34.0 (18.2±13.7)
Length (cm)	13.0 - 20.0 (15.0±2.8)	0	9.4 - 14.5 (11.3±2.8)
Twinspot Bass *Serranus flaviventris* (Cuvier, 1829)			
Captures (%)	1 (2)	0	0
Weight (g)	15.4	0	0
Length (cm)	9.3	0	0
SPARIDAE			
Common Seabream *Pagrus pagrus* (Linnaeus, 1758)			
Captures (%)	1 (2)	0	0
Weight (g)	26.0	0	0
Length (cm)	11.6	0	0
South American Silver Porgy *Diplodus argenteus* (Valenciennes, 1830)			
Captures (%)	0	8 (9)	0
Weight (g)	0	51.9 - 159.0 (92.1±38.8)	0
Length (cm)	0	14.5 - 21.0 (16.7±2.4)	0
SYNANCEIIDAE			
Smooth-cheek Scorpionfish *Scorpaena isthmensis* Mees & Hildebrand 1928			
Captures (%)	1 (2)	1 (1)	17 (20)
Weight (g)	24.1	46.9	8.5 - 82.5 (26.6±19.6)
Length (cm)	11.1	13.5	7.8 - 17.5 (10.7±2.1)

Capture values represent the number of captured individuals. Values in brackets represent the percentual relative abundance in relation to the total individuals captured in the sampled area. The values for weight and length represent minimum value – maximum value (mean ± DP).

large size species with high commercial value (Sethi et al., 2010). Among all captured species, the only ones with commercial value are the Mutton Snapper *L. analis* (Cuvier, 1828) and the Lane Snapper. Besides these two species, none of the other species which have commercial value and are part of the local ichthyofauna, such as Goliath Grouper *Epinephelus itajara* (Lichtenstein, 1822), Dusky Grouper *Epinephelus marginatus* (Lowe, 1834) and the Common Snook *Centropomus undecimalis* (Bloch, 1792) were captured (Rocha and Rossi-wongtschowski, 1998). Such results can be a reflection of the historical fishing pressure in the region (Vianna and Valentini, 2004). Fishing pressure on target species results in serious consequences to the local ecological relations (Shin et al., 2005). Some of these consequences are reductions of the maximum size of the individuals, age and size of sexual maturity (Jennings et al., 1999).

Using gill net at a depth of five meters in mussel crops, Souza-Conceição et al. (2003) captured 43 individuals belonging to 18 species of fish. The most frequent species captured was the *Monacanthus ciliatus*. The ichthyofauna associated with

Table 4. Catchability and diversity indices of the marine fish community sampled in the control area and areas with macroalgae and mussel farms.

	Control Area	Farms present in the sampled area	
		Macroalgae	Mussels
Total number of species	8	9	13
Total Biomass	4.6	3.8	7.5
Catchability (CPUE)	5.8 ± 3.3	7.9 ± 7.8	6.95 ± 7.5
Richness	1.1 ± 0.7	0.8 ± 0.5	1.2 ± 0.6
Diversity	0.7 ± 0.4	0.6 ± 0.4	0.7 ± 0.3
Evenness	0.9 ± 0.02	0.9 ± 0.06	0.9 ± 0.01

The values presented represent the mean ± standard deviation.

mussel farming provides an economic advantage for traditional communities, which can exploit commercially important fish species associated with the mariculture activity (Souza-Conceição et al., 2003). Barbanti et al. (2013) sampled the Bertioga channel (São Paulo state) and observed the importance of using traps as a complementary sampling tool, especially on benthic groups. Possamai et al. (2014) using fauna sample traps in estuarine environments captured seven species of fish, the most abundant being the *Atherinella brasiliensis* and the *Bathygobius soporator*. These results indicated to the authors the traps selectivity, as well as the importance of their use as a complementary sampling method.

In our study we observed that juveniles and adult individuals were sampled, hence providing evidence that the presence of mariculture did not influence the occurrence of species in different age ranges. On the other hand, it was noticed that species had a preference for some areas. For instance, the Smooth-cheek Scorpionfish and Planehead Filefish, which are species with reduced swimming and lower locomotory capacity, occurred more abundantly in areas with mussel farming. Meanwhile, the Lane Snapper and the Black Grunt, whose anatomy is more adapted to swimming and known for migrating (Claro and Lindeman, 2008), were more abundant in areas with macroalgae or no maricultural activities. These results indicate that maricultural activities can affect the species of the local community differently.

The licensing for farming the macroalgae *K. alvarezii* is conditional to a judicious regularization as well as an analysis of resulting environmental impacts (Ostrensky et al., 2008). One of the consequences of this kind of farming is the shadowing of the water column. The farming of macroalgae is done in the most superficial part of the water column and directly impacts the darkening of the areas below (Bergman et al., 2001). In our study, we could observe that the activity had no negative impact on the richness and diversity of the fish. Nevertheless, it is worth noting that the sampled area of water surface covered by the farming of *K. alvarezii* was about 30m^2, which can be relatively small to have an impact on the local ichthyofauna. Despite the shadowing of the water, macroalgae are capable of sheltering a diverse epifauna that can serve a food resource for some fish species. Granted, mussels also foster several invertebrate species that serve as food sources as well (López-Jamar et al., 1984; Khalaman, 2001; Freitas and Velastin, 2010).

The difference between these two cultures is the manner they alter the habitat and the kind of species they attract. While the macroalgae are cultivated using only the surface of the water mass, the ropes used for mussel farming create mazes that enhance the habitat complexity. Such complexity offers an ample variety of resources to the local ichthyofauna far beyond food supply, including refuge against predation, protection against physical factors, among others (McKindsey et al., 2006). It is likely that such habitat complexity enabled the area with mussel farms to present more biomass and distinct species composition.

Positive and negative impacts of mussel farming have been studied for years (Kaiser et al., 1998). Besides fauna aggregation, another positive impact such activity can occasion to the ecosystem is the removal of nutrients in areas with excessive effluents discharge. Mussels remove nutrients (nitrogen and phosphorus) from their consumption of phytoplankton and organic particles and when harvested for commercialization, these nutrients are also removed from the system (Kaiser et al., 1998). On the other hand, organic materials deposited below the farms (originated from the feces of the organisms) could increase sedimentation rates affecting the benthic community. Nevertheless, most studies have demonstrated that such impact is minimum or even null (Danovaro et al. 2004; Costa and Nalesso, 2006; Petersen et al., 2014).

Despite the extreme relevance of habitat complexity to marine fish species, studies on the relationship between ichthyofauna and mariculture artificial structures are still incipient in Brazil (Johnson, 2007; Freitas and Velastin, 2010). Based on our results, we can observe that the habitat complexity created by mussel farming is capable of aggregating to the marine ichthyofauna of the region. Such results corroborate local communities' belief that mussel farming is beneficial to fish aggregation. The farming of macroalgae assessed in our study, however, was less efficient in this sense, most likely because it creates a solely superficial shelter and a less diverse and less abundant food source for the fish and other organisms. Nonetheless, regardless of the maricultural activity assessed, no negative effects on the fish community were observed.

Faunal surveys are important to the assessment of environmental impact, especially when the goal is to estimate the potential of marine resources exploration (Barbanti et al., 2013). In our study, we recorded that, the fish of the gender *Haemulon* were more abundant, likely due to its low commercial value. Species from this gender are encountered mainly in shallow waters and rocky coasts. They also play a key ecological role, essential to the integrity of the marine ecosystem (Rocha et al., 2003). Preliminary faunal surveys in the areas where mariculture is to be implemented would serve as a tool to a more judicious assessment of the degenerative or regenerative potentiality that maricultural activities can entail.

According to Castro and Menezes (1998), the marine ichthyofauna of São Paulo state is well known, with about 512 species of fish registered for the region. In this sense, the diversity of the benthic ichthyofauna obtained in our results can be considered low, between 8 to 13 species. This may be related to the type of fishing gear used, which is targeted to benthic fish. Although this kind of fishing gear is not a recommended method to evaluate an activity impact in all local biodiversity, that is because the demersal ichthyofauna is hardly sampled. Our target community was the benthic ichthyofauna, therefore, the methodology was appropriated. However, for further investigations on fish assemblages, we recommend that future studies should be complemented with waiting nets and preferably associated with visual census techniques.

Currently, due to the decline of fishing stocks, it is becoming even more imperative to preserve marine species and to foster the sustainability of the ecosystems (Christensen et al., 2014). Considering the significant increase of maricultural activities in Brazil, our work has great relevance, as the consequences of such activities to the Brazilian ecosystems are still unknown. The present study has demonstrated that mariculture, notably mussel farming, has a positive impact on ichthyofauna, contributing to the maintenance of biodiversity in protected areas.

CONCLUSIONS

Mariculture has not caused any negative impact on the richness and diversity of the local marine fish community of the Itaguá Bay.

Macroalgae farming presented very similar results to those registered in areas without maricultural activities.

Mussel farming has a positive impact on local ichthyofauna and, respecting the carrying capacity of the system, could be used as a tool for the maintenance of biodiversity in protected areas.

ACKNOWLEDGEMENTS

The authors would like to thank the Project Meros do Brasil (PMB) for its support. The PMB is sponsored by Petrobras through the program Petrobras Socioambiental. V.V.K. Postdoctoral scholarship was funded by Programa Nacional de Pós Doutorado/ Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (PNPD/CAPES).

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