The role of mariculture in CO_2 and CH_4 emissions

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1. INTRODUCTION

Coastal waters are naturally rich in organic matter, becoming large carbon accumulators and potential sources of GHG (HOU et al., 2016). Intensive mariculture could be an increasing contributor to organic matter inputs (FENG, et al., 2004). Most seafood farming areas are installed in sheltered areas, with a low water renewal rate, increasing organic matter deposition and oxygen depletion (LOUNAS et al., 2020). However, the food demand, especially animal protein, coupled with the decrease of fish stocks turns mariculture into a full expansion activity. (MERINO et al., 2012). Efforts and studies are being made to minimize emission from terrestrial agriculture, meanwhile, the role of marine ecosystems has been insufficiently researched (ORTIZ-LLORENTE e ALVAREZ-COBELAS, 2012). Marine inventory emissions in mariculture areas can qualify the activity as sustainable or not.

Ray et al. (2019) reported the sequestration of CO_2 equivalent to 22.99 kg kg^{-1} of protein during shells formation. The same study estimates that the production of oysters emits a total of 0.13 kg CO_2-eq per kg of protein, a significantly lower value when compared to the production of beef (67.8 kg CO_2-eq per kg of protein), poultry (45.6 kg CO_2-eq per kg of protein) and pigs (5.6 kg CO_2-eq per kg of protein) (FAO, 2013a; FAO, 2013b).

Brazil has several areas of mariculture, being in the South region, dominated by the cultivation of mussels and oysters, responsible for 98% of the national production. On the north-central coast of Santa Catarina, the Armação do Itapocoroy inlet is considered one of the main mussel farm areas of the region (RORIG et al., 1998). This is a sheltered area governed by physical, biological, anthropic processes and climatic factors. The main species cultivated in the region is the mussel *Perna perna* (LINNEUS, 1758), which is easy to handle and has high productivity (MARENZI; BRANCO, 2006). *Perna perna* production in Penha in 2017 was 597 tons.

This study aimed to evaluate the mariculture influence on the balance of two greenhouse gases (CH_4 e CO_2). For this analysis biogeochemical data from water and sediment samples were also collected over three successive days to identify the influence of the environment on the GHG balance.

2. METHODOLOGY

The study area is located at Armação do Itapocoroy inlet, municipality of Penha in the state of Santa Catarina, Brazil. GHG and water sampling occurred between 02 and 04 October 2018 at three sites: 1- beach points, without crops; 2- mariculture with mussel breeding (*Perna perna*) and 3- control points, further away from cultivation (Figure 1).

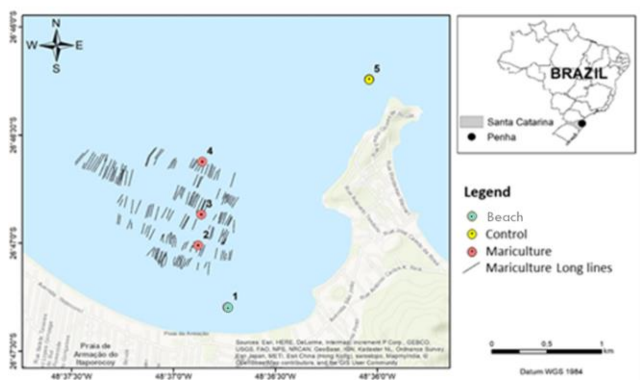

Figure 1: Study area location and sampling sites.

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2.1. Greenhouse gases fluxes

Carbon dioxide (CO_2) and methane (CH_4) fluxes were determined by the static chamber technique using 1000 ml cylindrical chambers of chloride polyvinyl (PVC) (IEA/HYDRO, 2012). A single flux measurement consisted of taking periodic samples from one chamber (every 7 min over a 21-min measurement period) using 60-mL polyethylene syringes. Samples were transferred to glass bottles (60 mL) with butyl rubber stoppers and transported for laboratory analysis through gas chromatography.

2.2. Environmental parameters

Water column physical-chemical parameters (salinity, temperature, turbidity, pH, Eh, conductivity, dissolved oxygen, and total dissolved solids) were measured using a multiparameter probe (Horiba-U53). Subsurface water samples were collected with a Ninskin bottle and stored in plastic bottles until processing. Chlorophyll-a, total organic phosphorus (TOP), phosphate (PO_4^{3-}), nitrate (NO_2^-), nitrite (NO_3^-), ammonia (NH_4^+), silicates (SiO_4^{4-}) by colorimetric methods (SMEWW, 2017). Suspended particulate matter (SPM) was analyzed by gravimetry and these particulate matter metals were analyzed (Pb, Cu, Ni, Zn, Cd, and Cr) by atomic absorption spectrophotometry (SMEWW, 2017). The analysis of environmental parameters tried to understand the combined effect of environmental variables on GHG fluxes.

2.3. Statistical analysis

The variation of flux in the different sampling sites was compared using the Kruskall-Wallis test. Pearson's correlation coefficient (r) was used to measure the strength of the association between GHG fluxes with environmental parameters. A significance level of 0.05 was considered for statistical analysis.

3. RESULTS AND DISCUSSION

CO_2 fluxes varied between -81.8 and 76.1 mg C-CO_2 $m^{-2}d^{-1}$, while the CH_4 flux ranged from 0 to 2.5 mg C-CH_4 $m^{-2}d^{-1}$. For CO_2, the first and last days performed positive fluxes, indicating the gas transported from the water to the atmosphere.

The second day of sampling presented negative flux (-2.2 mg C-CO_2 $m^{-2}d^{-1}$) representing the sequestration of atmospheric carbon but hasn't shown significant differences between control and mussel farm sites. CH4 fluxes were all positives and have shown significative highest concentrations in control sites (Figure 2), indicating that mussel culture did not influence marine gas balance.

Table 1 – Diffusive fluxes of CO_2 and CH_4 (mg.$m^{-2}d^{-1}$) for day and assessed sites.

		CO2		CH4	
		Mean	*SD*	Mean	*SD*
Date	Oct-2	4.5	*17.2*	0.1	*0.2*
	Oct-3	-2.2	*24.7*	0.3	*0.6*
	Oct-4	7.1	*19.9*	0.3	*0.2*
Site	Beach	6.4	*21.9*	0.5	*0.7*
	Mariculture	2.6	*23.3*	0.1	*0.1*
	Control	0.9	*13.4*	0.3	*0.3*

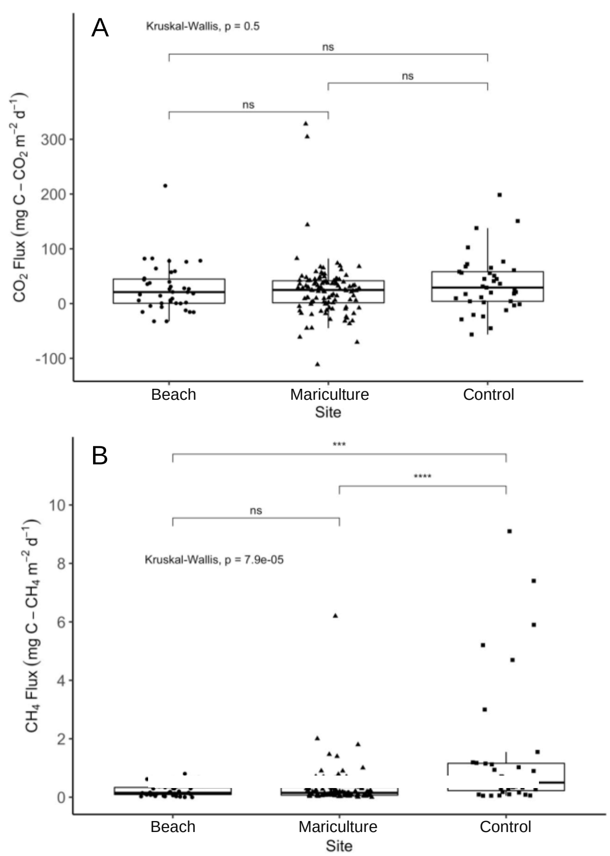


Figure 2: Diffusive fluxes of CO_2 (A) and CH_4 (B) in control and mariculture sites (ns: p > 0,05; *: p <= 0.05; **: p <= 0.01).

The study area has an average salinity of 28.7. Oxygen concentration varied between 7.8 and 8.8 mg / L, which is expected for the area. The mean pH was 8.2 throughout the entire area, considered ideal for mariculture development (BRASIL, 2005). The average concentration of NO2- was 0.93 ± 0.76 µg-N / L (Table 1), representing only 0.4% of the average NH4+

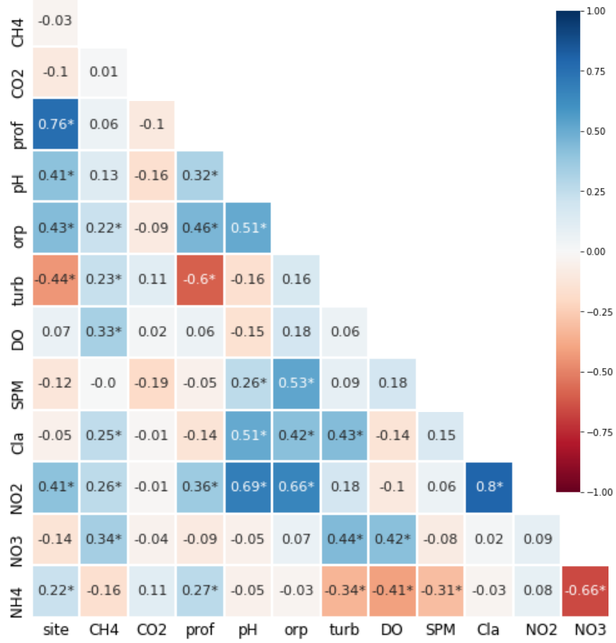
concentration (233.28 ± 85.24). This behavior is common in environments with recent inputs of inorganic nitrogen compounds, such as the input of effluents. The temporal distribution of NO2- showed an increasing trend over the monitored days. This increase may be representing the oxidation of NH4+ over this period in small quantities, considering that the decrease in NH4+ was not observed. Spatially, an increasing gradient is observed in the concentrations of NH4+ towards the mariculture area, indicating a possible source of this nutrient, by the excretion of bivalves. (Zieritz et al., 2019). Authors have been reporting the increase in nitrogen compounds in the presence of mussels, and consequently the increase in the N: P ratio (Atkinson et al., 2013; Vaughn et al., 2004)

Table 1 - Results of physical and chemical parameters: Depth in meters, Salinity, pH, Dissolved Oxygen (DO) in $mg.L^{-1}$, Oxidation-Reduction Potential (ORP) in mV, Conductivity in $mS.cm^{-2}$, Turbidity , Total dissolved solids (TSD), Chlorophyll-a ($\mu g.L^{-1}$), Suspended particulate matter (SPM) in $mg.L^{-1}$), Total organic phosphorus (TOP) in mg/L, Phosphate (PO_4) in µg/L, sulphate (SO_4^{2-}) in $mg.L^{-1}$, nitrate (NO_2^-) in $\mu g.L^{-1}$, nitrite (NO_3^-) in $\mu g.L^{-1}$, ammonia (NH_4^+) in $\mu g.L^{-1}$, silicates (SiO_4^{4-}) in $mg.L^{-1}$., Pb in $\mu g.L^{-1}$, Cu in $\mu g.L^{-1}$, Ni in $\mu g.L^{-1}$ and Zn $\mu g.L^{-1}$. *Concentration on SPM

Param.	Beach		Mariculture		Control	
	Mean	SD	Mean	SD	Mean	SD
Depth	4.2	*0.1*	9.1	*1.2*	11.8	*2.1*
Salinity	28.6	*0.6*	28.8	*0.3*	28.6	*0.1*
pH	8.20	*0.01*	8.21	*0.01*	8.22	*0.01*
DO	8.2	*0.4*	7.6	*0.8*	8.4	*0.1*
ORP	273	*4*	263	*18*	297	*13*
Conduct.	44.3	*0.9*	44.6	*0.5*	44.8	*0.6*
Turbidity	1.7	*0.5*	0.3	*0.2*	0.6	*0.4*
TSD	27.0	*0.5*	27.2	*0.3*	27.0	*0.1*
Chloroph-a	1.9	*0.6*	1.4	*0.7*	1.8	*0.5*
SPM	3.6	*0.9*	2.3	*1.8*	3.1	*1.6*
TOP	21.7	*2.2*	22.1	*1.8*	23.2	*3.7*
PO_4	14.4	*13.6*	5.7	*2.9*	18.1	*6.8*
SO_4	2.3	*0.0*	2.2	*0.2*	2.3	*0.1*
NO_2	0.8	*0.8*	0.7	*0.7*	1.7	*0.4*
NH_4	182.2	*50.1*	254.1	*78.0*	228.8	*110.1*
NO_3	44.9	*15.9*	19.7	*9.32*	45.0	*30.8*
Si	0.33	*0.08*	0.28	*0.19*	0.27	*0.03*

Total organic phosphorus (POT) has no significant difference between the sites. Phosphate data (PO_4^{3-}), showed the highest concentration at control points (Table 1), which may be related to the continental supply of organic matter (JARVIE, et al. 2006; KROM et al., 2014). The spatial distribution of PO_4^{3-} did not show an increasing gradient towards cultivation, as observed by nitrogenous substances, probably because this substance, being more chemically reactive, suffers more interactions with biogeochemical processes, such as adsorption/desorption to suspended particulate matter, being quickly consumed by organisms (Zieritz et al., 2019).

Figure 3 – Correlations coefficients between CO_2 e CH_4 flux and biogeochemical environmental parameters. Spearman correlation was performed on python 3.8. Parameters do not present in the figure had no correlation with the other variables. * p value < 0,05.



Any parameter showed a high correlation with the emissions of GHG. CO2 didn't present any significative correlation. CH4 showed low positive correlations with ORP (r = 0,22), Turbidity (r = 0,23), Dissolved Oxygen (r = 0,33), Chlorophyll (r = 0,25), Nitrite (r = 0,26) and Nitrate (r = 0,34). Results reveal that mussels farming in the Itapocoroy inlet did not have an impact on the GHG balance.

All physical-chemical parameters analyzed are in accordance with the limits recommended by current legislation (BRASIL, 2005) or close to values suggested by the literature. What shows that the water quality of these environments is not being influenced by the cultivation activities or even by the anthropic activities of the surroundings.

4. CONCLUSIONS

Results showed that mussels farming in the Itapocoroy inlet did not have an environmental impact on the GHG emission. A few monitored parameters have no differences between the control areas and mussel areas, showing no impacts resulting from the mariculture activity in the Itapocoroy inlet. All parameters showed environmental healthy levels, indicating no impact on the quality of water and greenhouse gas emissions.

5. RECOMMENDATIONS FOR FUTURE STUDIES

The results obtained demonstrate the importance of further research in marine aquaculture parks in order to show that mariculture is an activity with the capacity to produce a protein with high added value and low environmental impact when compared to the main production chains. A larger survey of data in the Itapocoroy inlet and in other areas with mariculture allows the use of more complete tools such as the Life Cycle Analysis used to verify the impact of products on the environment through studies that cover since the extraction of raw materials until their destination. Thus, the analysis of the entire production cycle offers subsidies to establish mariculture as an activity with a low carbon impact.

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4. ACKNOWLEDGMENTS

We thank all the researchers and technicians who contributed to this research. This study was funded by BRS Aqua project (Funtec, BNDES, SAP / Mapa) and supported by University of Itajaí Valey, Federal University of Santa Catarina and Embrapa Environment. We also thank the CMAS conference for the support and opportunity.