NOTE

Variation in environmental characteristics of waters among oyster and mussel culture areas in Pilar Bay, Capiz

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ABSTRACT. This study assessed the ongoing environmental suitability and zonation of oyster (*Crassostrea iredalei*) and mussel (*Perna viridis*) culture areas within Pilar Bay, Capiz, with the aim of identifying optimal areas for continued or potential expansion of shellfish farming. The study was conducted in the municipalities surrounding Pilar Bay. *In situ* measurements of physicochemical parameters, including temperature, salinity, dissolved oxygen (DO), pH, oxidation-reduction potential (ORP), and conductivity, were conducted monthly across seven sampling sites from January to December 2023. Data were analyzed statistically using SPSS, and a geotagged map of the oyster and mussel culture areas was generated. Results showed significant differences in physicochemical parameters across months and sites, except for dissolved oxygen and salinity. Variations in environmental characteristics were attributed to freshwater influx from frequent precipitation, flooding, and tidal fluctuations. Water quality evaluation revealed that all sites station were capable and moderately suitable for oyster culture, except Pinamihagan (sites 1 and 2), which were categorized as poor. For mussel culture, Buntod (Site 1) emerged as the most suitable site, rated as excellent.

Key words: Physicochemical parameters, site suitability, water quality, coastal ecosystem.

Variación de las características ambientales de las aguas entre las áreas de cultivo de ostras y mejillones en Bahía Pilar, Capiz

RESUMEN. Este estudio evaluó la idoneidad ambiental actual y la zonificación de las áreas de cultivo de ostras (*Crassostrea iredalei*) y mejillones (*Perna viridis*) dentro de la Bahía Pilar, Capiz, con el objetivo de identificar áreas óptimas para la expansión continua o potencial del cultivo de mariscos. El estudio se llevó a cabo en los municipios que rodean la Bahía Pilar. Se realizaron mediciones mensuales de los parámetros fisicoquímicos, incluyendo temperatura, salinidad, oxígeno disuelto (OD), pH, potencial de oxidación-reducción (ORP) y conductividad, en siete sitios de muestreo entre enero y diciembre de 2023. Los datos se analizaron estadísticamente utilizando SPSS y se generó un mapa geoetiquetado de las áreas de cultivo de ostras y mejillones. Los resultados mostraron diferencias significativas en los parámetros fisicoquímicos entre meses y sitios, excepto para el oxígeno disuelto y la salinidad. Las variaciones en las características ambientales se atribuyeron a la afluencia del agua dulce por las precipitaciones frecuentes, inundaciones y fluctuaciones de las mareas. La evaluación de la calidad del agua reveló que todos los sitios eran aptos y moderadamente adecuados para el cultivo de ostras, excepto Pinamihagan (sitios 1 y 2), que se clasificaron como deficientes. Para el cultivo de mejillones, Buntod (Sitio 1) resultó ser el sitio más adecuado, con una calificación excelente.

Palabras clave: Parámetros fisicoquímicos, idoneidad del sitio, calidad del agua, ecosistema costero.

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Received: 25 March 2025
Accepted: 13 May 2025

ISSN 2683-7595 (print)
ISSN 2683-7951 (online)

https://ojs.inidep.edu.ar

Journal of the Instituto Nacional de Investigación y Desarrollo Pesquero (INIDEP)

Aquaculture rapidly emerged as an alternative to capture fisheries in delivering sustainable seafood supply for customers (Edwards 2009) as food demand has been increasing with the continuously rising global population (Godfray et al. 2010). Oyster and mussel production in the Philippines is dependent on aquaculture (Laguyan et. al 2018), in which many factors need to be considered, such as physicochemical parameters, microbial load, and heavy metal content of the water. Cebu and Orale (2017) studied physical and chemical properties of the Philippine mussel farms in Samar province and found a variation in the physicochemical characteristics of the three bays (Maqueday Bay, Kanbatutay Bay, and the Bay of Villareal). This variation was credited to the volume of water streaming into the cove and the bay's physical variables.

According to Bhaja and Kundu (2012), water quality is affected by a wide range of natural and human influences. Impacts of human activities on water quality are both extensive and diverse, destroying the natural flow and limit water use. Polluted water damages aquatic ecosystems and fisheries, decreases agricultural productivity, and causes diseases like cholera, typhoid, hepatitis, diarrhea, typhoid, gastroenteritis, and dysentery (WHO 2023). Therefore, assessment and monitoring of Pilar Bay is of utmost significance to assess the environmental characteristics and determine if it is still a suitable area for oyster and mussel culture with regard to its physicochemical parameters. This study provides updated suitability classifications that can inform future site management, such as identifying areas for expansion or recommending site rehabilitation or phase-out where conditions are unfavorable.

The study site was located in Pilar Bay, which comprises the coastline of the Municipalities of Pilar, Pontevedra, Panay, President Roxas, and the City of Roxas, where multiple mussel and oyster farms are present and serves as the primary source of supply for this commodity. A total of 13 sampling stations were selected on seven sampling sites where mussel and oyster farms exist (Figure 1).

At each sampling station, physicochemical parameters such as temperature (°C), salinity, dissolved oxygen (DO, mg l^{-1}), pH, water conductivity and oxidation-reduction potential (ORP) were measured at 0.5 m below the water surface using

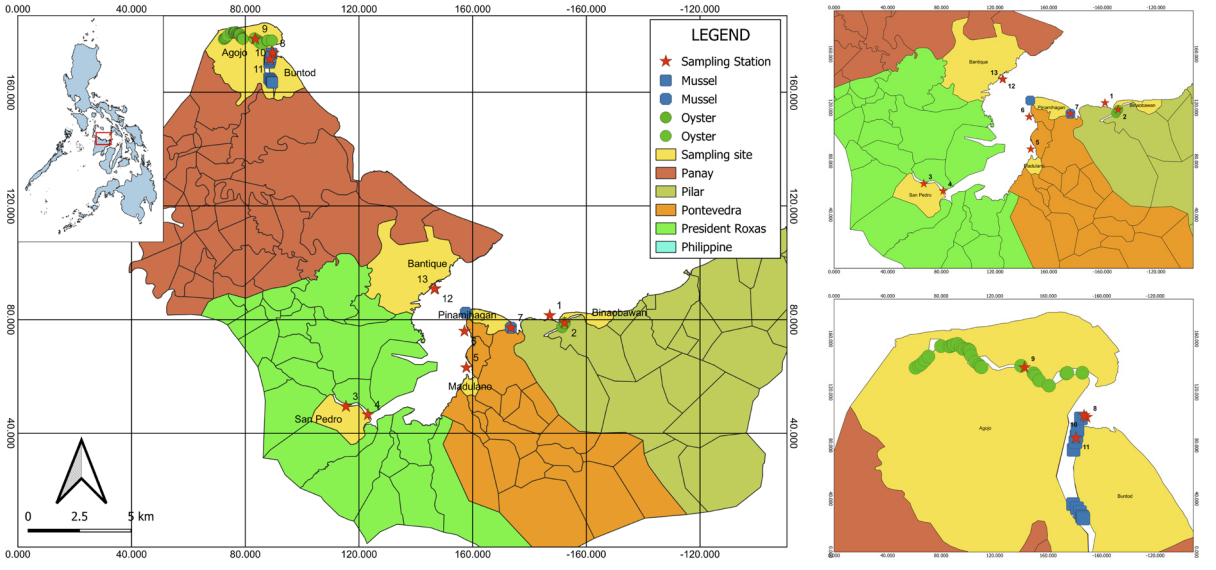

Figure 1. Sampling stations and existing oyster and mussel farms in Pilar Bay, Capiz, Philippines.

RCYAGO 6 in 1 pH/RH/EC/CF/TDS)/Temperature Rechargeable Multi-Parameter Wall-Mount Water Quality Tester. Sensors were calibrated every sampling period. Monthly sampling was done every third week of the month between January 2023 and December 2023.

The rating point of each site was determined based on parameters from Tan and Ransangan (2016) and FIGIS (2005) (Tables 1 and 2). The total weight value of each station was calculated by multiplying the rating value of each parameter by its weight value. Subsequently, total weighted

Table 1. Weighted value and rating points for the range of environmental parameters for oyster farming based on Tan and Ransangan (2016) and FIGIS (2005).

Rating point	Temperature (°C)	Salinity	Dissolved oxygen (mg l^{-1})	pH
10	20-30	17-26	> 8	7.5-8.5
9	19-31	15-28	6-7	7.3-8.7
8	18-32	13-30	5-6	7.1-8.9
7	17-33	11-32	4-5	6.9-9.1
6	16-34	9-34	3-4	6.7-9.3
5	15-35	7-36		6.5-9.5
4	14-36	5-38		6.3-9.7
3	13-37	3-40	3-2	6.1-9.9
2	12-38	1-42	2-1	5.9-10.1
1	11-39	0-44		5.7-10.3
Weight value	0.3	0.3	0.2	0.2

Table 2. Weighted value and rating points for the range of environmental parameters for mussel farming based on Tan and Ransangan (2016) and FIGIS (2005).

Rating point	Temperature (°C)	Salinity	Dissolved oxygen (mg l^{-1})	pH
10	26-32	27-32	> 8	7.7-8.4
9	25-33	25-33	6-7	7.5-8.6
8	24-34	24-34	5-6	7.3-8.8
7	23-35	23-35	4-5	7.1-9.00
6	22-36	18-36	3-4	6.9-9.2
5	21-37	15-40		6.7-9.4
4	20-38	12-45		6.5-9.6
3	19-39	10-50	3-2	6.3-9.8
2	18-40	5-55	2-1	6.1-10
1	17-41	0-65		5.9-10
Weight value	0.3	0.3	0.2	0.2

values were then used to evaluate the suitability of stations for oyster and mussel farming by comparing to the reference (Table 3). The following data from reference studies were used as basis to calculate the suitability of stations for mussel and oyster farming: The optimum level set for mussels (Babaran 2022) was 27-30 °C, salinity 27-35, pH 7.7-8.4, and DO > 8 mg l^{-1}; while the optimum level set for oysters (BFAR 2023) was 20-30 °C, salinity 17-26 (Blanco et al. 1951), pH 7.5-8.5, and DO > 8 mg l^{-1}. Suitability categories of sites for oyster and mussel farming were adapted from Sallih (2005), Salmon and Kingzett (2002), and Tan and Ransangan (2016) with slight modifications on remarks and rating points used (Table 3).

Monthly measurements of physicochemical parameters in Pilar Bay revealed notable seasonal variations (Figure 2). Temperature was significantly lower in July compared to other sampling months. The pH of the water in July was significantly more basic compared to other months, except for June and October, reflecting potential seasonal influences on water chemistry. In addition, fluctuations in the pH of coastal and estuarine waters are being predicted to increase with ocean acidification (Boulais et al. 2017). Dissolved oxygen levels peaked in August, with values significantly higher than other months, aligning with the desirable range for oyster and mussel culture (> 8 mg l^{-1} as per Layugan et al. 2018), indicating favorable oxygen availability for these shellfish during the dry season.

Salinity exhibited marked seasonal fluctuations, with significantly higher levels in May and notably lower levels in June and October ($p = 0.056$). These findings align with the optimum salinity range for oysters (17-26 according to Blanco et al. 1951) and mussels (27-35 according to Babaran 2022). Conductivity was significantly elevated in April and May, suggesting higher ionic concentrations during dry months, while October recorded the lowest conductivity values. The oxidation-reduction potential also followed a seasonal trend, with significantly higher values in May, indicating more oxidizing conditions, and significantly lower values in July, reflecting reduced oxidation-reduction activity during this period.

Physicochemical water parameters of Pilar Bay revealed significantly monthly variations (ANOVA, $p < 0.05$) in temperature, pH, salinity, conductivity, and ORP across sites. The temperature was highest in Madulano (32.29 °C) and lowest in Bantigue (18.73 °C). Bantigue also had the lowest pH (6.2-7.0). Agojo and Buntod had the highest salinity and conductivity, whereas Pinamihagan had the highest ORP (6.60) and Bantigue had the lowest (3.31). Dissolved oxygen levels showed no significant difference across sites.

For oyster culture, environmental parameters in Pinamihagan (Site 1 and Site 2) were categorized as ‘poor’, whereas all other sites were categorized as ‘moderate’ in terms of suitability (Table 4). For mussel culture, environmental parameters in Buntod (Site 1) were categorized as ‘excellent’, while sites in Binaobawan (Site 1) and Madulano (Site 1) were categorized as ‘poor’, and all other remaining sites were categorized as ‘moderate’.

Table 3. Suitability categories of sites for bivalves farming from Salmon and Kingzett (2002), Sallih (2005), and Tan and Ransangan (2016).

Weighted category	Site evaluation	Remarks
1.0-2.5	Not advisable	Not suitable for oyster and mussel farming and cannot support the culture
2.6-5.0	Poor	May support oyster and mussel but not recommended
5.1-7.5	Moderate	Capable and moderately suitable for oyster and mussel farming
7.6-10.0	Excellent	Suitable for oyster and farming and highly recommended

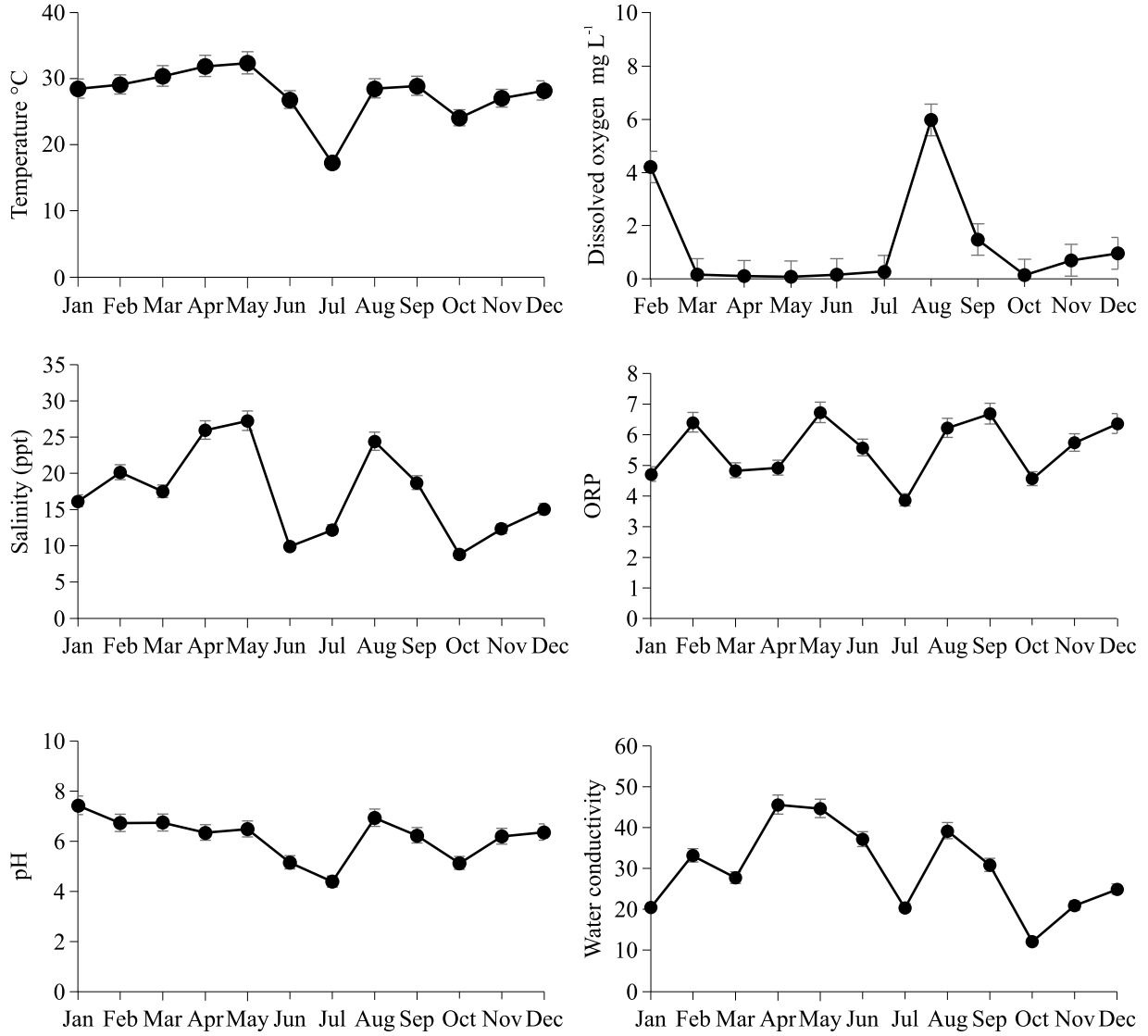

Figure 2. Monthly physicochemical parameters of Pilar Bay waters recorded from January 2023 to December 2023. ORP: oxidation-reduction potential.

Temperature differences across months and sites were likely influenced by higher solar radiation during dry months. Salinity variations across months could be attributed to freshwater influx from frequent precipitation and flooding, as well as tidal fluctuations. Dissolved oxygen concentrations were generally lower than the optimum limit of 8 mg l^{-1}, which may have implications for the growth and health of cultured shellfish. Site suitability assessments for oyster farming revealed that all sites were classified as capable and moderately suitable, except for Pinamihagan (Site 1 and Site 2), which was categorized as 'poor'. This classification indicates that while oyster culture is possible, these sites are not recommended. The 'poor' suitability of Pinamihagan could be due to

Table 4. Results for site suitability for oyster and mussel culture at sites studied.

Site	Station	Oyster culture		Mussel culture	
		Rating	Category	Rating	Category
Binaobawan	S1	5.4	Moderate	4.9	Poor
	S2	5.3	Moderate	5.1	Moderate
San Pedro	S1	5.4	Moderate	5.4	Moderate
	S2	5.4	Moderate	5.4	Moderate
Madulano	S1	5.1	Moderate	4.5	Poor
Pinamihagan	S1	4.8	Poor	5.1	Moderate
	S2	4.5	Poor	4.8	Poor
Bantigue	S1	5.2	Moderate	4.9	Poor
	S2	5.6	Moderate	5.9	Moderate
Buntod	S1	6.6	Moderate	7.9	Excellent
	S2	6.1	Moderate	6.5	Moderate
Agojo	S1	5.2	Moderate	7.1	Moderate
	S2	5.9	Moderate	6.9	Moderate

its location along a navigation route, which may lead to disturbances from boat traffic, reduced water quality, and other challenges affecting culture operations. For mussel culture, results identified Binaobawan (Site 1) and Madulano (Site 1) as 'poor', while the remaining sites were categorized as 'moderate'. Notably, Buntod (Site 1) emerged as the best potential site for mussel culture. These findings highlight the importance of strategic site planning and the adoption of appropriate technologies and best practices to enhance the sustainability and productivity of oyster and mussel culture in Pilar Bay.

ACKNOWLEDGEMENTS

This study was funded by USAID under the INSPIRE Project. We thank SIKAT Capiz, partner organizations, LGUs, and all supporters, especially drs Alfon, Linan, and Madiclum. Appreciation also goes to the Fisheries and Food Research Development staff and contributors.

Author contributions

Stephanie S. Pimentel: conceptualization; methodology; formal analysis; writing-review and editing; supervision. Efren L. Linan: conceptualization; funding acquisition; consultation; supervision. Raesa Mae B. Matias: data curation; investigation; methodology; writing-original draft.

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