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A time series analysis of aquaculture milkfish production volume using the Box-Jenkins SARIMA Model: A case study from Davao Oriental, Philippines

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ABSTRACT

Milkfish farming has been historically practiced in the Philippines for a long time and is a significant source of income and livelihood for fish farmers in the country. In this paper, the researchers analyzed the aquaculture milkfish production volume in Davao Oriental from 1996 to 2023 using Seasonal Auto-Regressive Integrated Moving Average (SARIMA). The SARIMA model was used to forecast milkfish production future values, which provided insights into the aquaculture sector's potential development in the province. The autocorrelation, partial autocorrelation, and stationarity tests indicate that milkfish production from 1996 to 2023 was not stationary. Thus, seasonal differencing was used to achieve stationarity. Several models weredeveloped and diagnosed, and SARIMA (2,0,2) $(1,1,1)_4$ provided satisfactory accuracy and precision in forecasting. However, the forecast showed some fluctuations or uncertainty in the predicted milkfish production. This can be reasoned out to be due to other environmental factors such as typhoons, rain, diseases or abnormally high sea surface temperature from climate change impacts. An actual environmental and socio-demographic survey is needed to explore further whether environmental factors are indeed affecting the production of milkfish in Davao Oriental, and therefore confirming the fluctuations of production.

Keywords: Aquaculture, Davao Oriental, forecasting, production volume, time series

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INTRODUCTION

Aquaculture in the Philippines has a long history. The earliest type of aquaculture in the Philippines was milkfish farming, which started in the Philippines approximately 400–600 years ago and then expanded to Indonesia, Taiwan, and other parts of the Pacific (FAO, 2009). Milkfish has become a national symbol, the official national fish, of the Philippines (FAO, 2009; Bagarinao, 1999). Aquaculture is essential for the food security and economic stability of fish farmers in the Philippines, with fisherfolk numbering close to 1.6 million fishers and fish farmers (Macusi et al., 2021 and Macusi et al., 2022). The Philippines ranked 11th as the world's top producer of fisheries, and the Philippines' fisheries rely heavily on aquaculture, with coastal aquaculture being the dominant form of production (Guerrero, 2022).

The dominant species cultivated for aquaculture is milkfish, cultured in a pond or in combination with other species (polyculture), such as shrimps or siganids. The first milkfish fishponds in the nation were brackishwater fishponds, which trap and grow fry from incoming tidal waters and use natural food, or "lablab," as feeds (BFAR, 2022).

In 2020, milkfish production reached 416,315 metric tons (MT), or 17.9% of the total fisheries production, contributing about Php 43.5 billion to the Gross Domestic Product (GDP) of the country, or approximately 2 to 3% of the country's Gross Value Added (GVA) for Agriculture, Fisheries, and Forestry (AFF). This has increased from a volume of 225,337 metric tons (MT) of milkfish harvested in 2001 to the present volume which is about 84.5% production growth for the past 20 years. On average, its production performance marked a 3.37% growth rate increment per year (PSA, 2020). Moreover, about 10% of the 36.8 kg of fish that the average Filipino household consumes yearly (BFAR Philippine Fisheries Profile, 2018).

Recently, milkfish farming has become popular in the Davao region as milkfish aquaculture has grown steadily throughout the years, reaching 19,398.77 metric tons (MT) in 2019, 16,527.34 metric tons (MT) in 2020, and 20,143.08 metric tons (MT) in 2021 (PSA, 2022). Likewise, the milkfish aquaculture production in Davao Oriental from 2015 to 2023 reached a total production of 7,594.23 metric tons (MT). Additionally, the total milkfish production in 2023 was only 240.23 metric tons (MT), about 53.96% and 81.28% decrease compared to the last output in 2022 and 2021, which were, 521.84 and 1,283.18 metric tons (MT), respectively (PSA, 2024).

Milkfish production, while prevalent in the country, faces challenges. Research on temperature management has shown significant effects on the growth, development, and survival of milkfish aquaculture in the Philippines. Warmer water affects the survival of milkfish eggs, and the Philippines' geographic location and geologic past make it vulnerable to typhoons and other natural disasters (Cruz et al., 2019). Additionally, low temperatures (<22.6°C) decrease activity and food intake, while higher temperatures (up to 33°C) enhance the growth and development of milkfish (Villaluz and Unggui, 1981). In floating net cages, milkfish have been successfully matured and spawned at temperatures ranging from 25-33°C, with spawning occurring during the natural breeding season (Marte and Lacanilao, 1986). Aside from temperature, the management of soil, water, and food significantly impacts milkfish survival and production in the Philippines. Eco-friendly practices in brackishwater ponds, including proper fertilization and water replenishment, are crucial for sustainable aquaculture (Guerrero, 2006). Biweekly fertilization and water replenishment have shown optimal results for milkfish growth and production (Bombeo-Tuburan, 1989). However, supplementary feeding may not be necessary at lower stocking densities when adequate pond fertilization is maintained (Otubusin and Lim, 1985).

These findings highlight the importance of temperature, soil, water, and food management in optimizing milkfish production in various aquaculture settings.

Due to the following environmental challenges and uncertain production, the use of ARIMA and SARIMA could possibly help in providing forecast to mitigate problems in production. In past studies, Mah et al. (2018) utilizes the ARIMA and ARFIMA models to forecast the demersal and pelagic marine fish production in Malaysia using the data from 1953 to 2023. The result of the study showed that the ARIMA model performed better in forecasting the demersal and pelagic fish production in Malaysia than the ARFI-MA model. Similarly, Rasdas et al. (2023) utilized K-Means and ARIMA techniques to map, cluster, and forecast the commercial fish species production in Manila Bay from 2018-2021. The result of the study showed that the large head hairtail *Trichiurus* sp., Devi's anchovy *Encrasicholina devisi*, squid, and common ponyfish *Leiognathus equula* are the top four abundant species in Manila Bay. The ARIMA forecast results indicate no significant relationships between the production of different species over time. On the other side, Ichon and Dela Gente (2023) utilized the SARIMA model to forecast the mean temperature in Davao Oriental from January 2010 to December 2022. The SARIMA (0,1,3) $(2,0,0)_{12}$ forecast a mean temperature of 28.03 in January, 27.86 in February, 27.90 in March, 28.14 in April, and 28.28 in May of 2023.

The objective of this study was to forecast the aquaculture milkfish production volume in Davao Oriental usingthe data from 1996 to 2023. This can contribute to the milkfish industry in the province by providing several insights into production trends, leading to better risk management decisions. The SARIMA model could help the milkfish aquaculture industry decide to enhance the productivity, profitability, and sustainability of milkfish aquaculture in Davao Oriental.

MATERIALS AND METHOD

Description of the study area

Davao Oriental boasts the longest coastal area in Region 11, stretching 586 km, and the largest municipal waters at approximately 5,135.04 km², accounting for 49 percent of the total municipal waters of the entire region. All municipalities, including the capital, Mati City, have coastal shores. The province's marine waters are abundant in fish, including major families such as grouper, goatfish, triggerfish, wrasses, surgeonfish, parrotfish, soldierfish, coral breams, and fusiliers. Other commercially important marine organisms include lobster, mackerel, blue crab, tridacna, sea cucumber, tuna, octopus, and scad. Most of the province's coastal residents are municipal fisherfolk engaged full-time in capture fisheries, such as hook-and-line, bagnet, and traps. These fisherfolk generally belong to lower income brackets due to the meager incomes derived from fishing. Davao Oriental has at least 15,000 municipal fisherfolk operating around 10,000 boats, 50 fish corrals, and 22 stationary bagnets across its municipalities. Major fishing grounds include Davao Gulf, Pujada Bay, Mayo Bay, Manay Bay, Baculin Bay, Caraga Bay, and Cateel Bay. Furthermore, in terms of fish production volume, aquaculture ranks third in Davao Oriental, following municipal fishing and the local commercial fishing industry. Local fish growers engage in producing a variety of low-to-medium-value freshwater, brackish, and marine products. Cultured species range from freshwater species like tilapia, catfish, and mud crab to brackishwater species such as milkfish and white shrimp. Approximately 80% of the province's aquaculture production comes from brackishwater sources, with species like milkfish, catfish, tilapia, crabs, and prawn being reared in existing coastal brackish water ponds. Mariculture, or aquaculture at sea using fish cages or pens, is primarily practiced at the Mati Mariculture Park in Brgy. Badas, Mati, which has 29 cage modules dedicated to milkfish production. Fish cage farming is also present in

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Governor Generoso and Baganga. Despite the presence of grow-out ponds, Davao Oriental lacks other aquaculture infrastructure such as hatcheries or nurseries. Nevertheless, pond and cage operators in the province source juveniles from several existing freshwater hatcheries in the neighboring Compostela Valley province for species like tilapia, catfish, and freshwater prawns. They also obtain milkfish fry from the BFAR Regional Fisheries Training Center (RFTC) located at the Panabo Mariculture Park in Panabo City, which is relatively nearby (Ilagan et al., 2013).

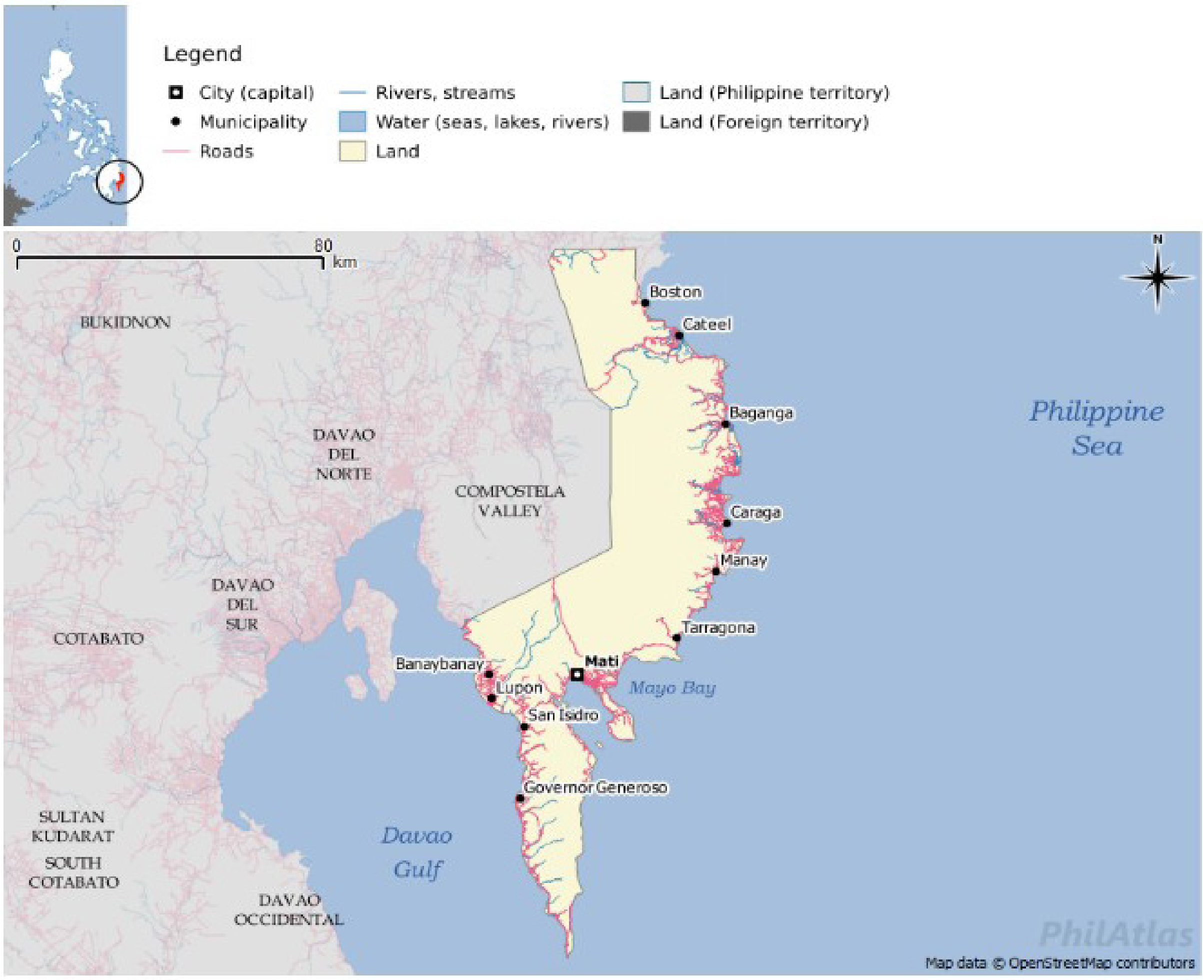

Figure 1. Area of the study.

Data Collection

Data were collected quarterly from the Philippine Statistics Authority's (PSA) open-source website. The analysis made use of one hundred twelve data sets collected from 1996 to 2023. The PSA provided relevant statistics on aquaculture milkfish production volume in Davao Oriental as it is the country's central statistical authority under R. A. 10625, the Philippine Statistical Act of 2013.

Statistical analysis

This study utilized Seasonal Autoregressive Integrated Moving Average (SARIMA) to forecast future values using R version 2024.04.2 + 764. When non-seasonal and seasonal factors are present in the time series, an additive SARIMA model can be applied. The Augmented Dickey-Fuller (ADF) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests will determine whether the data is stationary, as the SARIMA model strictly requires stationary data. If the data does not appear stationary, transformation is required to make it stationary.

The initial steps in data preparation include methodologies proposed by Box and Jenkins in 1970. First, the data needs to be transformed to stabilize the variance and apply differencing. Second, model selection. It begins by analyzing the autocorrelation function (ACF) and partial autocorrelation function (PACF) plots of the stationary data which determines the models from the SARIMA (p, d, q) (P, D, Q) family wherein p and q represent the possible order of AR and MA for the nonseasonal component of the model and P, D, and Q are seasonal auto-regressive orders, seasonal differencing, and seasonal moving average orders. If unsure, the *auto.arima()* function will identify potential models conveniently. Evaluation of the models are done using appropriate criteria such as the Akaike Information Criterion (AIC), Corrected Akaike Information Criterion (AICc), Bayesian Information Criterion (BIC), and accuracy measures like Root Mean Square Error (RMSE), Mean Absolute Error (MAE), and Mean Absolute Percentage Error (MAPE). The accuracy measures (RMSE, MAE, MAPE) and the AIC, AICc, and BIC values determine the best-fitted models, wherein a model with the lowest values in the

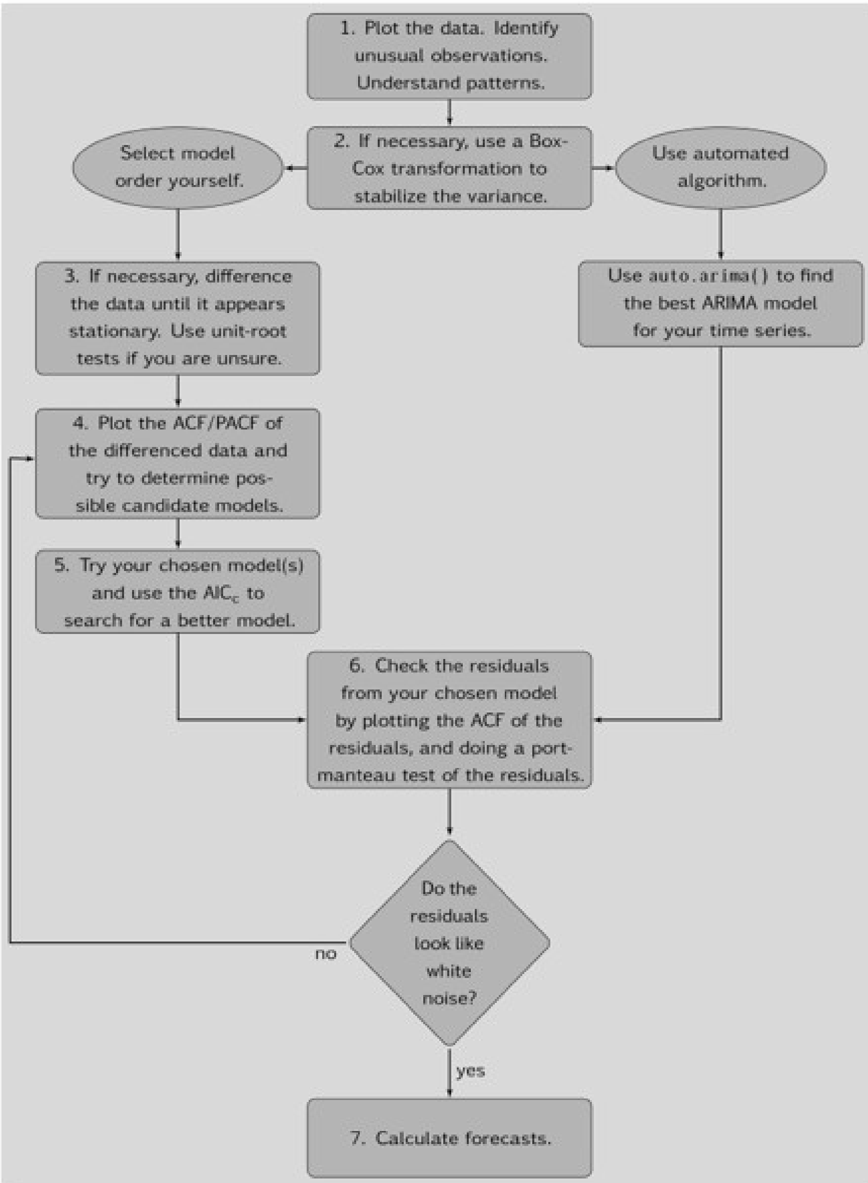

Figure 2. The process of SARIMA (Seasonal Auto-Regressive Integrated Moving Average).

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mentioned criteria would be the best, as it provides accurate forecasting and precision. Lewis (1982) stated that a MAPE less than 10% is highly accurate for forecasting; a MAPE greater than or equal to 10% but less than or equal to 20% is suitable for predicting; a MAPE greater than or equal to 20% but less than or equal to 50% is reasonable for forecasting; and a MAPE greater than 50% is inaccurate for predicting. Similarly, AIC, AICc, and BIC values are crucial in statistical modeling and model selection as they combine model estimation with structural and dimension determinations (Cavanaugh, 2019).

Third, the need to diagnose the model. The models underwent thorough diagnostics using the Ljung-Box test to determine the distribution of the residuals. The Ljung-Box test is crucial in SARIMA modeling as it assesses the homogeneity and randomness of the model's residuals (Martínez-Acosta et al., 2020). Lastly, if the model follows random white noise, it will be used to forecast future values.

RESULTS

Preliminary analysis

Table 1 shows the statistics of aquaculture milkfish production volume in Davao Oriental. The minimum and maximum milkfish productions are 2.57 and 786 metric tons (MT). The milkfish production in the first and third quartiles are 135.476 and 305.40 metric tons (MT), while the mean and median milkfish production are 201.72 and 234 metric tons (MT).

Table 1. Statistics for aquaculture milkfish production volume in Davao Oriental.

Variable	Mean	Median	1st Quartile	3rd Quartile	Minimum	Maximum
Production	201.72	234	135.476	305.40	2.57	786

In addition, Figure 3 visualizes the aquaculture milkfish production volume in Davao Oriental, highlighting seasonal variations as fluctuations in milkfish production occur throughout the years. On the other hand, milkfish production shows neither upward nor downward trends, which gives insights into the province's milkfish productivity.

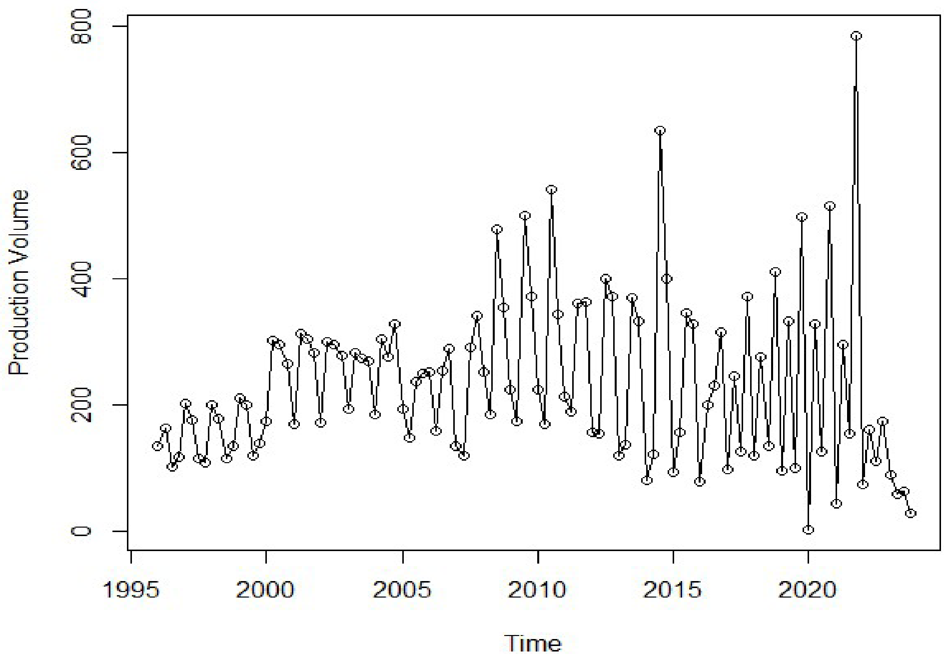

Figure 3. Time series plot of aquaculture milkfish (*Chanos chanos*) production volume in Davao Oriental.

Furthermore, the boxplot in Figure 4 shows an increasing trend in the median milkfish production volume, increasing from the first to the third quarters but slightly decreasing in the fourth quarter. Additionally, an outlier in the fourth quarter signifies the unusual milkfish production in Davao Oriental.

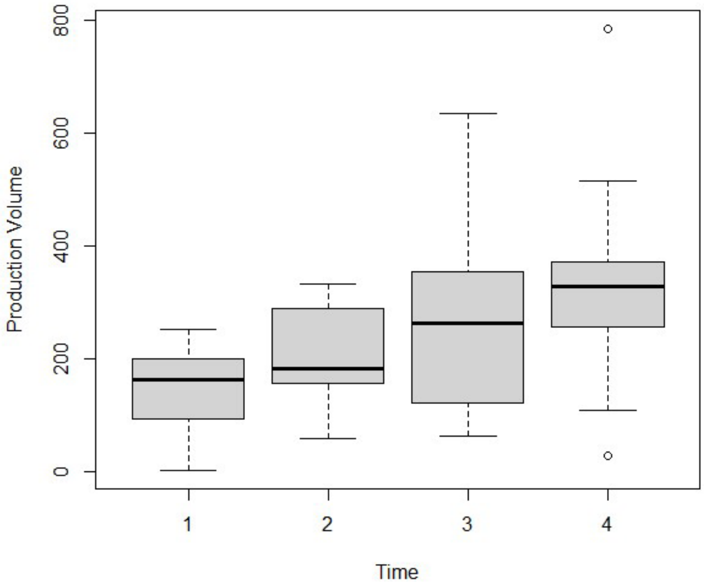

Figure 4. Boxplot of aquaculture milkfish (*Chanos chanos*) production volume in Davao Oriental by quarter.

Moreover, the additive seasonal and trend decomposition using Loess (STL) in Figure 5 visualizes the underlying pattern of aquaculture milkfish production volume in Davao Oriental. The seasonal component displays periodic fluctuations, which implies a seasonal pattern in milkfish production. Similarly, the trend component lacks long-term direction, while the residuals are distributed randomly around zero in the remainder component.

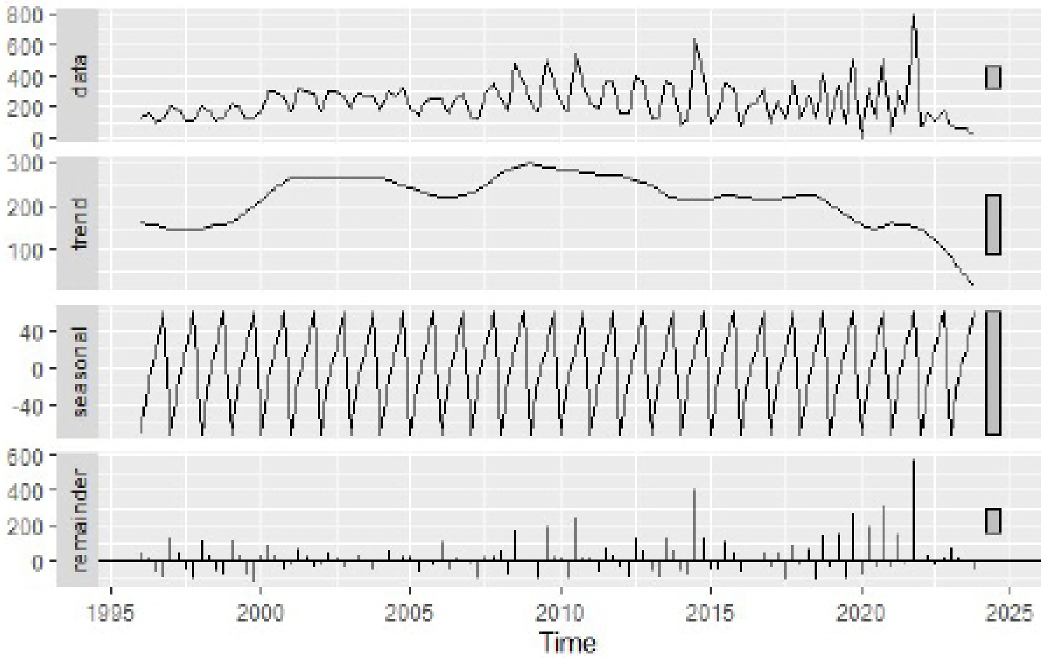

Figure 5. Additive seasonal and trend decomposition of milkfish (*Chanos chanos*) production using Loess.

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ARIMA (Box-Jenkins) modelling

The data were split into training sets (80%), consisting of 89 observations, and testing sets (20%), comprising 23 observations for model training and validation. The stationarity of the data was determined using KPSS and ADF tests before model building and parameter estimations. The original data is not stationary, given by a *p*-value greater than 0.05 in the ADF test. Conversely, upon seasonal differencing, the data is stationary, given by a *p*-value less than 0.05 in the ADF test and greater than 0.05 in the KPSS test, as shown in Table 2.

Table 2. Stationarity testing using KPSS and ADF test.

	KPSS level	*p*-value	Dickey-Fuller	*p*-value	Stationary
Original data	0.28	0.1	-1.43	0.81	No
First difference	0.03	0.1	-6.65	0.01	Yes

After reaching stationarity, the order of parameters should be explored to determine the potential models. The ACF and PACF plots of the stationary data will determine the fitted autoregressive (AR) and moving average (MA) values. The PACF plot in Figure 6 showed significant autocorrelation at lag one, which signifies a fitted AR of the model. With these, it is hypothesized that the possible parameter order of the model is SARIMA (1, 0, q) (1, 1, Q).

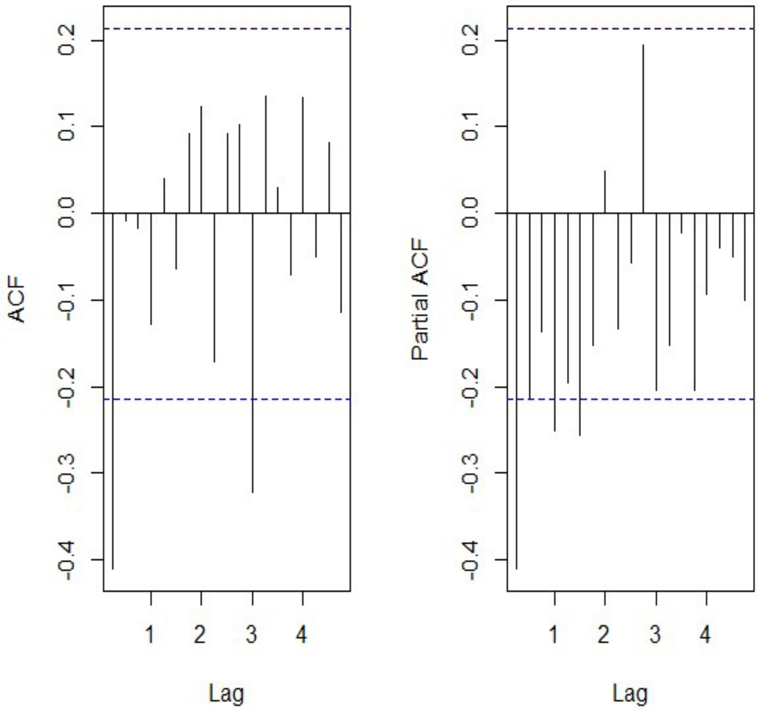

Figure 6. Autocorrelation and partial autocorrelation after the first difference.

Moreover, Table 3 presents the potential models to forecast future values. A model with the most minor estimates and standard error values indicates a better-fitting model. The SARIMA (1,0,0) $(2,1,2)_4$ displayed the smallest values among the three models in estimates. The SARIMA (1,0,1) $(1,1,1)_4$ displayed the smallest values among the three models in standard error, and the SARIMA (2,0,2) $(1,1,1)_4$ displayed significant values in both the non-seasonal and seasonal components of the model.

Table 3. Parameters of SARIMA models.

Models	Components	Estimates	Standard error	*p*-values
SARIMA (2,0,2) $(1,1,1)_4$	AR1	-0.70	0.09	0.00
	AR2	-0.74	0.09	0.00
	MA1	0.96	0.05	0.00
	MA2	1.00	0.05	0.00
	SAR1	-0.86	0.15	0.00
	SMA1	0.68	0.21	0.00
SARIMA (1,0,0) $(2,1,2)_4$	AR1	0.17	0.11	0.11
	SAR1	-0.06	0.13	0.66
	SAR2	0.81	0.11	0.00
	SMA1	-0.18	0.18	0.33
	SMA2	-0.82	0.17	0.00
SARIMA (1,0,1) $(1,1,1)_4$	AR1	0.33	0.52	0.52
	MA1	-0.16	0.54	0.76
	SAR1	-0.93	0.10	0.00
	SMA1	0.81	0.15	0.00

In addition, the accuracy measures in Table 4 will determine the best model for forecasting future values. The SARIMA (2,0,2) $(1,1,1)_4$ has the lowest RMSE, MAE, and MAPE accuracy measures among the three models.

Table 4. Accuracy measures of SARIMA models.

Models	RMSE	MAE	MAPE
SARIMA (2,0,2) $(1,1,1)_4$	59.99	37.40	15.73
SARIMA (1,0,0) $(2,1,2)_4$	62.80	39.37	16.34
SARIMA (1,0,1) $(1,1,1)_4$	64.87	39.65	16.55

Similarly, the Akaike Information Criterion (AIC), Corrected Akaike Information Criterion (AICc), and Bayesian Information Criterion (BIC) in Table 5 will select the best-fitting model. Among the three models, SARIMA (2,0,2) $(1,1,1)_4$ has the lowest values in AIC, AICc, and BIC.

Table 5. Model selection using AIC, AICc, and BIC.

Models	AIC	AICc	BIC
SARIMA (2,0,2) $(1,1,1)_4$	960.52	961.97	977.62
SARIMA (1,0,0) $(2,1,2)_4$	965.51	966.59	980.17
SARIMA (1,0,1) $(1,1,1)_4$	965.5	966.26	977.71

Model diagnostic

This study utilizes the Ljung-Box test to determine the distribution of the model's residuals, where the *p*-value is for hypothesis testing. A *p*-value greater than 0.05 suggests that the model residuals exhibit no significant autocorrelation, indicating independent distributions. The *p*-values in Table 6 are greater than 0.05, which indicates no significant autocorrelation; thus, the residual distribution is independent. In addition, SARIMA (2,0,2) $(1,1,1)_4$ has the highest *p*-value, effectively capturing the autocorrelation in the time series data. With these, the SARIMA (2,0,2) $(1,1,1)_4$ will forecast future values of aquaculture milkfish production volume in Davao Oriental.

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Table 6. L-jung box test p values of SARIMA models.

Models	*P*-values
SARIMA (2,0,2) $(1,1,1)_4$	1.00
SARIMA (1,0,0) $(2,1,2)_4$	0.77
SARIMA (1,0,1) $(1,1,1)_4$	0.91

In addition, Figure 7 displays the model's residuals' ACF and histogram plots, which show a normal distribution in the histogram plot and no significant autocorrelation in the ACF plot.

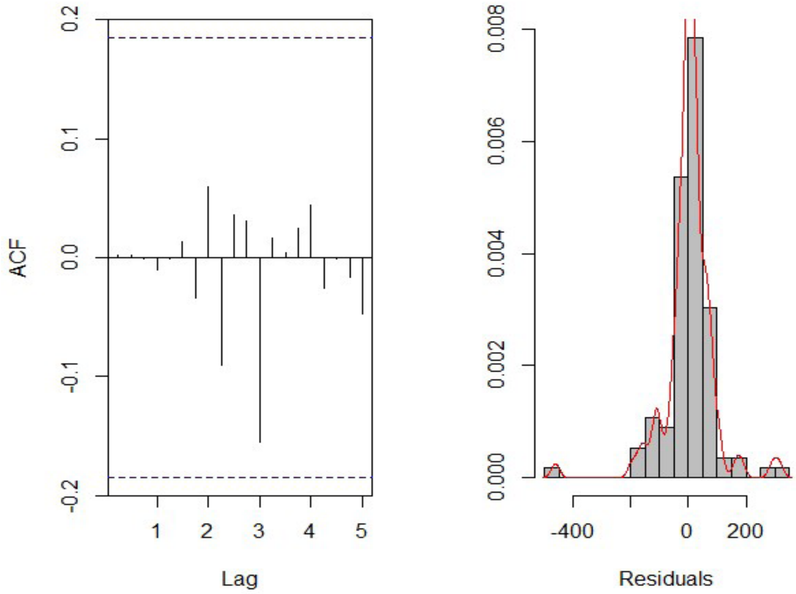

Figure 7. The autocorrelation function and histogram plot of SARIMA (2,0,2) $(1,1,1)_4$

Furthermore, the SARIMA (2,0,2) $(1,1,1)_4$ will forecast future values as it follows random white noise upon model diagnostics. Table 7 presents the forecasted future values of aquaculture milkfish production volume with a 95% confidence interval, wherein the predicted milkfish production in the quarter of 2024 is higher compared to the actual milkfish production in 2023. The predicted milkfish production in quarter 1 of 2024 is 64.36 metric tons (MT), about a 27.56% decrease compared to the actual milkfish production of 88.85 metric tons (MT) in 2023. Conversely, the predicted milkfish production in quarter 4 of 2024 is 86.75 metric tons (MT), about a 66.12% increase compared to the actual milkfish production of 293.39 metric tons (MT)in 2023. Additionally, PSA published recent data on aquaculture milkfish production volume in Davao Oriental; about 64.95 metric tons (MT) was produced in the first quarter of 2024, closer to the predicted value of 64.36 metric tons (MT), with a forecast error of 0.59. With these, the SARIMA (2,0,2) $(1,1,1)_4$ effectively captures the pattern of milkfish production in Davo Oriental. However, the forecast shows considerable uncertainty, as indicated by the wide confidence intervals, implying an unpredictability of forecasted values.

Table 7. Forecasted future values of aquaculture milkfish production volume (metric tons) in Davao Oriental with a 95% confidence interval (CI).

Quarters	Point forecast	Lower 95% CI	Upper 95% CI
1st quarter of 2024	64.36	-112.48	241.20
2nd quarter of 2024	60.91	-117.09	238.91
3rd quarter of 2024	105.43	-75.74	286.60
4th quarter of 2024	86.75	-94.44	267.95

Likewise, the aquaculture milkfish production volume in Davao Oriental and forecasted values in Figure 8 fluctuated as the quarter changed. Thus, the SARIMA model effectively captured the underlying patterns of milkfish production in Davao Oriental.

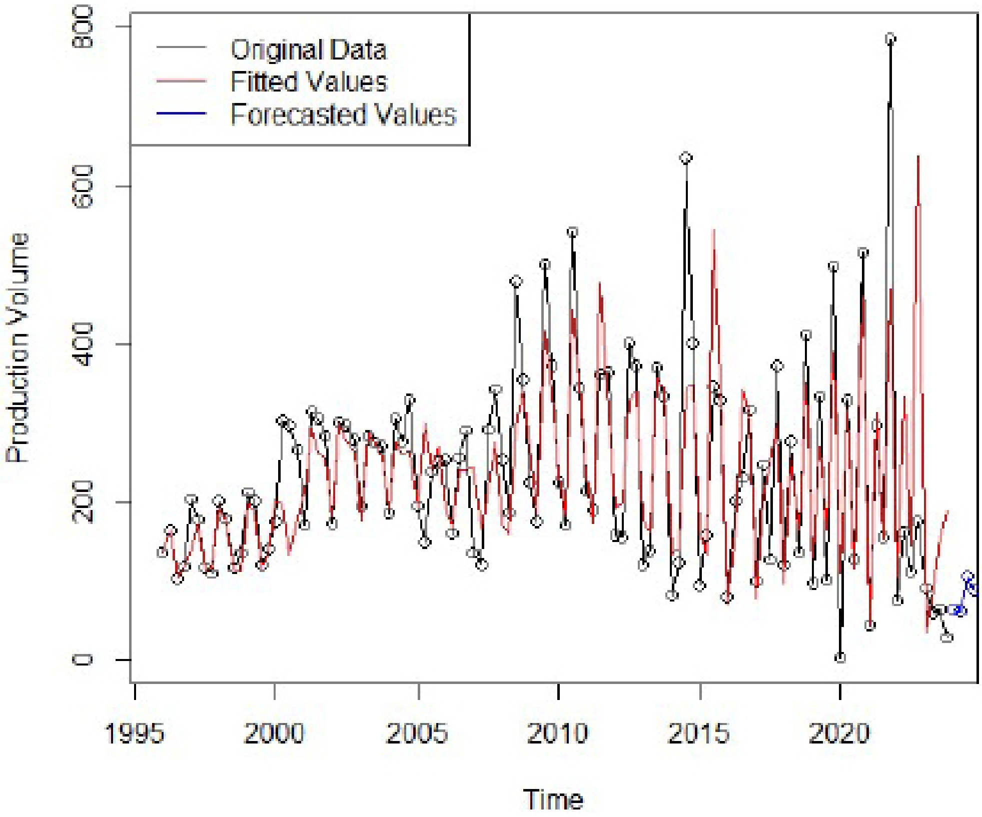

Figure 8. Time series plot of aquaculture milkfish (*Chanos chanos*) production volume in Davao Oriental.

DISCUSSIONS

The findings of the study on aquaculture milkfish production volume in Davao Oriental hold significant implications for fisherfolk and agencies such as the Bureau of Fisheries and Aquatic Resources (BFAR) and the City Agriculture Office. The observed fluctuations in milkfish production highlight the vulnerability of the aquaculture sector to environmental and climatic factors. Macusi et al. (2023) highlighted overfeeding, pollution, disease, climate change, water quality, and fish behavior as the factors that impact milkfish farming. Overfeeding results in excess nutrients entering the water column, which accumulate on the sea bottom over several production cycles, degrading water quality. Oxygen levels in the sediment beneath the cages decrease, making the aquaculture area prone to fish kills (FAO, 2018). Significant disease cases reported were attributed to bacterial, mycotic, parasitic, and toxic causes. Bacterial infections, primarily due to *Vibrio* sp., have been frequently associated with milkfish mortality (Lio-Po, 1984). Climate change, on the other hand, impacts milkfish farming. Extremely high temperatures lead to massive fish kills for milkfish farmers in the Philippines and hot temperatures stress fish and can destroy farmers' livelihoods by eradicating whole stocks (White, 2013).

The forecasted future values of aquaculture milkfish production volume with a 95% confidence interval showed an accurate prediction estimate that would give insights into the fisherfolk and agencies for better decision-making in enhancing milkfish productivity in the province in many years to come. However, in a lower 95% confidence interval the forecasts are negative, which indicates a significantly high uncertainty in the predicted values of milkfish production.

The productivity of milkfish in the province was affected by external factors such as environmental and climatic factors. Itinfluences the livelihoods of fisherfolks, and for agencies, it underscores the need for adaptive management practices that can buffer against such uncertainties. A collaborative effort of both the fisherfolk and agencies will help avoid uncertainty and mitigate the risk of low productivity of milkfish in the province. Garcia (1990) stated the importance of good water quality maintenance as one of the keys to the successful culture of milkfish. The water depth for culturing milkfish with lablab as the natural food is as follows: 20 to 30 cm for the nursery, 30 to 40 cm for the transition, and 40 to 50 cm for the rearing ponds. When algae is used as food, 20 to 60 cm water depth is maintained in rearing ponds; if plankton, 70 to 100 cm. About 30 to 50% of the pond water is changed during full and new moon periods or every 14 days. Ponds are drained either late in the evening or early in the morning about 2 to 3 hours before an incoming high tide. Pond water is not drained to a level lower than the expected tide level for that particular day. Additionally, the Network of Aquaculture Centres in Asia-Pacific (NACA, 2012) suggested adaptation measures of small-scale milkfish farmers in the Philippines to climate change. It includes (1) strengthening perimeter dykes to prevent fish escape during intense rainfall, flood, storm surge, or extreme tides; (2) installation of wave breakers such as limestone rip rap on seaward dykes can reduce the impacts of wave action, encourage siltation and allow natural development of mangroves; (3) there is a need to improve pond fertilization techniques using both organic and inorganic fertilization and to test the efficacy of probiotics to improve water quality stability during fluctuating climate conditions; (4) higher and stronger pond dykes and deeper ponds will help to prevent fish escape due to dyke damage and help to improve water quality stability and fish productivity. Improved fish productivity will also help the farmers to be more profitable and so be more resilient to cope with climate change. This will require investment in pumps to maintain water depth and aerators to increase productivity; and (5) milkfish farmers can adapt to small changes in weather patterns and short-term gradual climate change but they are not prepared for rapid changes or long-term continuous climate change. The farmer needs to be assisted by scientific research and technology development to find solutions that will allow them to adapt to the predicted future climate changes. Furthermore, for small-scale fish farmers in developing nations like the Philippines who largely rely on purchasing costly commercial feeds, rising feed and related costs are often too high to be absorbed into already-thin profit margins. Thus, it is important to provide good alternatives to purchasing costly commercial feeds, especially for small-scale fish farmers who are vulnerable to fluctuations of feed costs. This can be done by reducing the amount of fish-based ingredients in feed formulations by utilizing alternative sources of feed ingredients that are sustainable, efficient, and cost-saving, and that can compete with commercial feeds in terms of growth performance and other biological parameters. By making the feed cost-effective and sustainable, it will increase profits and encourage more fish farmers, giving a higher return on investments (Macusi, et al., 2023). Good water quality management, adaptation to climate change, and cost-effective feeding practices are some of the strategies that help fisherfolk and agencies for productive and profitable milkfish in Davao Oriental in many years to come.

While the SARIMA model has proven effective for forecasting milkfish production in Davao Oriental, exploring hybrid models like those used in other contexts could further enhance forecasting accuracy and precision. This can lead to more informed decision-making, better resource allocation, and improved resilience against environmental and climatic uncertainties for fisherfolk and agencies, which benefits milkfish production in the province.

CONCLUSION

In this study of building a model that can forecast milkfish production in Davao Oriental, albeit in a limited manner, the winning candidate was SARIMA (2,0,2)$(1,1,1)_4$. Upon model diagnostic, the models' residuals were uncorrelated because they followed the same pattern as random white noise, and the residuals showed a normal distribution. The model forecasted future values of aquaculture milkfish production volume in Davao Oriental in 2024 which showed fluctuations in the different quarters. Future researchers are encouraged to explore hybrid models combining SARIMA and ANN to further improve its predictive accuracy. These integrations will help better forecast the milkfish production in the fish farming industry and make better decisions and enhance milkfish productivity in the province.

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REFERENCES

Bagarinao, T. (1999). Ecology and farming of milkfish. Tigbauan, Iloilo, Philippines: *Southeast Asian Fisheries Development Center, Aquaculture Department.*

BFAR. (2018). Philippine Fisheries Profile 2018. BFAR. (2022). The National Milkfish Industry Roadmap Industry Roadmap (2021-2040). Fisheries Building Complex, BPI Compound, Visayas Ave., Quezon City: *Bureau of Fisheries and Aquatic Resources.*

Bombeo-Tuburan, I. (1989). Comparison of various water replenishment and fertilization schemes in brackishwater milkfish ponds. *Journal of Applied Ichthyology*, 5(2), 61-66.

Cavanaugh, J. E., and Neath, A. A. (2019). The Akaike information criterion: Background, derivation, properties, application, interpretation, and refinements. *Wiley Interdisciplinary Reviews: Computational Statistics*, 11(3), e1460.

Cruz, R. A. L., Kumar, V., and Ragaza, J. A. (2019). Some Current Trends and Challenges in Philippine Aquaculture, with an Emphasis on Synergies with Biodiversity Initiatives. Archīum. (pp. 35-42). *World Aquaculture*.

FAO. (2009). Chanos chanos. In Cultured aquatic species fact sheets. Text by Nelson, A.L. and Marygrace C.Q. Edited and compiled by Valerio Crespi and Michael New. CD-ROM (multilingual).

FAO. (2018). Better management practices for feed production and management of Nile tilapia and milkfish in the Philippines. Rome, Italy: Food And Agriculture Organization Of The United Nations.

Garcia, L. M. (1990). Fisheries biology of milkfish (*Chanos chanos Forskal*). In Proceedings of the Regional Workshop on Milkfish Culture Development in the South Pacific, 21-25 November 1988, Tarawa, Kiribati (pp. 66-76). Food and Agriculture Organization of the United Nations, South Pacific Aquaculture Development Project.

Guerrero III, R. D. (2006). Eco-Friendly Fish Farm Management and production of safe aquaculture foods in the Philippines. *Aquaculture*, 1(43.7), 896-445.

Guerrero III, R., Rasco, Jr., E., and Aliño, P.M. (2022). Developing Philippine Coastal and Oceanic Aquaculture for Food Security and Livelihood Generation. Transactions of the National Academy of Science and Technology.

Ichon, L. M., Dela Gente, J. M. (2023). Time Series Analysis of Mean Temperature using SARIMA: An Example from Davao Oriental, Philippines. *Davao Research Journal (DRJ)*, 14(1), 73-83.

Ilagan, L.; Andigan, C.; Nobillos, J. and Meru, F. (eds). High-Value Aquaculture Industry Development Plan for Davao Oriental, 2013-2020. USAID GEM Technical Paper. Philippines, USAID. 2013. 212p.

Lewis, C.D. (1982). Industrial and business forecasting methods. London: A practical guide to exponential smoothing and curve fitting. Butterworths.

Lio-Po, G. (1984). Diseases of milkfish. In J. V. Juario, R. P. Ferraris, and L. V. Benitez (Eds.), Advances in milkfish biology and culture: Proceedings of the Second International Milkfish Aquaculture Conference, 4-8 October 1983, Iloilo City, Philippines. (pp. 147-153). Metro Manila, Philippines: Published by Island Pub. House in association with the Aquaculture Department, Southeast Asian Fisheries Development Center and the International Development Research Centre.

Macusi, E. D.; Macusi, E. S.; Bongas, H. P.; and Cayacay, M. A. Typology of Milkfish (*Chanos chanos*) Farms: Their Operations, Socio-Economic Viability, and Challenges. Preprints 2023, 2023120507.

Macusi, E. D., Estor, D. E. P., Borazon, E. Q., Clapano, M. B., and Santos, M. D. (2022). Environmental and Socioeconomic Impacts of Shrimp Farming in the Philippines: A Critical Analysis Using PRISMA. *Sustainability* 14(5), 2977.

Macusi, E. D., Geronimo, R. C., and Santos, M. D. (2021). Vulnerability drivers for small pelagics and milkfish aquaculture value chain determined through online participatory approach. Marine Policy 133, 104710.

Mah, P.J., Ihwal, N.A., and Azizan, N.A. (2018). Forecasting Fresh Water And Marine Fish Production In Malaysia Using Arima And Arfima Models. *Malaysian Journal Of Computing*.

Marte, C.L., and Lacanilao, F.J. (1986). Spontaneous maturation and spawning of milkfish in floating net cages. *Aquaculture*, 53, 115-132.

Martínez-Acosta, L., Medrano-Barboza, J. P., López-Ramos, Á., Remolina López, J.F., & López-Lambraño, Á.A. (2020). SARIMA Approach to Generating Synthetic Monthly Rainfall in the Sinú River Watershed in Colombia. *Atmosphere*.

Network of Aquaculture Centres in Asia-Pacific. (2012). Technical brief: Vulnerability and adaptation to climate change for milkfish farming in the Philippines. Network of Aquaculture Centres in Asia-Pacific.

Otubusin, S.O., and Lim, C.E. (1985). The effect of duration of feeding on survival, growth, and production of milkfish, Chanos chanos (Forskal), in brackish water ponds in the Philippines. *Aquaculture*, 46(4), 287-292.

PSA. (2020). Selected Statistics on Agriculture 2020, Bureau of Agricultural Statistics (BAS). ISSN-2012-0362. Quezon City, Philippines.

PSA. (2022). Fisheries Statistics of the Philippines 2019-2021, in: Mapa, D. (Ed.). Philippine Statistics Agency, Quezon City, Philippines, p. 327

PSA. (2024). OpenStat website. Retrieved from https://openstat.psa.gov.ph/

Rasdas, S. M., Costales, J. A., Fajardo, A. C., and Limbago, J.S. (2023). Abundance Mapping of Commercial Fisheries Production using K-Means and Forecasting Algorithm in Manila Bay, Philippines. 2023 IEEE 8th International Conference for Convergence in Technology (I2CT), 1-5.

Villaluz, A.C., and Unggui, A.S. (1981). Effects of temperature on behavior, growth, development and survival in young milkfish, Chanos chanos (Forskal). *Aquaculture*, 35, 321-330.

White, P. G. (2013). Case study on the impacts of climate change on Milkfish pond production in the Municipalies of Borotok Nueva and Dumangas, Panay Island, Philippines.