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APPLICATION OF THE COCHRANE-ORCUTT METHOD IN ANALYZING THE IMPACT OF WATER QUALITY DYNAMICS ON THE GROWTH OF VANNAMEI SHRIMP (*Litopenaeus vannamei*)

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Abstract: Vannamei shrimp (Litopenaeus vannamei) is a key commodity in aquaculture due to its high survival rate, short cultivation period, and disease resistance. Water quality plays a crucial role in shrimp growth and productivity, particularly in intensive farming systems. This study aims to analyze the effects of water quality dynamics (pH, temperature, and dissolved oxygen) on shrimp growth, measured through Average Body Weight (ABW) and Specific Growth Rate (SGR). Multiple linear regression analysis was employed, but given the time-series nature of water quality data, the assumption of non-autocorrelation was violated. To address this issue, the Cochrane-Orcutt method was applied to obtain efficient parameter estimates and valid hypothesis testing results. The findings indicate that temperature significantly affects ABW and SGR ($p < 0.05$), while pH and dissolved oxygen do not show a significant partial effect. The simultaneous F-test confirms that these three water quality variables collectively influence shrimp growth. The Durbin-Watson test revealed autocorrelation in the initial model, which was resolved through the Cochrane-Orcutt method. The final regression model demonstrated improved estimation accuracy without autocorrelation. This study highlights that temperature is the primary factor influencing vannamei shrimp growth, while pH and dissolved oxygen play supporting roles in maintaining an optimal environment. Furthermore, the Cochrane-Orcutt method proved effective in addressing autocorrelation, ensuring more accurate analysis results that can guide the management of intensive vannamei shrimp farming.

1. INTRODUCTION

Vannamei shrimp is one of the leading commodities in the aquaculture sector. Its high survival rate, relatively short cultivation period, and resistance to diseases make this shrimp species highly sought after. Water quality significantly influences the growth and production of vannamei shrimp, especially in intensive farming systems, where maintaining good water

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quality is crucial [1]. Water quality is dynamic and fluctuates over time. Ensuring water parameters remain within the acceptable thresholds for aquaculture activities is essential for shrimp farmers [2]. Daily monitoring of water quality in shrimp ponds helps prevent issues and provides valuable information for farmers to make informed decisions regarding their aquaculture operations.

Regression analysis is a common method used to examine the relationship between variables. However, this method assumes that no autocorrelation exists in the residuals [3]. The non-autocorrelation assumption states that the error terms of the regression model should not be correlated with each other. Violating this assumption, known as autocorrelation, can result in inefficient parameter estimates and invalid hypothesis tests. Autocorrelation often occurs in time-series data, where observations recorded close in time may exhibit correlated errors. Since water quality data in this study is collected daily or periodically, it constitutes time-series data, which may lead to violations of the non-autocorrelation assumption.

To address autocorrelation issues, several corrective methods can be applied, one of which is the Cochrane-Orcutt method. This technique calculates the autocorrelation coefficient ($\hat{\rho}$) using the residuals from the regression model. The process iteratively estimates the $\hat{\rho}$ value until it converges to ensure that autocorrelation is no longer present [4].

Given the importance of water quality for vannamei shrimp growth, maintaining optimal water quality leads to better growth and productivity. However, the time-series nature of water quality data makes it prone to autocorrelation, requiring the application of the Cochrane-Orcutt method for efficient parameter estimation and valid hypothesis testing. This approach helps identify the water quality parameters that significantly impact shrimp growth.

This study aims to develop a regression model to analyze the impact of water quality dynamics on the growth of vannamei shrimp, ensuring that the non-autocorrelation assumption is met using the Cochrane-Orcutt method. Additionally, it seeks to determine which water quality variables significantly influence shrimp growth.

2. LITERATURE REVIEW

2.1. Growth of Vannamei Shrimp

In this study, the growth of vannamei shrimp is measured using Average Body Weight (ABW) and Specific Growth Rate (SGR). ABW represents the average weight recorded over a specific period. The average shrimp weight can be influenced by the population density in a given pond. A high shrimp population may limit movement, access to food, and oxygen. According [5], ABW refers to the average weight of shrimp obtained from sampling. [6] state that ABW can be calculated using the following formula:

$$W = \frac{\mathrm{B}}{\mathrm{N}} \tag{1}$$

Where :

W = Average weight per shrimp (grams)
B = Total weight of sampled shrimp (grams)
N = Number of sampled shrimp (individuals)

Specific Growth Rate (SGR) is an essential parameter in aquaculture activities. The growth rate period of shrimp directly influences the success and efficiency of the cultivation

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time. SGR measures the difference between the final and initial average body weights, normalized over the measurement period, and expressed as a natural logarithm (Ln). According to Scabra [7], the formula for calculating SGR is as follows:

$$SGR = \frac{\mathrm{LnW}_t - \mathrm{LnW}_0}{\mathrm{t}} x100\% \tag{2}$$

Where:

W_t = Final average body weight of shrimp (grams)
W_0 = Initial average body weight of shrimp (grams)
t = Duration of cultivation (days)

Water quality in aquaculture involves physical, chemical, and biological factors that can affect production outcomes. Poor water quality can lead to low survival rates, hindered growth, and impaired reproduction of shrimp. In this study, the water quality parameters examined are temperature,pH and Dissolved Oxygen (DO). Monitoring these parameters is crucial to ensure optimal environmental conditions, which directly influence the health and productivity of vannamei shrimp farming.

2.2. Regression analysis

Regression analysis is a statistical method used to understand the relationship between two or more variables. This method helps determine how one or more independent (predictor) variables influence a dependent (response) variable [8]. Based on the number of independent variables, regression analysis is generally divided into two types: Simple linear regression: When there is only one independent variable. Multiple linear regression: When there are two or more independent variables. In this study, there are three independent variables, so the appropriate method is multiple linear regression. The estimated regression model equation used is:

$$\hat{y} = \hat{\beta}_0 + \hat{\beta}_1 X_1 + \hat{\beta}_2 X_2 + \hat{\beta}_3 X_3 \tag{3}$$

This model helps assess the significance and strength of the relationships between water quality parameters and shrimp growth.

Where:

$\hat{y}$ = Dependent variable (e.g., shrimp growth: ABW or SGR)
$\hat{\beta}_0$= Intercept
$\hat{\beta}_1, \hat{\beta}_2, \hat{\beta}_3$ = Regression coefficients for each independent variable
X_1, X_3, X_3 = Independent variables (pH, Temperature, and Dissolved Oxygen)

There are several assumptions that must be met in multiple linear regression analysis, including normality of residuals, homoscedasticity of residual variances, non-autocorrelation, non-multicollinearity. The assumption of non-autocorrelation is often violated when the research data consists of time-series data [9]. One way to detect violations of the non-autocorrelation assumption is through a formal test, specifically the Durbin-Watson test. The formula for the Durbin-Watson [10] statistic is as follows:

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$$d = \frac{\sum_{t=2}^{t=n}(e_t - e_{t-1})^2}{\sum_{t=1}^{t=n} e_t^2} \tag{4}$$

Detection of autocorrelation can be performed based on the rules outlined in Table 1. Below is a general guideline for interpreting the Durbin-Watson statistic values:

Table 1. Rules for Detecting Autocorrelation

No	Statistic Durbin- Watson value	Conclusion
1	$0 < d < d_L$	Positive autocorrelation
2	$d_L \leq d \leq d_u$	Areas of Uncertainty
3	$d_u \leq d \leq 4 - d_u$	No autocorrelation
4	$4 - d_u \leq d \leq 4 - d_L$	Areas of Uncertainty
5	$4 - d_L \leq d \leq 4$	Negative autocorrelation

Where d_L and d_u are critical value for Durbin-Watson test table.

Violations of the non-autocorrelation assumption can lead to inefficient parameter estimates and invalid hypothesis tests. Therefore, it is essential to implement corrective measures, one of which is the Cochrane-Orcutt Method. This method effectively addresses regression models that exhibit autocorrelation. If the structure of autocorrelation is unknown, the coefficient of autocorrelation can be determined using the following formula:

$$\hat{\rho} = \frac{\sum_{i=2}^{n} e_i \, e_{i-1}}{\sum_{i=2}^{n} e_{i-1}^2} \tag{5}$$

Where:

$\hat{\rho}$ = Estimated coefficient of autocorrelation
e_i = Residuals (errors) value at observation i
e_{i-1} = Residuals (errors) from the regression model at time i-1
n = Number of observations

3. METHODOLOGY

The research method employed in this study is a survey method, where data is obtained through the collection of water quality data and the growth data of vannamei shrimp from 13 shrimp ponds. The sampling method used is purposive sampling. Sampling in this study was conducted three times, with one sample taken weekly for each pond. The growth sampling started from Day of Culture (DOC) 32 to DOC 50.

The analysis stages in this study are as follows:

1. Measure Water Quality: Assess the water quality parameters, including pH, temperature, and dissolved oxygen (DO).
2. Calculate Shrimp Growth: Determine the growth of shrimp by measuring Average Body Weight (ABW) and Specific Growth Rate (SGR).
3. Estimate Regression Model: Conduct regression analysis using the Ordinary Least Squares (OLS) method and obtain the residual values from the regression model.

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4. Test for Autocorrelation: Evaluate the assumption of autocorrelation using the Durbin-Watson test.
5. Regress Residuals: Perform regression of the residuals at observation i against the residuals at observation i−1 to obtain the estimated coefficient of autocorrelation, denoted as $\hat{\rho}$
6. Regress $\hat{\rho}$ in the following equation:

$$\begin{aligned} Y_i - \hat{\rho}Y_{i-1} &= \beta_0 - \hat{\rho}\beta_0 + \beta_i X_i - \hat{\rho}\beta_i X_{i-1} + \hat{\rho}\varepsilon_i - \hat{\rho}\varepsilon_{i-1} \\ &= \beta_0(1-\hat{\rho}) + \beta_i(X_i - \hat{\rho}X_{i-1}) + \hat{\rho}\varepsilon_i - \hat{\rho}\varepsilon_{i-1} \end{aligned} \tag{6}$$

Thus, the model obtained is:

$$Y_i^* = \beta_0^* + \beta_i^* X_i^* + \varepsilon_i^* \tag{7}$$

This model is iterated until a convergent estimated coefficient of autocorrelation $\hat{\rho}$ is achieved. All data in this study are analyzed using R Studio software.

4. RESULTS AND DISCUSSION

The observations conducted on water quality and the growth of vannamei shrimp can be summarized in Table 2.

Table 2. Research Data Description

Parameter	Average	Standard Deviation	Minimum	Maximum
pH	8.077	0.179	7.7	8.35
Temperature (^{0}C)	28.949	0.536	28	30
Do (ppm)	4.552	0.370	3.94	5.23
AWB (gram)	6.795	1.751	4.3	9.73
SGR (gram)	6.141	2.772	2.65	12.43

Based on Table 2, it can be observed that the pH of the water in the vannamei shrimp grow-out ponds ranges from 8.077±0.179, with the lowest and highest pH values being 7.7 and 8.35, respectively. The pH value obtained is still within the optimal range, as the optimal pH for vannamei shrimp farming is between 7.0 and 8.5 [11]. The water temperature averages 28.949±0.5360C, with the lowest temperature recorded at 280C and the highest at 300C. This temperature also remains within the optimal range for shrimp farming; according to Hidayat [12], the optimal temperature for vannamei shrimp growth is between 280C and 300C. The dissolved oxygen (DO) levels in the shrimp grow-out ponds average 4.552±0.370 ppm, with the lowest recorded DO at 3.94 ppm and the highest at 5.23 ppm. The optimal DO level for vannamei shrimp farming is a minimum of 3 ppm [13]. The growth of shrimp measured in this study, based on Average Body Weight (ABW), averages 6.795±1.751 grams, and the Specific Growth Rate (SGR) averages 6.141±2.772 grams.

Subsequently, regression analysis using the Ordinary Least Squares (OLS) method was conducted, resulting in estimated regression parameters for each water quality variable with respect to the growth variables, as shown in Tables 3 and 4.

Table 3. Coefficients of the Regression Model between Water Quality and AWB

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Model	Coefficient	Standard Error	t-Statistic	p-value	F-statistic	p-value	r square	adj r square
Constant	68.2663	17.295	3.947	0.000364	5.968	0.002135	0.3384	0.2817
pH	-0.949	1.5414	-0.616	0.542087				
Temperature	-1.8776	0.4587	-4.093	0.000238				
Do	0.1207	0.7599	0.159	0.874745				

Based on Table 3, Regression Model 1 is obtained as follows:

$$ABW = 68.266 - 0.949pH - 1.878Temperature + 0.121Do$$

The p-value for the F-test is <0.05, indicating that, at a 5% significance level, there is a simultaneous relationship between water quality variables and ABW. In partial analysis, temperature is identified as the variable with a significant influence on ABW (p-value < 0.05).

Table 4. Coefficients of the Regression Model between Water Quality and SGR

Model	Coefficient	Standard Error	t-Statistic	p-value	F-statistic	p value	r square	adj r square
Constant	-115.965	25.7546	-4.503	7.13e-05	8.253	0.0002765	0.4143	0.3641
pH	4.3464	2.2954	1.893	0.0666 .				
Temperature	3.0573	0.6831	4.476	7.73e-05				
Do	-0.3305	1.1316	-0.292	0.772				

Based on Table 4, Regression Model 2 is formulated as:

$$SGR = -115.965 + 4.346pH + 3.0578Temperature - 0.331Do$$

Similarly, the p-value for the F-test is <0.05, suggesting that, at a 5% significance level, there is a simultaneous relationship between water quality variables and SGR. In partial analysis, temperature also emerges as the variable with a significant influence on SGR (p-value < 0.05).

Both regression models were further tested for the non-autocorrelation assumption using the Durbin-Watson test. For Regression Model 1, the Durbin-Watson statistic (d) is 0.656, with a p-value of 1.264×10^{-7}. For Regression Model 2, the Durbin-Watson statistic (d) is 0.767, with a p-value of 2.054×10^{-6}. Since both p-values are less than 0.05, it can be concluded that autocorrelation is present in both regression models, necessitating treatment using the Cochrane-Orcutt method.

The Cochrane-Orcutt method works by regressing the residuals at time i against the residuals at time i-1, which generates the estimated value $\hat{\rho}$. The residual values for both regression models are presented in Table 5.

Tabel 5. Residual Value

No	Residual Value	
	Model 1	Model 2
1	-2.44400855	3.00220278
2	-2.43556196	2.99907064
3	-1.8038528	3.67936192

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.	.	.
.	.	.
.	.	.
39	2.07474956	-2.1093895

The next step involves regressing the residuals at time *i* against the residuals at time *i-1* for each regression model (1 and 2) to obtain a convergent value of $\hat{\rho}$ using Equation (5). The convergent value of $\hat{\rho}$ for Regression Model 1 is $\hat{\rho} = 0.676$, achieved at the 8th iteration. For Regression Model 2, the convergent value of $\hat{\rho}$ is 0.660, achieved at the 9th iteration. Using the obtained $\hat{\rho}$ values, new regression analyses were performed based on Equation (6). The updated regression equation for the relationship between water quality dynamics and ABW is:

$$ABW = 81.273 - 0.588pH - 1.878Temperature + 0.121Do$$

The new regression equation for the relationship between water quality dynamics and SGR is:

$$SGR = -131.086 + 2.464\,pH + 3.933Temperature + 0.690\,Do$$

Based on the model in Equation (10), the Durbin-Watson test produced a statistic of d = 2.325 with a p-value of 0.856. For the model in Equation (11), the Durbin-Watson statistic is d = 2.057 with a p-value of 0.579. Since both p-values are greater than 0.05, it can be concluded that there is no autocorrelation present in either of the revised regression models.

The results of the simultaneous and partial effect tests between water quality variables and shrimp growth variables are presented in Table 6 and 7.

Table 6. Coefficients of the New Regression Model between Water Quality and AWB

Model	Coefficient	Standard Error	t-Statistic	p-value	F-statistic	p value	r square	adj r square
Constant	81.272906	5.9116	4.452	0.0000871	7.582	0.0005173	0.4008	0.348
pH	-0.587566	1.5173	-0.387	0.701				
Temperature	-2.331339	0.4976	-4.686	0.0000437				
Do	-0.427450	0.5803	-0.737	0.466				

Table 7. Coefficients of the New Regression Model between Water Quality and SGR

Model	Coefficient	Standard Error	t-Statistic	p-value	F-statistic	p value	r square	adj r square
Constant	-131.0861	9.7139	-4.583	0.0000593	9.306	0.0001237	0.4509	0.4024
pH	4.3464	2.3756	1.037	0.307				
Temperature	3.0573	0.7796	5.045	0.000015				
Do	-0.3305	0.9147	0.755	0.456				

The results indicate that water quality variables have a significant simultaneous effect on shrimp growth metrics, as evidenced by the F-statistics and p-values in both models (p-value = 0.0005173 for ABW and 0.0001237 for SGR). This demonstrates that the combination of pH, temperature, and dissolved oxygen (DO) plays a critical role in influencing shrimp growth. However, the partial effect analysis shows that not all variables contribute equally. In the ABW model, temperature has a significant negative effect (p-value = 0.0000437), while pH and DO do not exhibit significant influence (p-values = 0.701 and 0.466, respectively). Similarly, in the SGR model, temperature again emerges as the key influencing factor with a significant positive effect (p-value = 0.000015), whereas pH and DO remain statistically insignificant (p-values =

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0.307 and 0.456). Wang [14] found that temperature plays a crucial role in regulating metabolic processes, directly affecting growth rates and overall health of shrimp populations. Their research demonstrated that optimal temperature ranges are essential for maximizing both average body weight (ABW) and specific growth rates (SGR), while deviations from these ranges can lead to significant growth reductions. Additionally, [15] reported that while pH and dissolved oxygen (DO) are important for maintaining water quality, their direct influence on growth metrics, such as ABW and SGR, is often less pronounced compared to temperature. These findings align with the results of the current study, further reinforcing the conclusion that temperature is the most critical water quality parameter influencing shrimp growth, whereas pH and DO have limited partial effects. The model performance, as indicated by the R^2 values, suggests that 40.08% of the variation in ABW and 45.09% of the variation in SGR can be explained by the water quality variables.

5. CONCLUSION

The Cochrane-Orcutt method successfully developed regression models to analyze the impact of water quality dynamics on the growth of vannamei shrimp (ABW and SGR) and ensuring the non-autocorrelation assumption. The research results indicate that the convergent values of $\hat{\rho}$ obtained using the Cochrane-Orcutt method were $\hat{\rho}$= 0.676 at the 8th iteration for Regression Model 1 and $\hat{\rho}$= 0.660 at the 9th iteration for Regression Model 2. The results show that water quality variables have a significant simultaneous effect on shrimp growth. Temperature was identified as the most critical factor, with a significant impact on both ABW and SGR, reinforcing its essential role in shrimp growth performance. Conversely, pH and dissolved oxygen (DO) did not exhibit significant partial effects.

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REFERENCES

[1] A. Wafi, H. Ariadi, M. Mahmudi, and M. Fadjar, "Tingkat transfer oksigen kincir air selama periode blind feeding budidaya intensif udang putih (*Litopenaeus vannamei*)," Journal of Fisheries and Marine Research, vol. 4, issue 1, pp. 7–15, April 2020.

[2] Y. Yunarty, A. Kurniaji, B. Budiyati, D. P. Renitasari, and M. Resa, "Karakteristik kualitas air dan performa pertumbuhan budidaya udang vaname (*Litopenaeus vannamei*) secara intensif," PENA Akuatika: Jurnal Ilmiah Perikanan dan Kelautan, vol. 21, issue 1, pp. 75–88 , March 2022.

[3] I. Nurdin, Sugiman, and Sunarmi, "Penerapan kombinasi metode *Ridge Regression* (RR) dan metode *Generalized Least Square* (GLS) untuk mengatasi masalah multikolinearitas dan autokorelasi," Indonesian Journal of Mathematics and Natural Sciences, vol. 41, issue. 1, pp. 58–68, April 2018.

[4] A. Aprianto, N. N. Debataraja, N. Imro'ah, "Metode Cochrane-Orcutt Untuk mengatasi autokorelasi pada estimasi parameter *ordinary least squares*," *Bimaster: Buletin Ilmiah Matematika, Statistika dan Terapannya*, vol. 9, issue 1, pp. 95–102, January 2020.

[5] A. Oktaviana. and D. Febriani. (2022, July). "Tingkat pertumbuhan udang putih

[DOI: 10.14710/JSUNIMUS.12.2.2024.10-18]

Litopenaeus vannamei dengan pemberian tepung batang pisang melalui pakan," JSIPi (Jurnal Sains Dan Inovasi Perikanan) [Online]. vol. 6, issue 2, pp. 130–134. Available: https://journal.uho.ac.id/index.php/jsipi/article/view/75/44

[6] I. Purnamasari. D. Purnama. and M. A. F. Utami. (2017, April). "Pertumbuhan udang vaname (*Litopenaeus vannamei*) ditambak intensif," Jurnal Enggano [Online]. vol. 2, issue 1, pp. 58–67. Available: https://ejournal.unib.ac.id/jurnalenggano/article/view/1359/1134.

[7] A. R. Scabra, D. Hermawan, and H. Hariadi, "Feeding different types of feed on vannamei shrimp (*Litopenaeus Vannamei*) maintaining with low salinity media," Indonesian Journal Of Aquaculture Medium, vol. 2, issue 1, pp. 31–45, 2022, June 2022

[8] S. Adrianto, I. H. N. Balqis, C. Z. N. Soetanto, and M. Ohyver. (2023, December). "Cochrane orcutt method to overcome autocorrelation in modeling factors affecting the number of hotel visitors in Indonesia." Procedia Computer Sci [Online]. vol. 216, issue 1, pp. 630–638. Available: https://www.sciencedirect.com/science/article/pii/S1877050922022566.

[9] H. M. Fathurahman, and Haeruddin "Pemodelan Regresi linier untuk data deret waktu linear Regression Modeling for Time Series Data," Jurnal Eksponensial, vol. 2, Issue 2, pp. 35–42, November 2011.

[10] Nawari, Analisis Regresi, 1st ed. Jakarta: PT. Elex Media Komputindo, 2010.

[11] S. Supriatna, M. Mahmudi, M. Musa, and K. Kusriani, "Hubungan pH Dengan parameter kualitas air pada tambak intesif udang vannamei (*Litopenaeus vannamei*)," Journal of Fisheries and Marine Research, vol. 4, issue 3, pp. 368–374, December 2020.

[12] K. W. Hidayat, I. A. Nabilah, S. Nurazizah, and B. I. Gunawan, "Pembesaran udang vannamei (*Litopenaeus vannamei*) di PT. Dewi Laut Aquaculture Garut Jawa Barat," Journal of Aquaculture and Fish Health, vol. 8, issue 3, pp. 123–128, August 2019.

[13] R. Manullang, S. L. Undap, H. Pangkey, D. J. Kusen, O. J. Kalesaran, and S. N. J. Longdong. (2023, March). "Kualitas air pada pembesaran udang vaname (*Litopenaeus vannamei*) PL 8 PT. Budi Agri Sejahtera, Kecamatan Tempilang, Provinsi Bangka Belitung." e-Journal Budidaya Perairan [Online]. vol. 11, issue 1, pp. 52–61. Available: https://ejournal.unsrat.ac.id/v3/index.php/bdp/article/view/46876

[14] Z. Wang, J. Zhou, J. Li, W. Lv, J. Zou, and L. Fan. (2020, January). "A new insight into the intestine of Pacific white shrimp: Regulation of intestinal homeostasis and regeneration in Litopenaeus vannamei during temperature fluctuation," Comparative Biochemistry and Physiology Part D: Genomics and Proteomics [Online]. vol. 35, issue 1, pp. 1–10. Available: https://www.sciencedirect.com/science/article/pii/S1744117X20300344.

[15] A. Mariu, A. M. M. Chatha, S. Naz, M. F. Khan, W. Safdar, and I. Ashraf, "Effect of Temperature, pH, Salinity and Dissolved Oxygen on Fishes," Journal of Zoology and Systematics, vol. 1, issue 2, pp. 1–12, November 2023.