Jurnal Serambi Engineering JSE
Volume IX, No.1, Januari 2024 Hal 8237 - 8245
p-ISSN : 2528-3561
e-ISSN : 2541-1934

The Impact of Oil and Fat Pollutants on The Aquatic Environment Around Panggang Island, Kepulauan Seribu, on The Lifespan of Seaweed (*Kappaphycus alvarezii*)

A Suhendra[1], N Karnaningroem[2], R Nugroho[3], W Sujatmiko[4]

[1]Research Center for Agroindustry, National Research and Innovation Agency, Bogor Indonesia.
[2]Department of Environmental Engineering, Institut Teknologi Sepuluh November, Surabaya Indonesia.
[3]Research Center for Environmental and Clean Technology, National Research and Innovation Agency, Bogor Indonesia.
[4]Research Center for Fishery, National Research and Innovation Agency, Bogor Indonesia
***Corresponding author**: ahmad.suhendra@gmail.com[1], n.karnaningroem@gmail.com[2]

Received: January 25, 2024 Approved : January 29, 2024

Abstract
The *Kappaphycus alvarezii* seaweed in Pulau Panggang, Kepulauan Seribu, DKI Jakarta, has experienced a significant decline in production. From 1984 to 2000, production ranged from 8,106 to 36,625 tons, contributing 25.61% to the total production in the Thousand Islands. However, in 2021, production drastically decreased, reaching only 254 tons in 2019. This study focuses on identifying the factors causing the decline in production. Analysis of water samples indicates that oil and fat pollution in the aquatic environment exceeds the established standards, surpassing 1 mg/L, potentially harming marine life, including seaweed. Field observations reveal the fact that the seaweed's ability to survive is within a specific timeframe (seaweed lifespan) that never reaches the harvesting age due to consistent occurrences of death. SEM-PLS analysis shows that both physical and chemical parameters influence the seaweed lifespan by 43.9%. Statistical analysis supports the hypothesis that physical parameters are not significant ($p>0.05$), while chemical parameters, indicating oil and fat pollution, significantly affect seaweed lifespan ($p<0.05$). This research provides profound insights into the causes of the decline in Kappaphycus alvarezii seaweed production in Pulau Panggang.
Keywords: *pulau panggang, seaweed lifespan, SEM-PLS*

Abstrak
Rumput laut *Kappaphycus alvarezii* di Pulau Panggang, Kepulauan Seribu DKI Jakarta, mengalami penurunan produksi yang signifikan. Sejak 1984-2000, produksi mencapai 8.106 - 36.625 ton, dengan kontribusi 25,61% terhadap total produksi di Kepulauan Seribu. Namun, pada 2021, produksi menurun drastis, hanya mencapai 254 ton pada 2019. Penelitian ini fokus pada faktor-faktor penyebab penurunan produksi. Hasil analisis sampel di perairan menunjukkan bahwa pencemaran minyak dan lemak telah melampaui baku mutu yang ditetapkan, yaitu di atas 1 mg/L, berpotensi merugikan kehidupan biota laut, termasuk rumput laut. Pengamatan di lapangan menemukan fakta bahwa ketahanan hidup rumput laut berada dalam rentang waktu (*seaweed lifespan*) yang tidak pernah mencapai umur panen karena selalu mengalami kematian. Hasil analisis menggunakan metode SEM-PLS menunjukkan bahwa parameter fisik dan kimia mempengaruhi *seaweed lifespan* sebesar 43,9%. Analisis statistik mendukung hipotesis bahwa parameter fisik tidak signifikan ($p>0,05$), sementara parameter kimia dengan indikator pencemaran minyak dan lemak signifikan ($p< 0,05$) terhadap *seaweed lifespan*. Penelitian ini memberikan wawasan mendalam tentang penyebab penurunan produksi rumput laut *Kappaphycus alvarezii* di Pulau Panggang.
Kata kunci: *pulau panggang, seaweed lifespan*, SEM-PLS

1. Introduction

Kappaphycus alvarezii is a type of seaweed extensively cultivated by seaweed farmers on Panggang Island, Kepulauan Seribu, DKI Jakarta. During the period 1984-2000, seaweed production on Panggang Island ranged from 8,106 tons to 36,625 tons, contributing an average of 25.61% to the total seaweed production in Kepulauan Seribu, amounting to 125,563 tons [1]. However, since then until 2021, seaweed production on Panggang Island has never reached those figures again. In fact, the highest production occurred in 2019, with a total seaweed production in Kepulauan Seribu reaching only 254 tons [2]. The decline in production is suspected to be due to environmental changes in the aquatic region. Several studies have been conducted, especially on the suitability of waters for seaweed cultivation [1], [3]. However, the presented results have not comprehensively addressed the issues of suboptimal growth and seaweed mortality, leading to a sharp decline in production.

This research utilizes the SEM-PLS method to analyze water quality data around Panggang Island, where seaweed cultivation takes place. The results of the data analysis indicate that oil and fat pollution in the waters around Panggang Island, which exceed the established standard of a maximum of 1 mg/L [4], is the sole factor significantly affecting the lifespan of seaweed. This can be understood due to the interrelated negative effects.

When oil and fat are dispersed on the water surface, a thin layer is formed that inhibits the penetration of sunlight into the water. The optical properties of oil and fat can reflect or absorb sunlight [5]. The obstruction of sunlight has serious implications for seaweed growth, including a decrease in photosynthesis activity followed by a reduction in the growth rate. It increases vulnerability to stress and reduces resilience [6]. Moreover, the obstruction of sunlight also interferes with the growth of coral reefs [7], [8], which is a crucial part of the aquatic ecosystem.

Coral reef growth serves as a habitat for various animals and plants. Coral reefs are primitive organisms that rely on a single-celled microalga called zooxanthellae. In unfavorable environmental conditions due to pollution, zooxanthellae leave the coral as their host, leading to coral death (bleaching) [9], [10]. The demise of coral reefs prompts creatures like rabbitfish (*Siganus Sp*.) and hawksbill turtles (Eretmochelys imbricata) [11] to seek new places and food sources, sometimes attacking seaweed owned by seaweed farmers [12], [13]. These attacks elevate stress for the seaweed, making it more susceptible to pathogenic infections. Under stress conditions, seaweed releases organic substances, causing its thallus to become slimy and promoting bacterial growth. Bacterial infections can lead to ice-ice disease, which is contagious and seasonal [14].

2. Material and Methods

Location, time, and research data collection

This study was conducted as a survey during the rainy season (April - May 2023) and the dry season (July - August 2023) at 12 sampling points (refer to Figure 1). These sampling points are situated in the waters surrounding Panggang Island, including Karya Island, Semak Daun Island, Pramuka Island, and Karang Congkak. All of these sampling points serve as locations for cultivating seaweed (Kappaphycus alvarezii), being shielded from high waves. The substrate of the water bottom at these locations comprises a mixture of dead coral and sand, as detailed in Table 3.

Data on the water quality around Panggang Island were partially measured directly in the field. The measured physical and chemical parameters include indicators such as salinity, pH, temperature, Dissolved Oxygen (DO), clarity, water current, nitrate (NO3-N), phosphate (PO4-P), and total ammonia (NH3-N), as shown in **Table 1**. Meanwhile, some other parameters will be measured in the laboratory, such as Biochemical Oxygen Demand (BOD), Total Suspended Solids (TSS), Nitrate, Phosphate, Total Ammonia, Oil and Fat.

Table 1. Measuring the quality of waters directly in the field

No.	Water quality	Method
1.	Salinity (ppt)	Horiba U5000G/Device reading
2.	pH	Horiba U5000G/Device reading
3.	Temperature (C)	Horiba U5000G/Device reading
4.	Dissolved Oxygen (DO)	Horiba U5000G/Device reading
5.	Transparency /Clarity(m)	Secchi disk/Measuring depth
6.	Water currents (cm/s)	JFE AEM 1618/Computer downloads
7.	Nitrate (NO_3-N) (mg/l)	Hach DR900 / Spectrophotometer reading
8.	Phosphate (PO_4-P) (mg/l)	Hach DR900 / Spectrophotometer reading
9.	Total Ammonia (NH_3-N) (mg/l)	Hach DR900 / Spectrophotometer reading

Table 2. Measuring the quality of waters in the laboratory

No.	Water Quality	Method
1.	BOD (mg/l)	BOD_5 Winkler
2.	TSS (mg/l)	Gravimetric analysis
3.	Oil & Fat (mg/l)	Gravimetric analysis / Folch

The data on the lifespan of seaweed are collected from seaweed farms owned by local farmers around the sampling points. These farmers employ the long-line cultivation method, which involves using a 20-

meter-long rope with anchors and large floats placed at both ends. Additional floats are also installed every 2 meters along the rope. Seaweed seedlings, weighing between 50-100 grams, are tied to the rope with a spacing of 25 cm. Subsequently, these ropes are assembled into blocks with a distance of 0.5 meters between each rope.

Figure 1. Research location map
Source: Google Earth Pro

Table 3. Geographic location, characteristics of the study sites, and cultivation methods

Sampling Point	GPS coordinates		Wave exposure	Cultivation methods	Substrate
	Latitude	Longitude			
1	5°44'12.72"S	106°36'31.70"E	Low	Long-Line	Sand/Coral
2	5°44'11.50"S	106°35'57.60"E	Low	Long-Line	Sand/Coral
3	5°44'07.20"S	106°35'34.60"E	Low	Long-Line	Sand/Coral
4	5°43'30.20"S	106°35'59.10"E	Low	Long-Line	Sand/Coral
5	5°43'48.50"S	106°35'30.60"E	Low	Long-Line	Sand/Coral
6	5°43'50.30"S	106°34'58.00"E	Low	Long-Line	Sand/Coral
7	5°44'33.60"S	106°35'06.50"E	Low	Long-Line	Sand/Coral
8	5°44'24.80"S	106°35'36.00"E	Low	Long-Line	Sand/Coral
9	5°44'25.00"S	106°35'57.60"E	Low	Long-Line	Sand/Coral
10	5°44'42.20"S	106°36'04.40"E	Low	Long-Line	Sand/Coral
11	5°44'51.60"S	106°35'42.60"E	Low	Long-Line	Sand/Coral
12	5°44'48.30"S	106°36'35.10"E	Low	Long-Line	Sand/Coral

Observation of seaweed lifespan

Observations of the lifespan of seaweed at the sampling locations involve seaweed farmers. They will report if there is any seaweed found dead or depleted using the WhatsApp application.

Tabel 4. *Lifespan*

Seaweed *(K.alvarezii)*	Sampling point											
	1	2	3	4	5	6	7	8	9	10	11	12
Rainy Season												
1. *Lifespan* (days)	6	7	13	14	13	12	13	12	14	20	7	19
Dry Season												
2. *Lifespan* (days)	15	13	6	22	7	20	14	8	6	14	15	7

Data processing and evaluation

The obtained and collected data (see appendix) will be processed and evaluated using the Structural Equation Modeling (SEM) and Partial Least Square (PLS) methods as the analytical approach. PLS is a multivariate statistical analysis method used to estimate the simultaneous influence among variables for prediction, exploration, or the development of a structural model [15]. Model evaluation in PLS includes measurement model evaluation, structural model evaluation, and model fit evaluation. The SEM-PLS

Jurnal Serambi Engineering JSE Volume IX, No.1, Januari 2024 Hal 8237 - 8245 p-ISSN : 2528-3561 e-ISSN : 2541-1934

method is not only employed in social research but can also be applied in engineering research using measurement data [16], as conducted in this study.

In this study, SEM-PLS is employed to predict and elucidate the causes of seaweed production decline on Pulau Panggang. The purpose of this modeling is to identify influential variables contributing to the decrease in production. The SEM-PLS method is considered capable of addressing the direct and unidirectional relationship model between independent and dependent variables. It is utilized to test hypotheses regarding parameters with significant effects and analyze the patterns of relationships between latent variables and their parameters [15], [17].

Measurement and structural model

The measurement model constructed in this study involves two exogenous latent variables, namely physical parameters (X1) and chemical parameters (X2), and an endogenous variable, the seaweed lifespan (Y). The hypotheses include (H1) the physical parameters having a positive/negative impact on the seaweed lifespan and (H2) the chemical parameters having a positive/negative impact on the seaweed lifespan.

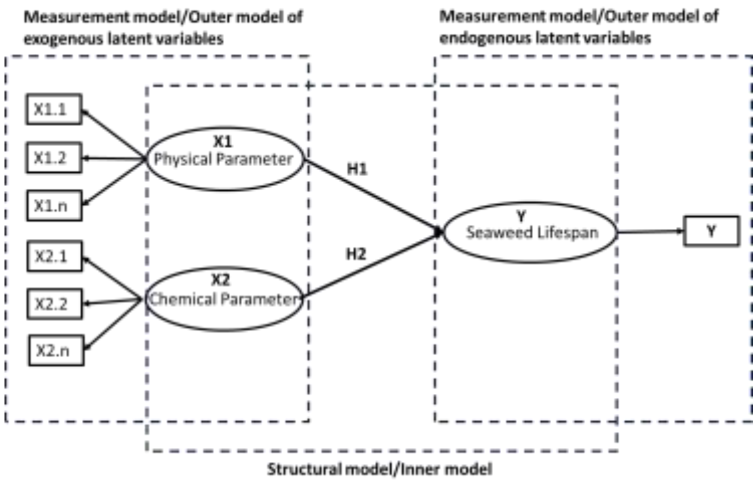

Figure 2. Inner and outer model

In this study, Variable X1 (physical parameter) is measured using the following indicators: X1.1 (current, cm/s); X1.2 (brightness, m); X1.3 (temperature, oC); X1.4 (salinity, ppt); X1.5 (TSS, mg/L). Variable X2 (chemical parameter) is measured using the following indicators: X2.1 (pH); X2.2 (BOD, mg/L); X2.3 (DO, mg/L); X2.4 (NO3-N, mg/L); X2.5 (PO4-P, mg/L); X2.6 (NH3-N, mg/L); X2.7 (oil and fat, mg/L). H1 and H2 represent hypotheses regarding the influence of variables X1 and X2 on Y, the lifespan of seaweed.

3. Results and Discussion

Model evaluation

Outer and Inner Model

This study is exploratory research employing descriptive quantitative data analysis, utilizing the formative measurement method. Through the bootstrapping process, as observed in **Figure 3**, the outer weights' values for the formative indicator measurements in the outer model were found to be non-significant ($p > 0.05$) (Table 5). According to Hair [17], if there are non-significant outer weights for indicators, there is no need to eliminate them from the model as long as the outer loadings or loading factors (LF) exceed 0.5. For exploratory research, Hulland [18] suggests values above 0.4 can be used, hence in this study, LF values greater than 0.4 were considered.

Indicator X1.3 (temperature) with LF > 0.4; indicator X1.4 (salinity) with LF > 0.4; indicator X2.5 (PO4-P) with LF > 0.4; and indicator X2.7 (oil & fat) with LF < 0.4. For indicator X2.7 with LF < 0.4, it is considered to be retained (Table 6) due to the relevance of indicator weights (Outer weights) standardized for values between −1 and +1. Thus, weights closer to +1 (or −1) indicate a strong positive (or negative) relationship, while weights closer to 0 indicate a relatively weak relationship [17].

Jurnal Serambi Engineering JSE Volume IX, No.1, Januari 2024 Hal 8237 - 8245 p-ISSN : 2528-3561 e-ISSN : 2541-1934

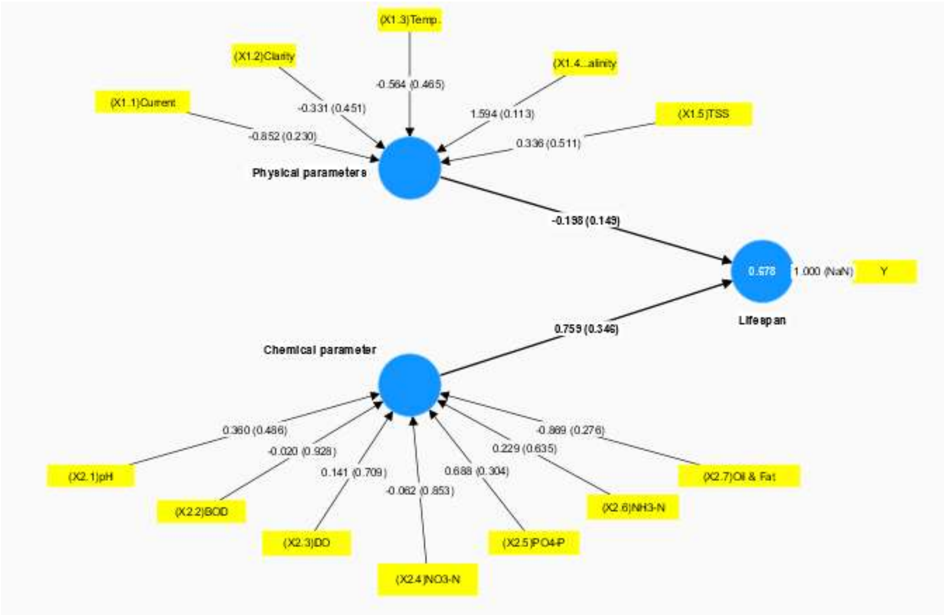

Figure 3. Outer model (outer weights & p-value) and inner model (path & p-value)

Table 5. *Outer weights output*

	Original sample(O)	*P (Value)*
X1.1 (Water current) --> Physical parameters	-0.852	**0.230**
X1.2 (Clarity) --> Physical parameters	-0.331	**0.451**
X1.3 (Temperature) --> Physical parameters	-0.564	**0.465**
X1.4 (Salinity) --> Physical parameters	1.594	**0.113**
X1.5 (TSS) --> Physical parameters	0.336	**0.511**
X2.1 (pH) --> Chemical parameters	0.360	**0.486**
X2.2 (BOD) --> Chemical parameters	-0.020	**0.928**
X2.3 (DO) --> Chemical parameters	0.141	**0.709**
X2.4 (NO_3-N) --> Chemical parameters	-0.062	**0.853**
X2.5 (PO_4-P) --> Chemical parameters	0.688	**0.304**
X2.6 (NH_3-N) --> Chemical parameters	0.229	**0.635**
X2.7 (Oil & Fat)--> Chemical parameters	-0.869	**0.276**
Y<--Lifespan	1	n/a

Table 6. *Outer loadings output*

	Original sample(O)	*P (value)*
X1.1 (Water current) --> Physical parameters	-0.085	0.828
X1.2 (Clarity) --> Physical parameters	-0.243	0.527
X1.3 (Temperature) --> Physical parameters	**0.486**	0.112
X1.4 (Salinity) --> Physical parameters	**0.663**	0.054
X1.5 (TSS) --> Physical parameters	0.189	0.600
X2.1 (pH) --> Chemical parameters	0.112	0.660
X2.2 (BOD) --> Chemical parameters	0.037	0.895
X2.3 (DO) --> Chemical parameters	0.070	0.782
X2.4 (NO_3-N) --> Chemical parameters	0.098	0.711
X2.5 (PO_4-P) --> Chemical parameters	**0.451**	0.293
X2.6 (NH_3-N) --> Chemical parameters	0.107	0.588
X2.7 (Oil & Fat)--> Chemical parameters	**-0.716**	0.299
Y<--Lifespan	1	n/a

After the removal of invalid indicators, the measurement model has undergone changes as depicted in **Figure 4** below.

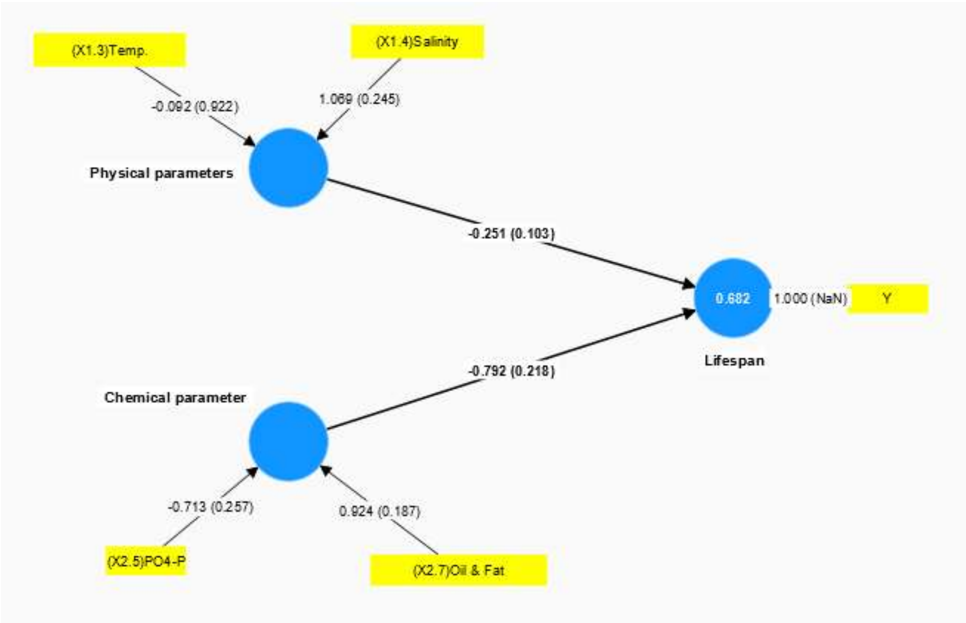

Figure 4. Outer model (outer weights & p-value) and inner model (path & p-value)

Table 7. Outer loadings output

	Original sample(O)	*P (value)*
X1.3 (Temperature) --> Physical parameters	0.732	0.04
X1.4 (Salinity) --> Physical parameters	0.998	0.002
X2.5 (PO_4-P) --> Chemical parameters	$\boxed{-0.459}$	0.333
X2.7 (Oil & Fat) --> Chemical parameters	0.728	0.185
Y<--Lifespan	1.000	

The outer loadings and p-values indicate that two indicators, namely X2.5 and X2.7, are not significant (P>0.05). Additionally, one indicator, X2.5, has an outer loading (LF) value of less than 0.4 (Table 7). As a result, the X2.5 indicator is excluded, as depicted in **Figure 5**.

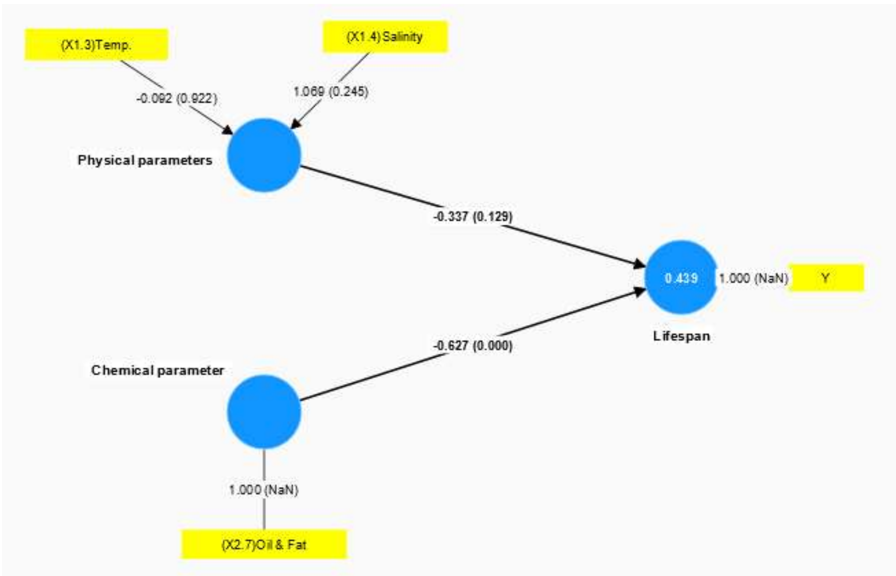

Figure 5. Outer model (outer weights & p-value) and inner model (path & p-value)

Jurnal Serambi Engineering JSE Volume IX, No.1, Januari 2024 Hal 8237 - 8245 p-ISSN : 2528-3561 e-ISSN : 2541-1934

Collinearity of outer and inner models

Collinearity testing is necessary to examine whether there is a significant correlation among independent variables in a regression model. A good regression model should not have correlations among its variables [19]. Collinearity can be assessed through the Variance Inflation Factor (VIF), obtained by performing the calculation process using the PLS-SEM algorithm feature in the smartPLS application.

Tabel 8. VIF Outer dan inner model

Outer	VIF
X1.3 (Temperature)	2.46
X1.4 (Salinity)	2.46
X2.7 (Oil & Fat)	1
Y	1
Inner	
Physical parameters Lifespan	2.46
Chemical parameters Lifespan	2.46

The VIF values for both the outer and inner models (**Table 8**) are less than 5 (VIF < 5), indicating that there are no symptoms of collinearity among the independent variables.

Evaluation of model quality (R square, F Square, and SRMR)

Evaluation of measurement model quality is necessary to strengthen confidence in the results and their interpretation. The quality of the model can be assessed through the values of R-square, f-square, and Standard Root Mean Square Residual (SRMR). To obtain these values, the calculation process is performed using the PLS-SEM algorithm feature, and the results can be seen in **Table 9**.

The R-square (R^2) value depicts the amount of variation in the endogenous latent variable, lifespan (Y), explained by the exogenous latent variables, physical parameter (X1), and chemical parameter (X2). The R^2 values vary between 0 and 1, with higher values approaching 1 indicating greater strength. As a general guideline, R^2 values of 0.75, 0.50, and 0.25 can be considered high, moderate, and low, respectively [20].

The f-square (f^2) value helps measure the magnitude of the influence between constructs to understand the impact of variables in model assessment and prediction. Effect size (f^2) guideline values are 0.02, 0.15, and 0.35, representing small, moderate, and large effects, respectively[21].

SRMR is used to measure the model fit in structural equation analysis, assessing the difference between the observed and proposed models. A lower value indicates a better fit. SRMR is employed in research to validate the structural model, obtain estimates of model fit, and evaluate model quality in data analysis with latent variables [22]. An SRMR value < 0.09 categorizes the model as good and suitable [23].

Tabel 9. R square, f square dan SRMR

	R-square	*R-square adjusted*	Explanations
Lifespan	0.439	0.385	The impact of exogenous variables (X1 & X2) on the endogenous variable (Y) at 43.9% is considered moderate.
	f-square		
Physical parameters--> Lifespan	0.197		The impact of physical parameters on lifespan is 0.197, indicating a small effect.
Chemical parameters--> Lifespan	0.683		The impact of chemical parameters on lifespan is 0.683, indicating a high level.
	Saturated model	*Estimated model*	
SRMR	0.032	0.032	Model fit (SRMR<0.09)

Significance of paths and hypotheses

Path coefficient is a number/value useful for indicating the direction of the relationship between variables, whether the hypothesis has a positive or negative direction, and the path coefficient value is between -1 and 1. By performing the bootstrapping process, one will obtain the values of the path coefficient, T statistic, and P value (**Table 10**). If T statistic > 1.96 or P value < 0.05, then it is considered significant [17].

Tabel 10. Significance of paths

	Original sample (O)	*T statistics*	*P Value*	Notes
Physical parameters-->Lifespan	-0.337	1.519	**0.129**	Not Significant ($p>0.05$ and $T < 1.96$)
Chemical parameters-->Lifespan	-0.627	5.759	**0.000**	Significant ($p<0.05$ and $T > 1.96$)

The hypotheses obtained indicate:

1. (H1) No significant impact of physical parameters (X1) such as temperature (X1.3) and salinity (X1.4) on seaweed lifespan (Y).
2. (H2) Significant negative influence of chemical parameters (X2), specifically oil & fat indicators (X2.7), on seaweed lifespan (Y).

4. Conclusion

Oil and fat pollution has exceeded the set quality standard, which is above 1 mg/L [4]. This can have adverse effects on marine life, including seaweed. Statistical test results indicate that the hypothesis (H1) stating that the influence of physical parameters is not significant to seaweed lifespan ($p>0.05$), and the hypothesis (H2) stating that chemical parameters with indicators of oil and fat pollution significantly affect seaweed lifespan ($p<0.05$). Field facts show that there is no seaweed production because the seaweed experiences death. Therefore, it is concluded that seaweed production (Kappaphycus alvarezii) is not suitable in the aquatic environment around Pulau Panggang. It is recommended to temporarily halt production until a new location is identified or until the issue of oil and fat pollution is adequately addressed.

5. References

[1] W. A. Kasih, *Kualitas Perairan terhadap Keberlangsungan Usaha Budidaya Rumput Laut di Pulau Pari, Kepulauan Seribu, DKI Jakarta*. Jakarta: Universitas Negeri Jakarta, 2017.

[2] BPS, "Tabel Dinamis Subjek Perikanan." Accessed: Nov. 09, 2023. [Online]. Available: https://www.bps.go.id/subject/56/perikanan.html#subjekViewTab5

[3] M. Aris and R. Labenua, "Evaluation of land suitability of Kappaphycus alvarezii cultivation in the dry and rainy season," in *IOP Conference Series: Earth and Environmental Science*, IOP Publishing Ltd, Oct. 2020. doi: 10.1088/1755-1315/584/1/012025.

[4] PP RI No.22, "Lampiran VIII Peraturan Pemerintah No.22 Tahun 2021: Baku Mutu Air Laut." Kementerian Sekretariat Negara RI , Jakarta, 2021. Accessed: Nov. 05, 2023. [Online]. Available: https://klikhijau.com/wp-content/uploads/2021/03/9.-Lampiran-VIII-Salinan-PP-Nomor-22-Tahun-2021.pdf

[5] N. Badr Eldeen, A. Bakr Abd El-karim Salman, A. Ali Elamin, M. Ali, and K. Mohammed Haroun, "Determination of Optical Properties of Olive Oil Mixed with Black Seed Oil at Different Volume Using UV/VIS Spectrometer," *American Journal of Optics and Photonics*, vol. 9, no. 4, p. 51, 2021, doi: 10.11648/j.ajop.20210904.11.

[6] S. Babaei, F. Najafi, N. Soltani, R. A. Khavari-Nejad, and B. Abbaspanah, "Physiological responses of Anabaena sp. ISC55 to crude oil and its potential for biodegradation," *Int J Algae*, vol. 15, no. 3, pp. 264–273, 2013, doi: 10.1615/InterJAlgae.v15.i3.60.

[7] F. Ferrario, M. W. Beck, C. D. Storlazzi, F. Micheli, C. C. Shepard, and L. Airoldi, "The effectiveness of coral reefs for coastal hazard risk reduction and adaptation," *Nat Commun*, vol. 5, May 2014, doi: 10.1038/ncomms4794.

[8] A. Tagliafico, P. Baker, B. Kelaher, S. Ellis, and D. Harrison, "The Effects of Shade and Light on Corals in the Context of Coral Bleaching and Shading Technologies," *Frontiers in Marine Science*, vol. 9. Frontiers Media S.A., Jul. 12, 2022. doi: 10.3389/fmars.2022.919382.

[9] P. W. Purnomo, D. Soedharma, N. P. Zamani, H. S. Sanusi, P. Studi Manajemen Sumberdaya Perikanan Jurusan Perikanan Fakultas Perikanan dan Ilmu Kelautan Universitas Diponegoro Semarang, and P. Studi Ilmu Kelautan Sekolah Pascasarjana Institut Pertanian Bogor, "Zooxanthellae Life Model and Massalization Growth in the Artificial Environment Waters," 2010.

[10] Thamrin, *Ekosistem Terumbu Karang: Hubungan antara Karang dan Zooxanthellae*. Pekanbaru: UR Press Pekanbaru, 2012.

[11] TN Kp Seribu, *RPJP TN Kepulauan Seribu 2020-2029*. 2019. Accessed: Nov. 02, 2023. [Online]. Available: https://tnlkepulauanseribu.menlhk.go.id/wp-content/uploads/2022/08/RPJP-TN-KEPULAUAN-SERIBU-2020-2029.pdf

[12] R. Bohari and M. Musbir, "Seaweed production based on the distance of culture location from river mouth and oceanographic factors," in *IOP Conference Series: Earth and Environmental Science*, Institute of Physics, 2022. doi: 10.1088/1755-1315/1119/1/012007.

[13] A. Putra Basir, L. Abukena, and Amiluddin, "The Growth of Seaweed (Kappaphycus Alvarezii) Cultivated with Long Line and Off Bottom Method on Tita Banda Neira Maluku Coastal Area," *Journal of Fisheries and Marine Science*, vol. 1, pp. 20–23, 2017, [Online]. Available: http://jfmr.ub.ac.id

[14] M. Achmad, A. Indarjo, and G. Salim, "Identification of bacteria in seaweed (Kapapphycus alvarezii) affected by the ice-ice disease in Amal and Tanjung Tarakan waters, Indonesia," vol. 15, no. 6, 2022, [Online]. Available: http://www.bioflux.com.ro/aacl

[15] J. F. Hair, J. J. Risher, M. Sarstedt, and C. M. Ringle, "When to use and how to report the results of PLS-SEM," *European Business Review*, vol. 31, no. 1. Emerald Group Publishing Ltd., pp. 2–24, Jan. 14, 2019. doi: 10.1108/EBR-11-2018-0203.

[16] J. E. Villalva A., "Structural equation models - PLS in engineering sciences: a brief guide for researchers through a case applied to the industry," *Athenea*, vol. 2, no. 4, pp. 5–18, Jun. 2021, doi: 10.47460/athenea.v2i4.17.

[17] J. F. Hair, G. T. M. Hult, C. M. Ringle, M. Sarstedt, N. P. Danks, and S. Ray, "Partial Least Squares Structural Equation Modeling (SEM-PLS) Using R," in *Classroom Companion: Business*, Springer, 2021, pp. 1–208. doi: 10.1007/978-3-030-80519-7.

[18] J. Hulland, "Use of Partial Least Squares (PLS) in Strategic Management Research: A Review of Four Recent Studies," *Strategic Management Journal Strat. Mgmt. J*, vol. 20, pp. 195–204, 1999.

[19] R. S. Hamid and S. M. Anwar, *Structural Equation Modeling (SEM) Berbasis Varian: Konsep Dasar dan Aplikasi dengan Program SmartPLS 3.2.8 dalam Riset Bisnis*, 1st ed. Jakarta: PT Inkubator Penulis Indonesia, 2019.

[20] J. F. Hair, C. M. Ringle, and M. Sarstedt, "PLS-SEM: Indeed a silver bullet," *Journal of Marketing Theory and Practice, 1*, vol. 9, no. 2, pp. 139–151, 2011.

[21] J. Cohen, "A power primer," in *Psychological Bulletin*, vol. 112, 1992, pp. 155–159.

[22] G. Pavlov, A. Maydeu-Olivares, and D. Shi, "Using the Standardized Root Mean Squared Residual (SRMR) to Assess Exact Fit in Structural Equation Models," *Educ Psychol Meas*, vol. 81, no. 1, pp. 110–130, Feb. 2021, doi: 10.1177/0013164420926231.

[23] L. Hu and P. M. Bentler, *Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. Structural Equation Modeling*, vol. 6. 1999.