Variance Analysis of Negative Impacts of Offshore Construction on Marine Environment

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Abstract. With the advancement of technology and social development, China has witnessed a gradual increase in offshore construction activities. However, this has led to the destruction and pollution of the marine environment, resulting in severe disruptions to the survival of marine life. Therefore, this paper proposes using variance analysis to statistically analyze the changes in water quality-related indicators before and after offshore construction activities. Through scientific analysis of monitoring data, conclusions can be drawn to strengthen the control and monitoring of negative impacts on the marine environment during the design and implementation of offshore construction activities.

Keywords: offshore construction, negative impacts on the marine environment, variance analysis

1 INTRODUCTION

With the continuous advancement of modern construction, offshore construction has become a common engineering method. Although this method provides convenience for the construction and maintenance of engineering projects, it may also bring a series of negative impacts, the most important of which is the impact on the marine environment. The fragility and complexity of the marine ecological environment make it susceptible to the influence of human activities, and offshore construction as an important human activity in the marine environment has attracted widespread attention to its potential negative impact on the marine environment [1-5].

Existing studies have shown that offshore construction has varying degrees of negative impact on the marine environment. Some studies indicate that during the construction process, a large amount of harmful substances, such as heavy metals and organic pollutants, may be released, causing damage to the marine ecosystem and biodiversity [2,3]. In addition, physical effects such as noise and vibration may also have an impact on the marine ecological environment and biological behavior [4,5]. These research findings indicate that the impact of offshore construction on the marine environment cannot be ignored and further exploration is needed.

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This paper aims to analyze the negative impact of offshore construction on the marine environment through more detailed research methods and a more comprehensive indicator system and compare the difference in marine water quality before and after construction to explore the impact of offshore construction on the marine environment. Specifically, this paper will use variance analysis statistical methods to compare marine water quality data before and after construction and explore whether the impact of offshore construction on marine water quality has significant differences. To more comprehensively analyze the impact of offshore construction on the marine environment, this paper will also discuss the impact of construction on the marine ecological environment and human economic activities, providing a scientific basis and reference for future offshore construction activities.

The relevant methods and research status of analyzing the impact of offshore construction on the marine environment are introduced in Section 2 of this paper. The basic knowledge of variance analysis required for this paper is introduced in Section 3. Monitoring data for case analysis is used to test the validity of the method and analysis conclusions are provided in Section 4. The last part is the conclusion of the article.

2 ANALYSIS OF THE IMPACT OF MARINE CONSTRUCTION ON THE MARINE ENVIRONMENT: RELATED WORKS

The negative impact of offshore construction on the marine environment is one of the current hot topics in environmental research, and many studies have explored this issue. Some studies have analyzed the impact of construction on the marine environment from the physical effects, chemical substances, and noise generated during the construction process.

Regarding the impact of construction on the marine ecological environment, some studies [6] have found that construction may significantly impact the marine ecological environment by monitoring changes in the marine biological community before and after construction. Other studies [7] have shown that the construction of offshore wind farms may affect the migration and growth of marine organisms such as fish and seabirds, affecting the ecosystem's balance and stability. Some studies have also explored the impact of construction on the water quality of the marine environment from the perspective of chemical substances. For example, some harmful substances such as heavy metals and organic pollutants may be produced during construction [2,3], which may potentially threaten the marine ecosystem and human health. In addition, some studies have focused on the impact of construction on the noise of the marine environment. The noise generated during the construction process may affect the auditory system and behavioral patterns of marine organisms, thereby affecting the stability of the marine ecological environment and ecosystem [8-12]. The literature review suggests that offshore construction activities negatively impact marine ecosystems and the environment, and that variance analysis can be a useful tool to assess and quantify these impacts. Measures such as proper planning, monitoring, and mitigation strategies can be taken to reduce the negative effects on marine ecosystems [9-18].

It should be noted that the above studies only represent part of the impact of offshore construction on the marine environment, and other factors such as bottom disturbance, seawater mixing, and sediment suspension also need to be further studied.

Based on the relevant studies mentioned above, the negative impact of offshore construction on the marine environment has become a global issue of concern. Studies have shown that the impact of offshore construction on the marine environment mainly includes but is not limited to the following aspects. First, offshore construction will cause damage to the marine ecosystem. For example, the construction of artificial islands will change the original marine ecosystem's structure and destroy marine species' habitats. Second, the waste and pollutants generated during the construction process will or indirectly harm the marine ecosystem. For example, materials generated during construction such as sediments, cement, and waste will cause physical and chemical damage to benthic organisms. The burning of fossil fuels such as fuel and lubricating oils used during construction will produce a large amount of greenhouse gases and atmospheric pollutants, affecting the marine ecological and atmospheric environment. In addition, the construction process may also affect local marine environmental parameters such as water quality, water temperature, and water flow, and the impact area may be relatively extensive. Overall, the impact of offshore construction on the marine environment is complex and diverse, and comprehensive research and analysis are needed.

It should be pointed out that the current evaluation methods and standards for offshore construction environmental assessment still have certain problems and limitations and need to be improved and perfected. For example, the evaluation method may have certain subjectivity and uncertainty, and the selection of evaluation indicators and the determination of weights need to be more scientifically reasonable; the evaluation standards may not be comprehensive and systematic enough and cannot accurately reflect the impact of construction on the marine environment. Therefore, further research is needed to strengthen the research and development of evaluation methods and standards and to improve the evaluation process of offshore construction environmental impact.

3 ANALYSIS OF VARIANCE

Analysis of Variance (ANOVA) is a commonly used statistical method widely applied in various fields, such as medicine, biology, social sciences, environmental science, etc. It is primarily used for comparing whether the means of two or more populations are equal or to determine if different factors significantly affect the means of populations. ANOVA can typically be classified into two types: one-way ANOVA and factorial ANOVA. One-way ANOVA is used to compare the effect of a single factor on the means of populations, while factorial ANOVA considers the effect of multiple factors on the means of populations.

In ANOVA, the variance of the population is decomposed into different sources of variance, such as variance between factors and error variance. By comparing the ratios of these variances to the total variance, one can determine if different factors significantly affect the means of populations. The basic assumptions of ANOVA include: the populations are normally distributed, the variances of the populations are equal, and the observations are independent and identically distributed.

For single-factor ANOVA, the basic steps are as follows:

(1) Calculate the total population variance (SST)

SST represents the total sum of squares, which can be obtained by calculating the sum of the squared deviations of all sample data from the population mean:

$$\mathrm{SST} = \sum_{i=1}^{n}\sum_{j=1}^{m_i}(x_{ij} - \overline{x})^2 \tag{1}$$

Where n represents the total number of groups, m_i represents the sample size of the i-th group, x_{ij} represents the j-th sample data in the i-th group, and x represents the mean of all sample data.

(2) Calculate the between-group variance (SSB).

The SSB (sum of squares between) represents the variability among group means and can be calculated as the sum of the squared differences between each group mean and the overall mean.

$$\mathrm{SSB} = \sum_{i=1}^{n} m_i(\overline{x_i} - \overline{x})^2 \tag{2}$$

where $\overline{x}_i$ represents the mean of the i-th group samples.

(3) Calculate the error variance (SSE)

SSE, or the sum of squares within groups, represents the error sum of squares and can be obtained by calculating the sum of squared deviations of all sample data from their respective group means:

$$\mathrm{SSE} = \sum_{i=1}^{n}\sum_{j=1}^{m_i}(x_{ij} - \overline{x_i})^2 \tag{3}$$

(4) Calculate the *F*-value

The *F*-value is the ratio of the between-group variance to the within-group variance and can be used to determine if there are significant differences between groups. The formula for calculating the F-value is as follows:

$$F = \frac{\mathrm{SSB}/(n-1)}{\mathrm{SSE}/(N-n)} \tag{4}$$

where SSB is the between-group sum of squares, SSE is the error sum of squares, N is the total sample size, and n is the number of groups. A larger *F*-value indicates a more significant difference between groups.

(5) Conduct hypothesis testing.

In the analysis of variance (ANOVA), hypothesis testing is often required. In one-way ANOVA, the null hypothesis H_0 represents that all population means are equal, and the alternative hypothesis H_1 represents that at least one population mean is different. Usually, the *t-test* is used for hypothesis testing by determining the significance level (usually 0.05) and calculating the F-value and the critical value of the t distribution. If the calculated F-value is greater than the critical value, the null hypothesis is rejected; otherwise, it cannot be rejected. Rejecting the null hypothesis means that the differences between the data of different groups are significant.

In practical applications, if there are multiple factors, a multiple-factor analysis of variance can be used for analysis. Multiple-factor analysis of variance can be divided into two cases: the case of no interaction and the case of interaction.

In the case of no interaction, a two-way ANOVA can be used for analysis. In two-way ANOVA, the total sum of squares is decomposed into three parts: sum of squares between groups (Factor A), sum of squares between columns (Factor B), and sum of squares within groups (error sum of squares). When calculating the F-value, the denominator is the error sum of squares divided by its degrees of freedom, and the numerator is the ratio of the sum of squares between groups and the sum of squares between columns, as follows:

$$F = \frac{\text{Group sum of squares} / (a-1)}{Sum\ of\ squares\ of\ errors / (a-1)(b-1)} \tag{5}$$

or

$$F = \frac{\text{Column sum of squares} / (b-1)}{Sum\ of\ squares\ of\ errors / (a-1)(b-1)} \tag{6}$$

Here, a and b represent the number of levels for Factor A and Factor B, respectively.

In the case of the presence of interaction effects, the analysis can be carried out using the interaction effect in the two-way ANOVA. In two-way ANOVA, the interaction effect represents the joint effect of Factor A and Factor B on the population mean, which is not simply an additive effect, but rather a mutual influence. If there is an interaction effect, a test for interaction is required.

In conclusion, analysis of variance (ANOVA) is an important statistical method that can be used to analyze the influence of different factors on the overall mean. It also has certain application value for studying the impact of offshore construction on the marine environment.

4 MONITORING DATA ANALYSIS

This paper conducted continuous monitoring of water quality at an offshore construction site, including the total phosphorus (TP), total nitrogen (TN), and water quality pollution index (I_p) before and after construction. The datasets used in the analysis are shown in Figures 1 and 2, where time points 1-7 represent pre-construction monitoring data and time points 8-18 represent post-construction monitoring data.

Variance analyses were separately performed on the TP, TN, and I_p monitoring data before and after construction, and the analysis results are presented in Tables 1, 2, and 3, respectively. The values of the parameters in variance analyses are set as follows:

$n=2, m_1=7, m_2=11, N=18, a=b=2.$ Experiments are conducted with Python 3.8 and the stats models module of Python.

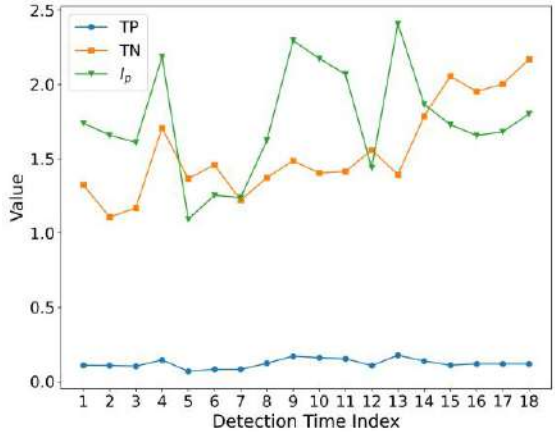
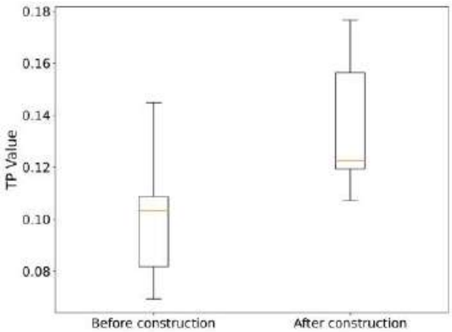
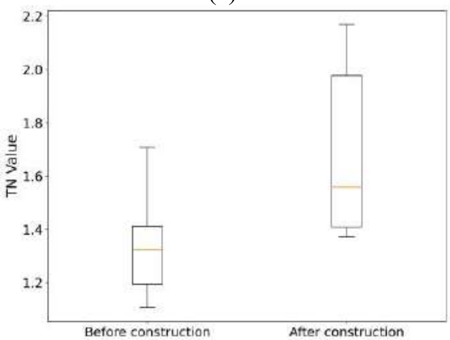


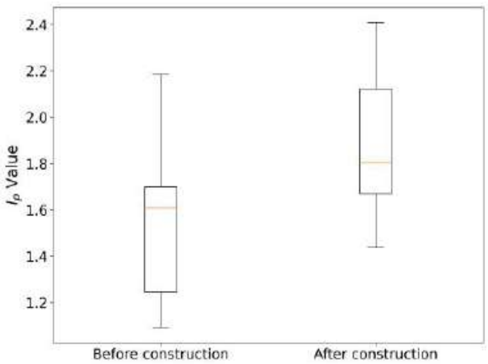
Fig. 1. The temporal variation of TP, TN, and I_p values.



(a) TP



(b) TN



(c) I_p

Fig. 2. The distribution patterns of TP, TN, and I_p values.

According to these variance analysis tables, significant differences were found in the TP, TN, and I_p values before and after construction at a significance level of 0.05. However, it should be noted that at a significance level of 0.01, there was no significant difference in the total nitrogen content and water quality pollution index before and after construction, while the total phosphorus content showed a significant difference. These results suggest that effective control should be exercised over relevant pollution sources during offshore construction, especially on nitrogen-containing substances, acid-base substances, and heavy metals.

Table 1. Variance analysis of TP values before and after construction.

	df	**sum square**	**mean square**	**F**	**PR (>F)**
Monitoring Type (Before/After Construction)	1.0	0.0056	0.0056	8.998	0.0085
residual	16.0	0.009960	0.000622	Not Applicable	Not Applicable

Table 2. Variance analysis of TN values before and after construction.

	df	**sum square**	**mean square**	**F**	**PR (>F)**
Monitoring Type (Before/After Construction)	1.0	0.5370	0.5370	7.207	0.0163
residual	16	1.1923	0.07452	Not Applicable	Not Applicable

Table 3. Variance analysis of I_p values before and after construction.

	df	**sum square**	**mean square**	**F**	**PR (>F)**
Monitoring Type (Before/After Construction)	1	0.5129	0.5129	4.5552	0.0486
residual	16	1.8015	0.1126	Not Appli-cable	Not Appli-cable

5 Conclusion

In this paper, we mainly investigated the negative impact of offshore construction on the marine environment. We compared the water quality before and after construction and used variance analysis to test the results statistically. In the introduction section, we reviewed existing relevant research and pointed out the current problems. Then, we provided detailed introductions to the basic knowledge of variance analysis, including one-way ANOVA and two-way ANOVA, and gave corresponding formulas. Finally, we discussed the application of variance analysis, including hypothesis conditions and multiple comparisons.

Through the research in this paper, we found that the impact of offshore construction on the marine environment is significant, and the pollution degree of the water quality after construction is significantly higher than that before construction. This result helps draw attention to the protection of the marine environment and provides a reference for future related research.

In general, this paper analyzed the impact of offshore construction on the marine environment, introduced the basic knowledge of variance analysis, and discussed the application of variance analysis. The results of this study have a certain importance for promoting marine environmental protection and the development of offshore construction technology.

References

1. Zhao Yanran, Liu Yanqiu, Huang MuKe. Optimization study of a selection of marine environment monitoring stations around the Hong Kong-Zhuhai-Macao Bridge[J]. Environmental Engineering, 2018, 36(7):149-154.
2. Zhang Guanggui, Wang Chouming, Tian Qi. Analysis of water quality changes in Dongting Lake before and after the operation of the Three Gorges Project[J]. Journal of Lake Science, 2016, 28(4):734-742.
3. Ou Decai. Study on hydrological and water quality changes in Dongting Lake after the operation of the Three Gorges Project[J]. Hunan Water Resources and Hydropower, 2020(4):64-65+72.
4. Sun Changqing, Guo Yaotong, Zhao Kesheng. Numerical study on hydrodynamic and water quality impacts of the Jiu Long Bay area improvement project[J]. Marine and Lake Science Bulletin, 2016(4):17-23.

5. Rong Simin. Comparative analysis and evaluation of water quality in the adjacent sea areas of the Fengjia River estuary[J]. Scientific and Technological Innovation, 2020(31):1-3.
6. Cui Lei, Lv Songhui, Dong Yuele, et al. Impact of reclamation engineering on environmental factors and biological communities in the waters near Qiao Ao Island[J]. Journal of Tropical Oceanography, 2017, 36(2):96-105.
7. Zhao Bei, Zhou Yanrong, Xing Congcong, et al. Study on the impact of the Tangshan Leting Puti Island offshore wind farm on marine ecological space[J]. Marine Environmental Science, 2022, 41(4):496-503.
8. Fu Yingying, Tian Zhenkun, Li Yumei. Interpretation and hypothesis testing of regression analysis with variance analysis[J]. Statistics and Decision, 2019, 0(8):77-80.
9. Yang, S., Shi, W., Chen, J., & Fang, Z. (2020). Quantitative assessment of offshore construction noise impact on marine mammals using acoustic propagation modeling. Environmental Pollution, 264, 114704.
10. Deary, A., Sequeira, A. M., & Meekan, M. G. (2021). Predicting the spatial variability of the impacts of dredging and marine construction on reef fish assemblages. Journal of Environmental Management, 277, 111524.
11. Wu, Y., Yang, L., & Cui, Y. (2020). Analysis of the Impact of Offshore Construction on Marine Environment Based on the Theory of Sustainable Development. In IOP Conference Series: Earth and Environmental Science (Vol. 528, No. 1, p. 012007). IOP Publishing.
12. Ong, M. C., Huang, Y., & Chang, C. H. (2019). Spatial-temporal assessment of the environmental impacts of offshore wind farm construction on the marine ecosystem. Renewable Energy, 141, 631-641.
13. Li, X., & Wu, X. (2020). The Impact of Offshore Wind Farm Construction on Marine Ecosystem and Countermeasures. In 2020 International Conference on Intelligent Transportation, Big Data and Smart City (ICITBS) (pp. 218-221). IEEE.
14. Chang, C. H., Huang, Y., & Ong, M. C. (2020). Environmental impact assessment of offshore wind farm construction using life cycle assessment and fuzzy logic approach. Renewable Energy, 154, 414-427.
15. Niu, M., Yu, L., Wang, J., & Wang, X. (2020). Effect of offshore wind farms on marine ecosystems and mitigation measures: A review. Ocean & Coastal Management, 186, 105115.
16. Lü, Y., Cao, W., Li, Y., & Huang, Y. (2020). Study on the ecological impact assessment and countermeasures of offshore wind power construction. Journal of Cleaner Production, 242, 118515.
17. Zhou, X., Zhao, X., Zhang, J., & Zuo, J. (2020). Impacts of offshore wind farm construction on marine mammals: A review. Renewable and Sustainable Energy Reviews, 124, 109779.
18. Li, M., Li, X., Li, J., & Yan, H. (2020). Analysis of the Impact of Offshore Wind Power Construction on Marine Environment. In 2020 International Conference on Energy and Electrical Engineering (ICE) pp. 126-129.