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Bangus (Chanos Chanos) Farming: Preparing for SMART Farming and Predictive Analysis using Artificial Intelligence Tools

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Abstract*:* The study looks at how traditional Bangus (chanos chanos) farming methods in the Philippine province of Pangasinan can be adapted to incorporate cutting-edge technology and predictive analytics. The study's objective is to boost the local aquaculture sector's production, efficiency, and sustainability in order to promote economic development and food security in the long run. The study starts off by thoroughly reviewing the body of prior research on SMART farming, predictive analysis, and the situation of Bangus farming in the area. This literature review lays the groundwork for the study by highlighting the possible advantages and difficulties of implementing modern technologies in aquaculture. Then, primary data is gathered through document analysis from the reliable source of the internet. These measure if there is a need to adapt SMART farming ideas for improvements. The study also gathers crucial historical information on past climatic trends, water quality, and other pertinent environmental aspects that affect Bangus cultivation. This data serves as the foundation for predictive modeling, which projects future outcomes under various scenarios utilizing cutting-edge analytical tools. Predictive analysis tries to improve Bangus farming enterprises' overall efficiency by optimizing feeding practices, reducing disease outbreaks, and anticipating market demand. The study's findings provided insight into the Bangus farmers of Pangasinan's existing level of knowledge and readiness about SMART farming techniques. Additionally, the predictive models provide useful insights into the potential advantages and difficulties of deploying SMART agricultural technologies in this particular area. The study's conclusions have important results for agricultural extension agencies, legislators, and technology providers because they can guide targeted interventions and support systems to encourage the adoption of SMART farming in the neighborhood aquaculture industry. In the context of food production and rural development, the research also contributes to a larger conversation about sustainable agriculture, technological integration, and predictive analytics.

Keywords: *data mining, decision tree, machine learning, random forest, regression analysis, support vector machine, WEKA*

1. Introduction

Aquaculture, in particular the farming of Bangus (milkfish), is essential for supplying the world's food needs and boosting the economic well-being of coastal areas. Pangasinan is one of the major provinces in the Philippines that contributes significantly to the nation's aquaculture output. The sustainability and effectiveness of conventional Bangus farming methods in the area, however, have been hampered by problems like environmental uncertainties, market changes, and socioeconomic concerns.

This study suggests if the SMART farming technologies and predictive analysis can address these issues and maintain the long-term survival of Bangus farming in Pangasinan. SMART farming a cutting-edge strategy that blends technology and data-driven decision-making to enhance agricultural methods. The Food and Agriculture Organization of the United Nations (FAO) endorsed this idea in its 2016 "The State of World Fisheries and Aquaculture" report, stressing its potential to increase aquaculture output and sustainability.

According to Ahmad et al. (2003), the socioeconomic situation of fisheries in Malaysia gives important insights into the importance of aquaculture for rural development and the improvement of livelihoods. Additionally, Mazuki (2015) clarifies the tilapia market situation in Malaysia while demonstrating how strategic interventions can foster market competitiveness and expansion in the aquaculture industry. Understanding these local success stories can help develop specialized strategies for Pangasinan's Bangus farming business.

The Department of Fisheries underlines the significance of embracing technology and innovation to drive growth and sustainability in the agricultural and fisheries industry in the context of Malaysia's National Key Economic Areas (NKEA) on agricultural (Yusof). This is in line with the goal of transforming Bangus farming in Pangasinan into SMART agriculture, which aims to maximize resource efficiency, minimize negative environmental effects, and boost production effectiveness.

Fishkills, or large-scale fish deaths, have been a persistent problem in Pangasinan's aquaculture sector. These occurrences have a huge negative influence on the region's Bangus farming industry on a social, economic, and environmental level. Fishkills can be caused by a number of things, including as environmental stressors, disease outbreaks, and declining water quality.

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The study of Jarin (2018) highlights a number of important difficulties faced by Pangasinan's Bangus farmers. Among these, the diminishing fish catch is seen as a relatively serious issue because it shows a progressive decline in the number of fish. Numerous factors, including overfishing, environmental changes, and habitat loss, may be responsible for this problem. A similar grade of "moderately serious" is given to the declining water quality, emphasizing the possible harm to fish health and growth that could result in lower yields and a higher risk of contracting diseases. Another worrying issue is that fish species that were once caught are no longer being caught today, which indicates a very serious issue. This is a sign of ecosystem changes, overfishing, or other environmental stresses that have caused some fish species to become rare or extinct in the fishing grounds. A significant issue is the overabundance of fishpens and cages. Aquaculture can increase fish productivity, but poor management of fishpens and cages can change the ecosystem, degrade the water, and interfere with traditional fishing methods. Fish kills are also considered to be quite problematic, with considerable economic and environmental repercussions for fish farmers and coastal ecosystems. Fish deaths can be caused by disease outbreaks, water pollution, and a lack of oxygen, demanding mitigation and prevention efforts. The study draws attention to worries about pollution. Agricultural waste runoff is extremely dangerous since it can contribute to nutrient and chemical discharge, which degrades water quality. Similar issues arise from the runoff of industrial waste, which introduces contaminants and chemicals into the aquatic environment. Siltation, a serious issue that has an impact on fish habitats and water quality, is linked to soil erosion and sedimentation. Even though incorrect waste disposal is considered a less serious issue, it still needs to be addressed because it can affect aquatic ecosystems and cause pollution. Overall, these findings highlight the need for a comprehensive strategy to solve the problems affecting Pangasinan's Bangus cultivation. The long-term survival and sustainability of the region's aquaculture business will depend on the integration of sustainable fishing methods, responsible aquaculture management, and environmental conservation initiatives. Additionally, it is essential to reduce pollution from various sources and improve waste management in order to maintain the ecological balance and preserve the coastal towns' aquaculture-dependent economies.

For the development of aquaculture to be sustainable, environmental issues must be addressed. The PHILMINAQ study (2008) offers useful advice for preserving water quality in Bangus farming ponds by outlining water quality requirements and standards for freshwater and marine aquaculture in the Philippines. Similar to this, the National Water Quality Standards of Malaysia from 2008 set the stage for the management of water quality in the region's aquaculture sector.

The success of aquaculture operations depends on the site selection process. Lessons learned from Kutty's site selection research in 1987 emphasize the significance of taking physical water features into account for the best farming circumstances. The research conducted by Harun et al. (2017) examines the buoyancy effect on the atmospheric surface layer and sheds light on how regional meteorological variables can affect aquaculture practices and technology advancements.

Predictive analysis is crucial for decision-making and planning when integrating SMART farming methods. The "Small-scale aquaponic food production" paper by Somerville et al. (2014) can be used to understand the importance of predictive models, specifically in aquaculture. This FAO paper places a strong emphasis on the use of data-driven decision-making to maximize fish and plant farming, which is similar to the goal of this study to increase the effectiveness of Bangus farming.

The study will also take into account the contributions that professional engineers have made to nation-building, as mentioned by Harun et al. (2013). In order to ensure that solutions are well-designed, technically sound, and sustainable, their experience might be crucial in applying SMART farming technologies and predictive analytics in the context of Bangus farming.

The extensive justification for the study, in short, is on the urgent need to increase the productivity and sustainability of Bangus farming in Pangasinan. This research aims to improve resource use, reduce environmental impacts, and support the economic development of the regional aquaculture industry by implementing SMART farming technologies and predictive analysis. This study intends to offer a data-driven, sustainable path for the future of Bangus farming in Pangasinan by integrating knowledge from local accomplishments in aquaculture, water quality regulations, site selection, and predictive modeling.

2. Materials and Methods

The study used historical data and quantitative research design that combines the gathering and analysis of both quantitative and qualitative data. The current situation of Bangus farming in Pangasinan, the historical data, ideas on SMART farming technology, and the possible effects of predictive analysis on aquaculture practices may all be fully understood using this method.

2.1. Secondary Data

Historical information from reliable sources, including governmental organizations, academic institutions, and agricultural reports, on climatic patterns, water quality indicators, fish production, and market trends. The basis for trend analysis and predictive modeling will be this data.

2.2. **Predictive Analysis**

This study suggests the development of prediction models using the historical data that has been collected in order to foresee future results under various circumstances in Bangus farming (Philippine Statistics Authority, 2023). The data will be thoroughly analyzed using cutting-edge analytical tools, such as statistical methods and machine learning algorithms (Smola & Schölkopf, 2004). The study intends to improve the efficiency and sustainability of Bangus farming operations by utilizing these methods. Optimizing feeding methods, predicting illnesses, and projecting market demand are the three main areas on which the predictive analysis will concentrate. Farmers may adjust the feeding process to fit the unique demands of Bangus at different growth phases by establishing predictive models for feeding strategies, which will enhance their overall growth and health. Furthermore, anticipating illnesses in Bangus can help with early diagnosis and prevention techniques, enabling farmers to put appropriate measures into place and lessen the impact of diseases on the fish population. This proactive strategy can lessen losses and enhance the Bangus stock's general health and wellbeing. Last but not least, market demand forecasting will offer insightful information about customer preferences and market trends. Farmers may maintain a continuous supply of Bangus to satisfy market demands and reduce wastage by anticipating changes in demand and adjusting production levels appropriately. Furthermore, Bangus farmers may make knowledgeable decisions, improve their farming techniques, and encourage the sustainability of their operations by utilizing the power of predictive analysis and sophisticated analytical tools like WEKA (Witten et al., 2016). In addition to increasing Bangus farming's production and effectiveness, this will also help ensure the aquaculture sector's long-term viability.

2.3. **Data Integration**

This study will conduct a thorough analysis of both quantitative and qualitative data in order to identify significant trends and patterns in the context of SMART farming and predictive analysis for Bangus farming (Tien, 2017). To find patterns and connections in the gathered quantitative data, advanced analytical approaches will be used, such as statistical methods and machine learning algorithms (Kenyhercz & Passalacqua, 2016). In order to fully understand the viewpoints and experiences of Bangus farmers about SMART farming and predictive analysis, qualitative data will also be collected through surveys and interviews with these farmers. A thorough understanding of the opportunities and challenges in implementing SMART farming techniques will be acquired by fusing the insights from these qualitative data sources with the quantitative analysis (Jarin, 2018). The results of the predictive analysis will be thoroughly tested and validated against historical data on Bangus farming in order to assure the reliability and validity of the predictive models (Philippine Statistics Authority, 2021). Through this validation process, the models' reliability and accuracy in predicting future outcomes under various circumstances will be evaluated.

2.4. Ethical Considerations

The study will adhere to ethical principles. Before any data is collected, participants' informed consent will be sought. Participants' private information will be kept secure, and confidentiality and anonymity will be guaranteed. The study will abide by the moral standards for using human participants in research.

2.5. Data Analysis

To produce descriptive statistics and inferential analysis, quantitative data from surveys will be examined using statistical software. To find recurrent themes and patterns, qualitative data from interviews will be transcribed and thematically evaluated. Results of the predictive study will be examined in order to determine any potential repercussions for Pangasinan's Bangus cultivation.

2.6. Interpretations

The study's findings will be discussed in light of the study's goals, the principles of SMART farming, and the findings of the predictive analysis. The main conclusions will be outlined in the conclusion, along with recommendations for policymakers, farmers, and other stakeholders on how to improve the sustainability and productivity of Pangasinan's aquaculture sector. These recommendations will be drawn from the implications for the use of SMART farming technology in Bangus farming.

2.7. Limitations

The study is aware of some potential drawbacks, including the sample size and representativeness, data accessibility, and the complexity of predictive modeling. The validity and trustworthiness of the study's conclusions will be guaranteed while efforts will be made to mitigate these constraints.

3. Results and Discussions

3.1. Data on Volume of Bangus Production in Aquaculture

The data in the following tables was taken from the Fisheries Statistics of the Philippines, which provides information on the province-by-province breakdown of aquaculture production in the Philippines from 2019 to 2021. The production variations that happened over a three-year period in various regions are shown in the following table. (PSA, 2023)

Fig. 1. The Milkfish also known as "Bangus" in the Philippines (source: https://www.tagaloglang.com/bangus/)

Table 1. Volume of Bangus Production in Aquaculture by Region and Province Philippines 2019-2021 in Metric Tons

Region	2019 (Metric Tons)	2020 (Metric Tons)	2021 (Metric Tons)
NCR	9,860.73	680.95	217.53
CAR			
Ilocos Region	116,796.79	125913.08	137,880.69
Cagayan Valley	543.73	555.07	634.82
Central Luzon	66,960.66	78015.63	89,608.27
CALABARZON	53,227.96	43338.17	41,073.29
MIMAROPA	1,331.95	1604.55	1,758.24
Bicol Region	4,342.89	2390.56	4,198.03
Western Visayas	97,265.96	98326.86	97,564.21
Central Visayas	4,694.35	6287.21	7,657.06
Eastern Visayas	6,947.04	3221.29	3,430.87
Zamboanga Peninsula	6,329.28	6026.77	7,729.52
Northern Mindanao	15,185.62	14791.77	14,585.64
Davao Region	13,398.77	16527.34	20,143.08
SOCCSKSARGEN	2,391.87	3732.93	3,085.78
Bangsamoro Autonomous Region in Muslim Mindanao	5,246.55	7336.85	7,315.64
Caraga	5,385.41	4839.9	5,385.07

Several interesting patterns are observed based on the data provided by the Philippine Statistics Authority.

Regional Variations in Fish productivity. The results show that there are significant regional differences in fish productivity. Fish production in the National Capital Region (NCR) fell significantly from 9,860.73 metric tons in 2019 to 217.53 metric tons in 2021. In contrast, several areas, like Central Luzon, the Cagayan Valley, and the Ilocos Region, had a steady increase in fish production over the three-year period. The aquaculture and fishing industries in these areas have made good strides.

Variations in Some Regions. Over the course of the study period, fish productivity varied in a few regions. For instance, the latter years (2019 to 2021) observed decreased fish production in the CALABARZON and Bicol Region, indicating future difficulties or changes in the fishing industry in those regions. These oscillations might be impacted by a number of variables, including as the state of the ecosystem, consumer demand, and modifications to fishing techniques.

Growth in Regions Driven by Aquaculture. Fish output increased steadily in a few areas where aquaculture is a major focus. Because of its substantial aquaculture operations, Western Visayas consistently produced fish over the course of the three years. Despite minor changes, Central Visayas and the Davao Region both showed growth in their fish production.

Fish production resilience. Despite difficulties caused by the COVID-19 pandemic and other elements, numerous regions were able to sustain or boost their fish production. Throughout the study period, the fish production levels in Northern Mindanao, SOCCSKSARGEN, and the Bangsamoro Autonomous Region in Muslim Mindanao (BARMM) showed resiliency.

Potential Influencing Factors. A number of factors may combine to affect the patterns in fish production that have been observed. Fish production trends in various regions may be impacted by environmental factors, climatic changes, fishing methods, aquaculture technologies, and market demand.

Implications for Food Security and the Economy. In the Philippines, many coastal communities rely on fishing and aquaculture for their food security and means of subsistence. Regional variations and shifts in fish productivity could have a big impact on local economy, the availability of food, and the welfare of fishing communities.

3.2. Prediction of the Bangus Aquaculture Production in the Philippines

The study predicts aquaculture fisheries production in the coming years using k-Nearest Neighbors, Linear Regression, Decision Tree, Multi-Layer Perceptron, and Support Vector Machines. Machine learning uses these algorithms for classification and regression. Linear Regression finds linear correlations between variables, while k-Nearest Neighbors predicts based on data point similarity. Decision Tree uses feature values to make tree-like judgments, and Multi-Layer Perceptron may learn complex patterns. SVMs classify binary data. These algorithms will help policymakers and resource managers make sustainable fisheries management decisions by creating reliable prediction models. Table 2 shows the results of performance measures of the prediction algorithms.

To understand Bangus output changes in the National Capital Region, more research is needed. Bangus production in the Ilocos Region increased, indicating good conditions and successful aquaculture. Central Luzon, CALABARZON, and Davao Region showed constant Bangus output growth, proving their aquaculture operations work. Understanding these regions' success factors can inform Bangus production methods statewide. The changes in Eastern Visayas and Zamboanga Peninsula may require more investigation to determine the causes and take suitable steps to stabilize production.

Table 2. Summary Performance Measures of Aquaculture Production of Bangus in Predicting the Production of Fisheries in the coming years

Algorithm	Correlation Coefficient	RMSE
Linear Regression	0.9963	3657.90
k-Nearest Neighbors	0.8652	20596.51
Decision Tree	0.4472	39872.01
Support Vector Machine	0.9907	5661.88
Multi-Layer Perceptron	0.9905	7655.87

The provided information evaluates the performance of different machine learning algorithms in a regression task using correlation coefficient (R-squared) and Root Mean Squared Error (RMSE) as the metrics. Among the algorithms examined, the linear regression model achieved outstanding results with a correlation coefficient of 0.9963, indicating an excellent linear relationship between predicted and actual values. The low RMSE of 3657.90 further validates the accuracy of the linear regression predictions.

The k-Nearest Neighbors (k-NN) algorithm also demonstrated decent performance with a correlation coefficient of 0.8652, suggesting a relatively strong relationship between its predictions and the actual data. However, the higher RMSE of 20596.51 indicates that k-NN has a larger average deviation from the actual data points compared to linear regression.

In contrast, the decision tree algorithm's performance was moderate, with a correlation coefficient of 0.4472, implying a weaker capture of the data's underlying patterns. The relatively high RMSE of 39872.01 further confirms the decision tree's larger prediction errors compared to other models.

Support Vector Machine (SVM) and Multi-Layer Perceptron (MLP) algorithms demonstrated high correlation coefficients of 0.9907 and 0.9905, respectively, which were very close to the linear regression performance. Both models effectively captured the underlying patterns, and their RMSE values (5661.88 for SVM and 7655.87 for MLP) indicated good accuracy in their predictions.

The analysis revealed that linear regression, SVM, and MLP performed exceptionally well in the regression task, displaying high correlation coefficients and relatively low RMSE values, which are indicative of accurate predictions. On the other hand, k-NN and the decision tree exhibited lower accuracy and larger prediction errors, suggesting the need for further improvement, potentially through tuning or feature engineering.

The most suitable algorithm depends on factors like the specific dataset, problem complexity, and desired accuracy level. Linear regression, SVM, and MLP are strong contenders for accurate predictions in this context, while k-NN and the decision tree may benefit from optimization. Further experimentation and evaluation are recommended to determine the optimal model for a particular regression task involving fish production data in the Philippines.

3.3. The Quest for SMART Fishpond Bangus Farming

The study's findings suggest that Bangus farming in the Philippines requires a SMART fishpond approach for a number of convincing reasons:

Regional Variations and Productivity Challenges. Significant geographical differences in fish productivity are highlighted in the study, with some regions seeing a fall in production. By applying targeted interventions and effective resource allocation to increase fish output, a SMART fishpond can assist in addressing the issues faced by regions with declining productivity.

Optimal Resource Management. The study exposes the effects of numerous elements, including environmental circumstances, climatic changes, and fishing methods, on fish output. Real-time data monitoring and analysis can be used by a SMART fishpond to optimize resource management, assuring the proper use of water quality, feeding procedures, and disease control measures.

Fish production resilience. Despite external difficulties like the COVID-19 epidemic, certain areas showed resilience in the production of fish. To increase resilience and responsiveness to outside shocks or changes in the fishing sector, a SMART fishpond can contain adaptive management tactics based on historical performance data.

Sustainable Aquaculture Practices. The study identified areas with a strong aquaculture industry that consistently produced more fish. To ensure long-term environmental and financial sustainability, a SMART fishpond can concentrate on fostering sustainable aquaculture practices in key areas, such as prudent stocking densities, water quality monitoring, and waste management.

The study used machine learning algorithms to forecast future aquaculture fisheries production. Predictive modeling for decision-making. Such predictive modeling can be used by a SMART fishpond to make well-informed choices on fish stocking, productivity goals, and investment tactics, ensuring cost-effectiveness and profitability.

Food Security and Economic influence. As many communities rely on fishing and aquaculture for nutrition and a living, regional variations in fish output can have a considerable influence on both food security and the local economy. By maximizing fish productivity and providing a consistent source of revenue for fishing communities, a SMART fishpond can help ensure global food security.

Time-Bound Interventions. A SMART fishpond strategy places a strong emphasis on time-bound interventions, allowing for swift responses to the market's shifting demands and environmental changes. Fishponds can remain productive and profitable with timely modifications to production tactics.

Data-Driven Decision-Making. The study places a strong emphasis on the value of data in comprehending changes in fish production. Data-driven decision-making is used by SMART fishponds to improve overall performance by informing farm management choices with real-time data monitoring and analysis.

4. Conclusions and Future Works

In conclusion, the study offers insightful information on how well various machine learning algorithms forecast the output of aquaculture fisheries, with a particular emphasis on Bangus farming in the Philippines. We were able to evaluate the precision and goodness-of-fit of the predictions made by each method using correlation coefficients and Root Mean Squared Error (RMSE) as evaluation measures.

In the regression job, the results showed that the algorithms for linear regression, Support Vector Machine (SVM), and Multi-Layer Perceptron (MLP) performed remarkably well, exhibiting high correlation coefficients and relatively low RMSE values. These models demonstrated precise predictions and were a good fit for the dataset. However, the decision tree method and k-Nearest Neighbors (k-NN) showed comparably lower accuracy and bigger prediction errors, indicating possible areas for development.

The research reveals regional differences in fish productivity and trends over a three-year span in several Philippine regions. Notably, there were notable regional differences in fish production, demonstrating the impact of the environment, consumer demand, and fishing methods.

The study emphasizes the significance of a SMART (Specific, Measurable, Achievable, Relevant, and Time-bound) fishpond method for Bangus farming in the Philippines given the effects of fish production on food security and the economy. Utilizing predictive modeling and real-time data monitoring, a SMART fishpond can improve resilience, manage resources more effectively, and advance sustainable aquaculture techniques. A SMART fishpond can support steady fish output, economic growth, and the wellbeing of fishing communities by using data-driven decision-making and prompt interventions.

The study shows how data-driven strategies and machine learning algorithms have the potential to improve the sustainability and productivity of Bangus farming in the Philippines. Policymakers, resource managers, and stakeholders can use the knowledge from this research to help them make decisions that will ensure the long-term development of the nation's aquaculture and fishing industries.

Several suggestions can be made to enhance Bangus farming and fisheries management in the Philippines in light of the study's findings:

1. SMART Fishponds can greatly improve the effectiveness and production of Bangus farming. Fish farmers will be able to respond quickly to changing environmental circumstances, allocate resources as efficiently as possible, and make educated decisions by integrating real-time data monitoring and predictive modeling.
2. Extensive data gathering and monitoring systems are required to enhance the accuracy of predictive models and better comprehend patterns in fish output. To ensure data availability and accessibility, cooperation between governmental organizations, academic institutions, and the fishing community is crucial.
3. Encourage research and development initiatives aimed at enhancing aquaculture technologies, fishing techniques, and ecosystem preservation. Higher yields and lessening of the impact on the environment are possible with the use of cutting-edge techniques like precision aquaculture and formulations for sustainable fish feed.
4. Promote knowledge sharing and capacity building

initiatives to spread the finest Bangus farming techniques. More effective production techniques will be made possible by providing fish farmers with technical know-how and the most recent aquaculture innovations.

5. Encourage public-private partnerships through working with private sector players to promote financial investments in cutting-edge aquaculture infrastructure and technology. Public-private partnerships can pool resources, knowledge, and finance to promote the expansion and sustainability of the fishing industry.

6. Implement sustainable fisheries management by creating and enforcing rules and laws that encourage resource conservation and sustainable fishing methods. The long-term wellbeing of fish stocks and ecosystems can be supported by the implementation of policies like catch quotas, closed seasons, and marine protected zones.

7. To reduce potential adverse effects on water quality, biodiversity, and coastal ecosystems, continuously evaluate how aquaculture activities are affecting the environment. Environmental conservation and sustainable fish farming practices ought to go hand in hand.

8. Analyze the socioeconomic effects of variations in fish production on coastal communities and regional economies on a regular basis. Making specific support and intervention plans will be made easier with an understanding of the effects of changes in fish productivity.

9. Give climate resilience a priority in aquaculture planning and management given the impact of climate-related factors on fish output. Creating climate adaption methods can help fish farms be less affected by extreme weather occurrences.

10. Foster forums, workshops, and conferences where stakeholders from the fishing industry, government, academia, and NGOs may share expertise and experiences in order to promote collaboration and knowledge exchange. Fostering an all-encompassing and integrated approach to fisheries management requires cooperation and communication.

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