Comparison of Exponential Smoothing Methods for Forecasting Marine Fish Production in Pekalongan Waters, Central Java

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Abstract. Pekalongan waters, a part of the Java Sea, has potency to develop marine fisheries sector to increase regional income and community livelihoods. The fluctuation of marine fish production every year requires serious attention in planning and policy strategies for the utilization of the fishery resources. Time series fish production data can be used to predict fish production in the following years through the forecasting process. The data used in this study is fish production data from Pekalongan Fishing Port, Central Java, from January 2011 to December 2020. The method used is data exponential smoothing by comparing three exponential smoothing methods consisting of single/simple exponential smoothing, double exponential smoothing and Holt-Winters’ exponential smoothing. The criterion that used to measure the forecasting performance is the mean absolute percentage error (MAPE) value. The smaller MAPE value shows the better the forecasting result. The smallest MAPE value is obtained by finding the optimal smoothing constant value which is usually calculated using the trial and error method. However, in this study, the constant value was calculated using the add-in solver approach in Microsoft Excel. The forecasting results obtained show that forecasting using the Holt Winter Exponential Smoothing method is reasonable with a MAPE value of 37.878.

1. Introduction

Pekalongan City, which is directly adjacent to the Java Sea and has a coastline of 6.15 km, has fishery potential that can be developed as a source of regional income. Layang fish, tuna, siro fish, skipjack and banyar fish are the types of fish that dominate the marine fish production of Pekalongan city throughout 2020 [1]. In developing fishery potential, it is necessary to reference past data to make forecastings or prediction in the future.

Forecasting or prediction of events related to fishery production in the future can be used as one of the considerations in planning. Forecasting is a science or method for estimating or predicting events that will occur in the future using time series data through a mathematical model approach. It often happens that the results achieved are not in accordance with the targets or goals that have been set.
Therefore, forecasting is needed in various fields as consideration in effective and efficient planning. Forecasting can be done in an annual period or even just a few minutes ahead according to specific needs [2]. If the conditions that will occur in the future can be predicted scientifically, it can be better prepared what will be done and how to do it.

Forecasting applications can be used to predict fishery production in an area. Fishery production forecasting information can be used as a planning reference for the government, business people and other stakeholders. Forecasting should be an integrated part of planning and decision making. Fishery production forecasting can be implemented for both aquaculture and capture fisheries [3]. There are many forecasting methods, but no one forecasting method is best for all job contexts. It’s just that a forecasting model can be more appropriate to a particular case and context [4][5].

The use of exponential smoothing methods, seasonal autoregressive integrated moving average (SARIMA), autoregressive neural network, and autoregressive recurrent neural network models have been used by Kim et al. [6] to forecast anchovy fishing in the Korean Sea. Based on his research on the application of the time series model for catching anchovies in the Korean sea, Kim, et al., concluded that SARIMA is good for data interpretation and investigation of fisheries science, while neural networks are good for forecasting the number of fishing in the future. Forecasting using neural networks shows good results although there are challenges in determining which input variables are important and the interactions between variables in the neural networks model.

The purpose of this paper is to compare three exponential smoothing methods to predict marine fish production in the city of Pekalongan. The methods are single exponential smoothing, double exponential smoothing and Holt-Winters' exponential smoothing.

2. Material and Methods
The data used in writing this article is in the form of monthly marine fish production for the last ten years from January 2011 to December 2020 obtained from the Central Bureau of Statistics [1, 7]. Data from January 2011 to December 2019 is used to create an exponential smoothing model. The model is used to forecast fishery production from January 2020 to December 2020. Forecasting results will be compared with real data in 2020 to evaluate the forecasting performance.

2.1. Exponential smoothing
Forecasting using the Exponential smoothing method, the value of the newer observation data is given a relatively greater weight than the value of the old observation data. While the value of the observation data that is longer given weighting decreases exponentially [2, 8, 9, 10]. The simple exponential smoothing method or can be called single exponential smoothing is the simplest exponential smoothing method. This method is suitable for forecasting data that does not show a clear trend or seasonal pattern, but the average of the data changes slowly over time. Holt developed simple exponential smoothing so that it can be used for forecasting trending data. This method is known as Holt's linear trend method or commonly called double exponential smoothing which uses two parameters, namely level and trend. The method was further developed by Winters by adding a seasonal pattern parameter, so that there are three smoothing parameters used, namely level, trend and seasonality. This method is known as the Holt-Winters' seasonal method [2]. These three methods will be used for forecasting the production of marine capture fisheries Pekalongan City.

Exponential smoothing equation:
Simple Exponential smoothing method [2], [11]

\[
\text{Level: } L_t = \alpha y_t + (1 - \alpha)L_{t-1}
\]  
(1)

\[
\text{Forecasting : } F_{t+m} = L_t
\]  
(2)

\[
\text{Double Exponential smoothing method (Holt’s linear trend method)} [2, 11]
\]

\[
\text{Level : } L_t = \alpha y_t + (1 - \alpha)(L_{t-1} + b_{t-1})
\]  
(3)
\begin{align*}
\text{Trend: } b_t &= \beta(L_t - L_{t-1}) + (1 - \beta)b_{t-1} \\
\text{Forecasting: } F_{t+m} &= L_t + b_t m
\end{align*}

Holt-Winter Multiplicative method formulation [11, 12, 13]

\begin{align*}
\text{Level: } L_t &= \alpha \left( \frac{y_t}{S_{t-m}} \right) + (1 - \alpha)(L_{t-1} + b_{t-1}) \\
\text{Trend: } b_t &= \beta(L_t - L_{t-1}) + (1 - \beta)b_{t-1} \\
\text{Seasonal: } S_t &= \gamma \left( \frac{y_t}{L_t} \right) + (1 - \gamma)S_{t-m} \\
\text{Forecasting: } F_{t+m} &= (L_t + T_t m)S_{t-s+m}
\end{align*}

where \( y_t \) is actual data at time \( t \), \( L_t \) is level forecasting at time \( t \), \( b_t \) is trend smoothing at time \( t \), \( S_t \) is seasonal smoothing at time \( t \), \( \alpha \) adalah smoothing constant for origin data, its value is \( 0 < \alpha < 1 \), \( \beta \) is smoothing constant for trend pattern, its value is \( 0 < \beta < 1 \), \( \gamma \) is smoothing constant for seasonal pattern, with value is \( 0 < \gamma < 1 \), \( m \) is number of future periods to be forecast.

2.2. Data processing

Microsoft Excel 365 was used to collect data and build Exponential smoothing models. The exponential smoothing method equation is poured into a formula in Microsoft Excel. The optimal value of the smoothing constant which is usually calculated using the trial and error method, in this paper the optimal value of the smoothing constant is proposed using an add-in solver in Microsoft Excel. Solver is an analysis tool that aims to find the optimal value of a target cell by changing the value in a specific cell that is used to calculate the target cell. The method chosen in Solver is GRG Non Linear because the problem used is nonlinear. Simply put Solver can be used to determine the maximum or minimum value by changing the values in other cells. Smoothing constant values of \( \alpha \), \( \beta \), \( \gamma \) are set as values that can be changed to get the minimum value of MAPE or RMSE.

2.3. Performance Evaluation

The measure used to determine the performance of the Exponential smoothing forecasting model is the root mean squared error (RMSE) which indicates the level of error in the forecasting/prediction results, where the smaller (closer to zero) the RMSE value, the more accurate the forecasting/prediction results. While the mean absolute percentage error (MAPE) which shows the relative accuracy measure used to determine the percentage deviation of forecasting results [2, 14, 15, 16].

The equation used is as follows:

\begin{align*}
\text{RMSE} &= \frac{1}{n} \sum_{i=1}^{n} (y_i - y_i')^2 \\
\text{MAPE} &= \frac{1}{n} \sum_{i=1}^{n} \left| \frac{y_i - y_i'}{y_i} \right| \times 100\%
\end{align*}

which \( n \) is sum of data, \( y_i \) and \( y_i' \) are real data and forecasting data.

3. Results and Discussion

Pekalongan city marine fish production from 2011 - 2020 tends to fluctuate, but has a relatively similar seasonal pattern every year. Fishery production tends to increase in the first quarter, then decreases in the third quarter and increases again in the third quarter (Figure 1). This trend shows that the volume of marine fish production is influenced by seasonal factors. Pekalongan’s marine fish production during the last ten years peaked in 2018, which was 14.1% of the total production. While, the least production occurred in 2019 which was 7.44% of total production (Table 1).
The pattern of increase and decrease in marine fish production in the city of Pekalongan each year has a relatively similar pattern but has experienced several shifts, for example in 2013 the highest catch occurred in November while the least catch occurred in January. Meanwhile, in 2014 the most catches occurred in October and the least catches occurred in February as presented in Table 1.

![Figure 1. Production Chart of Pekalongan City Marine Fish](image)

### Table 1. Catch/Production of Marine Fish in Pekalongan City

| Years | Total Production | MIN Month | MAX Month |
|-------|------------------|-----------|-----------|
| 2011  | 18,831           | Feb       | 3,021     |
| 2012  | 19,578           | Jul       | 2,839     |
| 2013  | 17,750           | Jan       | 2,424     |
| 2014  | 17,790           | Feb       | 2,848     |
| 2015  | 17,584           | Aug       | 2,700     |
| 2016  | 20,608           | Aug       | 3,752     |
| 2017  | 13,943           | Aug       | 2,414     |
| 2018  | 25,565           | Feb       | 3,703     |
| 2019  | 13,490           | Jul       | 2,189     |
| 2020  | 16,158           | Jun       | 2,621     |

### 3.1. Comparison of Forecasting results

Based on the results of the analysis, the best smoothing constant values calculated using the add-in solver in Microsoft Excel for each method are; forecasting using the single exponential smoothing method, value of $\alpha$ is 0.999, forecasting using the double exponential smoothing method (Holt's linear trend) value of $\alpha$ is 0.999, value of $\beta$ is 0.011, forecasting using the Holt's-Winter exponential smoothing method, value of $\alpha$ is 0.248, value of $\beta$ is 0.016 and value of $\gamma$ is 0.257 as shown in Table 2. At the smoothing constant value, the smallest MAPE and RMSE values are obtained, where these values indicate the optimal performance of the Exponential smoothing forecasting model [2], [14], [15]. So that, it can be said that the predicted value obtained at the smoothing constant has a level of conformity that is closest to the actual value.
Overall, it can be seen that the MAPE value of sea fish production data in Pekalongan city in 2011 to 2019 using the simple exponential smoothing method is 47.697, the MAPE double exponential smoothing (Holt's linear trend) value is 48.007 while the MAPE value for the Holt's-Winter exponential smoothing method is 37.878. The MAPE value of the Holt's-Winter exponential smoothing method has the smallest MAPE value compared to the other two exponential smoothing methods. In detail, the MAPE value of the Holt's-Winter exponential smoothing method on the model data is 37.878 and the test data is 41,423. The results of this forecast are still in the fairly good category (reasonable for MAPE values of 20-50%) [17], [18], [19], [20]

Table 2. Value for smoothing constant, MAPE and RMSE

| METHODS       | PARAMETER | MAPE   | RMSE   |
|---------------|-----------|--------|--------|
|               | α         | β      | γ      | MODEL | TEST | MODEL | TEST |
| Simple ETS    | 0.999     |        |        | 47.697| 64.716| 750.624| 688.313|
| Double ETS    | 0.999     | 0.011  |        | 48.007| 56.128| 792.183| 900.967|
| Holt-Winter ETS | 0.248   | 0.016  | 0.257  | 37.878| 41.423| 675.073| 761.671|

Figure 2. Comparison of Forecasting Results Using Exponential Smoothing Method with Actual Data of Marine Fish Production in Pekalongan City

The RMSE value based on Table 2 shows the simple exponential smoothing method of 750,624, the RMSE value of double exponential smoothing (Holt's linear trend) of 792,183 while the RMSE value of the Holt's-Winter exponential smoothing method is 675,073. The RMSE value of the Holt's-Winter exponential smoothing method has the smallest RMSE value compared to the other two exponential smoothing methods. In detail, the RMSE value of the Holt's-Winter exponential smoothing method on the model data is 675,073 and the test data is 761,671. The Holt's-Winter exponential smoothing method has the smallest MAPE and RMSE values so that this method is the best that can be used in the case of forecasting marine fish production in the city of Pekalongan, Central Java.
Figure 3. Comparison of the Results of Forecasting Marine Fish Production in Pekalongan City in 2020

Based on the forecasting results for January to December 2020 (period 103-120) in Figure 3 and the MAPE and RMSE values shown in Table 2, each method has a greater difference from the actual when compared to the value in the forecasting model. As previously explained, the MAPE and RMSE values in the test phase are greater than the MAPE and RMSE values of the forecasting model. According to the author, this significant difference is a weakness of the exponential smoothing method, forecasting in the next period is calculated based on the results of the last calculation, so it seems as if the overall data has less effect on the forecasting results. Even though, one of factors that affects forecasting accuracy is the amount of available data [2]. This research is only based on time series data on marine fish production. In fact, marine fish production is influenced by various factors such as weather, rainfall, wave height, wind and fishing effort. So the accuracy is still lacking.

4. Conclusion
The application of three exponential smoothing methods to predict marine fish production in Pekalongan city resulted in the Holt's-Winter Exponential smoothing method having a MAPE value of 37,878 on the model data and 41,423 on the test data. While the RMSE value of the Holt's-Winter exponential smoothing method on the model data is 675,073 and the test data is 761,671. The MAPE and RMSE values are the smallest values compared to the double exponential smoothing (Holt's linear trend) and Holt's-Winter exponential smoothing methods. The success of forecasting cannot be separated from the available data, therefore good fisheries management is endeavored to provide data with accurate records. The support and awareness of fishermen and the fishing community to report their production results accurately can increase the success of forecasting, thus indirectly supporting the success of fishery industrialization.

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