Implementation of ARIMA Model to Asses Seasonal Variability Macrobenthic Assemblages

by Widowati Widowati

Implementation of ARIMA Model to Asses Seasonal Variability Macrobenthic Assemblages

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Abstract

Human activities, including industrial and aquaculture, may have impact on water environment, especially organic enrichment. One of bioindicator of pollution that affect the quality of the water ecosystem is macrobenthic community. In general, the more diverse macrobenthic assemblages indicate the better of the waters quality. Understanding spatial and temporal distribution of macrobenthic abundance has become an important part of research in the field of ecology in understanding the level of environmental disturbance over time. This study discussed the application of the method of Autoregressive Integrated Moving Average (ARIMA) to asses seasonal variability ofmacrobentic assemplages. We found that forecasting using autoregressive integrated moving average method with the model of ARIMA (0,1,1) is obtained the smallest value of the Mean Square Deviation (MSD).

Keyworods : ARIMA; forecasting; macrobenthos; MSD; waters quality.

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1. Introduction

Macrobenthos are living organisms that live in the bottom of water sediments. Macrobenthic organisms are considered sensitive as aquatic organisms in response to environmental changes. With such properties, changes in water quality and substrate (sediment) greatly affects the abundance of macrobenthos (Robert, 2006; Day et al., 1989). Macrobenthos abundance depends on the tolerance or sensitivity to environmental changes (Dobson and Frid, 1998). Each community responds to changes in habitat quality in a way adjustment on the community structure. In a relatively stable environment, composition and abundance macrobenthos are relatively fixed (Putro et al., 2014; Ardi, 2002; Ruswahyuni, 1988).

Research in the field of ecology, especially discussion of the spatial and temporal distribution of macrobenthic abundance can be used to determine the level of environmental disturbance over time. Through their spatial and temporal variability, the water ecosystem may be in disturbed or undisturbed situation. If their abundance is relatively high in diversity, the water quality is considered good or not polluted, and vise versa.

Mathematics as one of the basic science has provided a solution to the problems of the real world, for example in mathemacical modeling, control problems, optimization problems, the spread the population, and many more. In this case, we proposed one of time series models (Makridarkis, 1992), i.e, Autoregressive Integrated Moving Average (ARIMA) model to asses seasonal variability macrobenthicassemblages. Settlement of these matters related to mathematical statistics and mathematical modeling. The goal is to analyze the macrobenthic assemblages using ARIMA model corresponding to seasonal variability, while theoretically benefit is the understanding of mathematical and statistical models.

2. Material and methods

The material of this research was the abundance of macrobenthos in the waters. Data sample for this study are the data obtained from Putro (2010). Plot of the time series original data macrobenthic assemblages is given in the figure bellow. Fig. 1 looks abundance macrobenthos plot of the original data, where the abundance macrobenthos with individual units/corer and index with units of one station at a time of sampling.
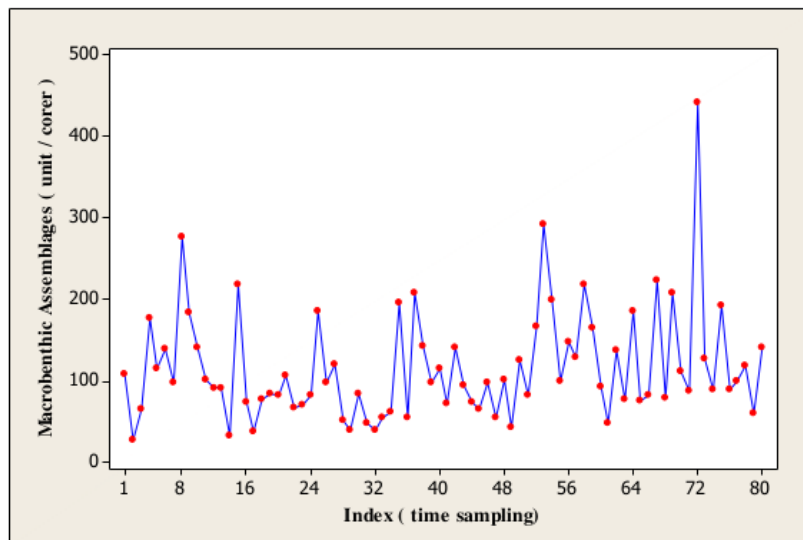

Fig. 1. Plot of original data macrobenthic assemblages

The method used to select of the appropriate   model for the times series data is achieved by a iterative approach based on four steps (Box-Jenkins et al., 1994) as bellow.

- Identification: determine the order and models including a data stationary test
- Estimation: efficient use of the data to make inference about the parameters. It is conditioned on the adequacy of the selected model.
- Diagnostic tests: checks the adequacy of fitted model to the data in order to reveal model inadequacies and to achieve model improvement.
- Forecasting: equation model to predict future values.

3. Results and discussion

3.1. Identification and stationary testing data

In this section will be discussed ARIMA model to asses seasonal variability macrobenthic assemblages. First, we do the test of stasionary data. To determine the stationary of the data, it can be seen in the plot data of macrobenthic abundance, in Fig. 2. This plot analysis to determine the trend of the data is stationary or not stationary.
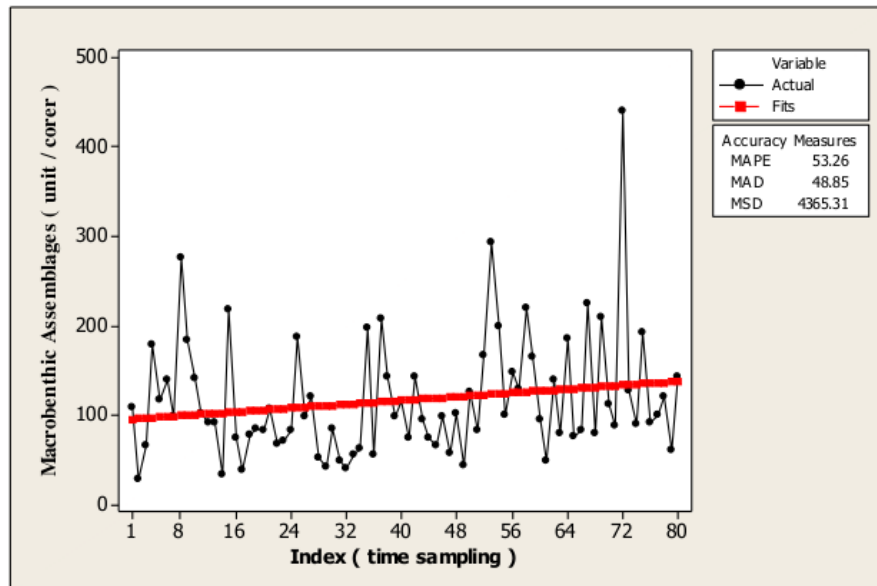

Fig. 2. Plot of trend analysis

In Fig. 2 where the abundance macrobenthos with individual units/corer and index with units of one station at a time sampling and analysis of the data shows that the trend is not symmetrical to the straight line and the actual data is not stationary because of data growth along the time axis (Wei, 1990). Therefore, the original data can not be used to look for initial models so that we do a differencing process. The first difference data of the macrobenthos abundance can be seen in Fig.3. The plot of trend analysis of the first difference data is given as follows:
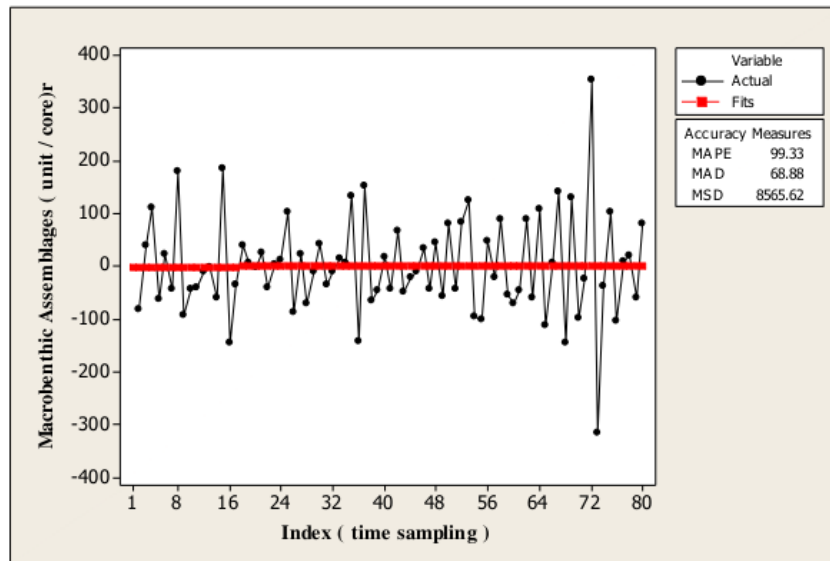
Fig. 3. Plot of trend analysis for differencing

In Fig. 3, an abundance of macrobenthos with individual units/corer and index with units of one station at a time of sampling and plot the data is obtained results of log transformationand diiferencing. From here is found that the data is stationary. Next, will be analyzed time series by using ARIMA modeling.

The data is already stationary 10 the mean and variance so that the assumption of the method have been satisfied. The next step to make the plot Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF) for identifying ARIMA models are suitable for use.
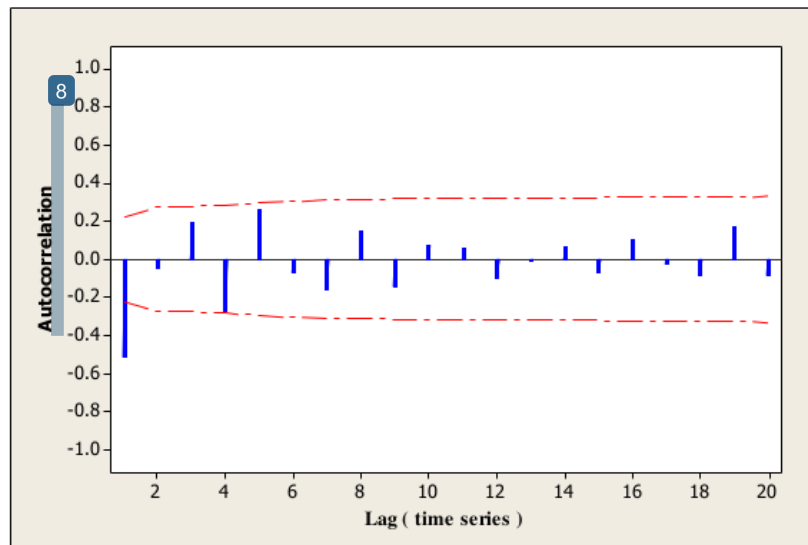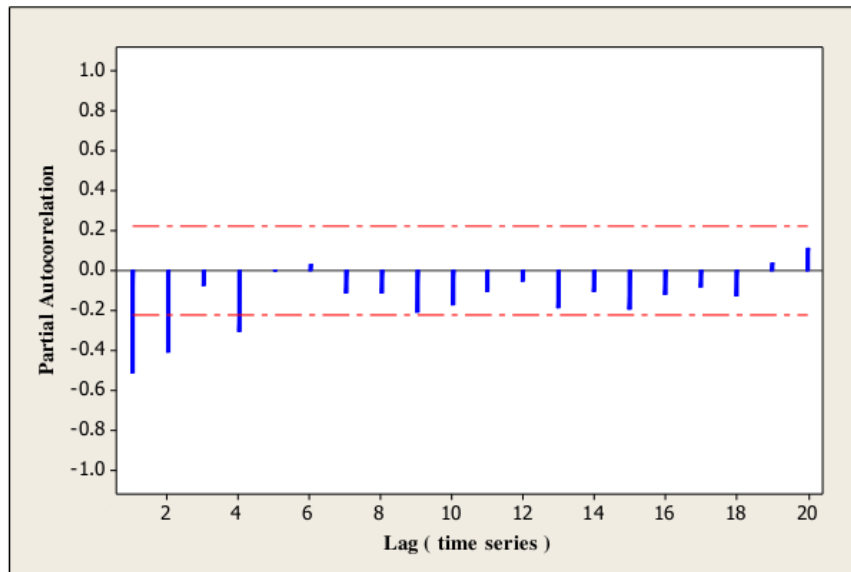

Fig. 4. Plot of autocorrelation function for macrobenthic abundance (with 5 % significance limits for the autocorrelations)

Fig. 5. Partial autocorrelation function for macrobenthic abundance (with 5 % significance limits for the partial autocorrelation)

From the plot of autocorrelation function (Fig. 4) and partial autocorrelation function (Fig. 5) can be seen that the value is not significant partial autocorrelation at lag 1 and lag 2, so that obtained initial model ARIMA (1,1,0). Although it is possible there are other models that are constructed. Obtained ARIMA models that enable the following:

Model 1: ARIMA (1,1,0)

$$\Delta Y_t = c + \alpha_1 Y_{t-1} + e_t \tag{1}$$

Model 2 : ARIMA (0,1,1)

$$\Delta Y_t = c + b_t e_{t-1} + e_t \tag{2}$$

Model 3 : ARIMA (1,1,1)

$$\Delta Y_t = c + \alpha_1 Y_{t-1} + b_t e_{t-1} + e_t \tag{3}$$

Model 4 : ARIMA (2,1,0)

$$\Delta Y_t = c + \alpha_1 Y_{t-1} + \alpha_2 Y_{t-2} + e_t \tag{4}$$

Model 5 : ARIMA (2,1,1)

$$\Delta Y_t = c + \alpha_1 Y_{t-1} + \alpha_2 Y_{t-2} + b_t e_{t-1} + e_t \tag{5}$$

Having obtained ARIMA models are possible, the next step is to estimate the parameters. Step estimate parameters of the models above is the hypothesis test for each parameter coefficient of models.

3.2. Parameter estimation of ARIMA model

Further, estimating the parameters in each model to obtain the best model that can be seen from the smallest value of the each SSR, MSD, and BIC. The following comparison table on the value of each model.

Table 1. Comparison of parameter, SSR, MSD, and BIC valuesbased model

	ARIMA (1,1,0)	ARIMA (0,1,1)	ARIMA (1,1,1)	ARIMA (2,1,0)	ARIMA (2,1,1)
c	0.64	0.50	0.46	1.03	0.39
α_1	-0.52	–	0.0233	-0.74	0.03
α_2	–	–	–	-0.74	0.06
b_2	–	0.97	0.97	–	0.99
SSR	494 490	357 899	357 648	407 759	352 007
MSD	6 422	4 648	4 706	5 365	4 693
BIC	8.88	8.54	8.65	8.76	8.71

A model that can be compared is ARIMA (0,1,1) and ARIMA (2,1,1). To see the best models of both models use criteria SSR value, MSD and the smallest BIC.In Table 1 shows that the ARIMA (0,1,1) has smaller values of MSD and BIC than ARIMA (2,1,1). Therefore it can be concluded that the ARIMA (0,1,1) is the best model for the abundance macrobenthos.Equation ARIMA (0,1,1) is generally written by

$$\Delta Y_t = 0.50 + 0.97\, e_{t-1} + e_t \qquad\qquad (6)$$

Where
  Δ : differencing first order
  Y_t : observation period- t
  e_t : error value in the period- t
  e_{t-1} : the value of errors in the period- (t - 1)

3.3. Diagnostic checking

After determining the model to estimate the parameters then the next step is done by checking at the diagnostic of the models error level, i.e., by checking the chart of ACF residue. If the values of correlation coefficients of residuals for various time lag is not significantly different from zero, the model was considered adequate for use forecasting models, in the figure below, the residual value indicate that there is no significant autocorrelation.
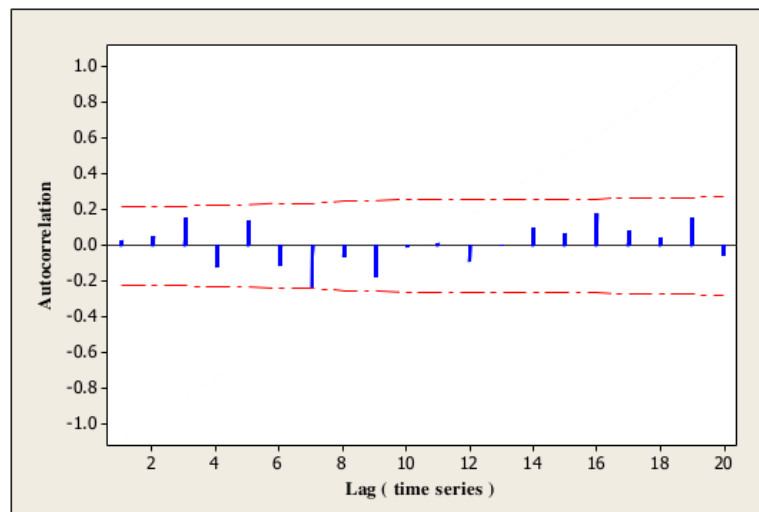

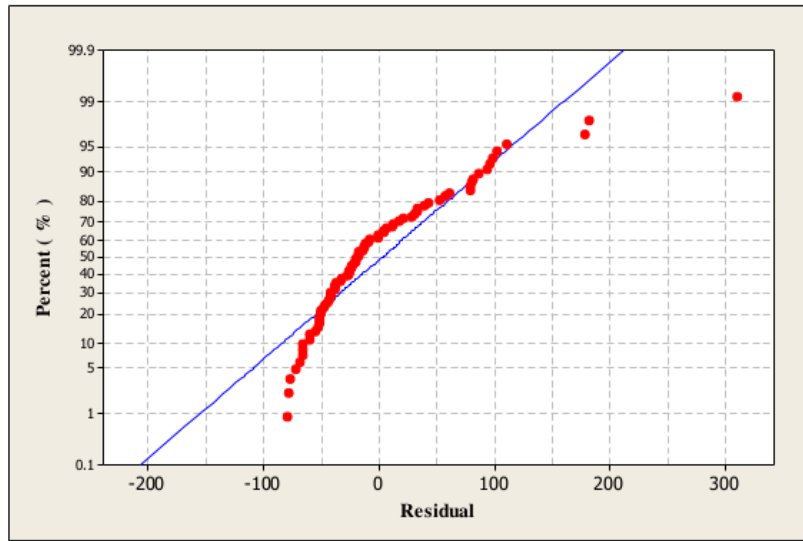Fig. 6. ACF of residuals for macrobenthic assemblages

Fig. 7. Plot of normal probability

In the graph ACF (Fig. 6), it can be seen that all the bars do not exceed the dotted line, which means that the residue is random. Normal probability plots is given in the Fig. 7. This Fig. shows the residuals follow a diagonal line, which means that the residue has a normal distribution. Because residues are random and normally distributed, then residual meet the assumption of white noise so that the model can be used to forcasting.

3.4. Forecasting

The next step in the analysis is to determine the time series forecasting or prediction for the next period. In this discussion will predict macrobenthic abundance for the coming period.
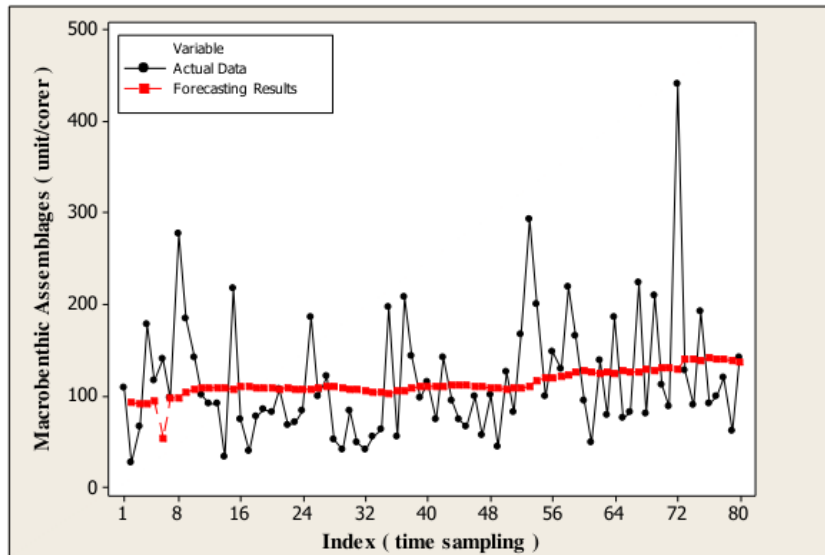

Fig. 8. Forecasting results of ARIMA (0,1,1)

Fig. 8 shows the result of forecasting ARIMA (0,1,1), where abundance macrobenthos with individual units per corer and index with units of one station at a time of sampling. Measurement of forecasting error for the ARIMA (0,1,1) by calculating the value of MAD and MSD as follows.

Mean Absolute Deviation (MAD) or the average absolute deviation

$$MAD = \frac{\sum_{t=1}^{n} |Y_t - \hat{Y}_t|}{n} = 51.03 \qquad (7)$$

Mean Squared Deviation (MSD) or the average squared error

$$MSD = \frac{\sum_{t=1}^{n} (Y_t - \hat{Y}_t)^2}{n} = 4\,597.13 \qquad (8)$$

Forecasting accuracy of measurements used in predicting abundance macrobenthos for future periods MAD error values obtained at 51.03 and MSD error value of 4 597.13.From ARIMA (0,1,1)model is found that prediction on macrobenthic abundancefor the coming period is 141 individuals/corer. From here indicates that macrobenthos seasonal community structure can be predicted by using ARIMA, although a macrobenthic assemblagesmay be fluctuated by time as a response to seasonal changes of water quality and sediment properties.

4. Concluding remarks

Macrobenthic assemblagesas may be used as an indicator of pollution, thus good to be used for assessment the quality of an aquatic environment. Forecasting methods Autoregressive Integrated Moving Average is obtained ARIMA (0,1,1) with the equation $\Delta Y_t = 0.50 + 0.97\ e_{t-1} + e_t$. Error values are obtained MAD (Mean Absolute Deviation) at 51.03 and MSD (mean square deviation) amounted to 4 597.13. ARIMA method to predict macrobenthic assemblages for the coming period is 141 individuals per corer. This indicates that although macrobenthic assemblages may be fluctuated by time as a response to seasonal changes of water quality and sediment properties, their seasonal community structure can be predicted using the ARIMA method.

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