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Performing *Multiscale Autoregressive* (MAR) Order 1, 2 And 3 Modeling for Hairtail Fish Production Forecast

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ABSTRACT

Hairtail fish is one of high demand export commodities for fish in Brondong Fishing Port. The practices of large-scale fishing performed by local fishermen in the last few years have caused the decrease in hairtail fish production per unit of fishing rod, which is regarded as the standard fishing gear for export purposes. Therefore, the production forecast of hairtail fish for one year ahead will be necessarily helpful for its resource management planning. Regarding that purpose, this research endorsed a wavelet transformation to predict the hairtail fish production by fashioning the model of *Multiscale Autoregressive* (MAR) in which the predictor was obtained from the *Maximal Overlap Discrete Wavelet Transform* (MODWT) decomposition using wavelet Haar filter. MAR order was determined based on the autoregressive order, through the ARIMA process. Yet, this hairtail fish production data is a moving average time series that more than one MAR was required. This research attempted the use of order 1, 2, and 3 on MAR modeling. Several selected MAR modeling were such models equipped with assumptions of normality and white-noise on residual. The wavelet forecast model involved the best MAR modeling build upon the squared correlation (R^2) closest to one. The purpose of this research is to form the best wavelet forecast model for Hairtail fish production data in Brondong fishing port, and forecast the Hairtail fish production for the next 12 month.

Keywords: *Wavelet, Multiscale Autoregressive (MAR), Fish Forecast, MODWT*

1. INTRODUCTION

Time series is a group of data achieved by observing certain phenomenon which particularly occurred in a constant range of a time index (Cryer, 2008). One of the time series of analysis methods is wavelet transformation. A wavelet transformation is an equipment used to preview data in such time components on a certain level (Renaud *et al.*, 2002). The non-stationer time series was decomposed by *Maximal Overlap Discrete Wavelet Transform* (MODWT) method such that the scales and wavelet coefficients could be attained then proceeded to MAR modeling. In an autoregressive (AR) data, MAR order could directly be attained from the AR order through the ARIMA process. Still, for the moving average type of time series, the MAR order required should have been more than one, seeing that MA(1) model is similar to AR(∞) model.

Capture fisheries is a fishery which bases its business in catching fishes from the ocean or open water. Accordingly, certain control policies is obligatory due to the outstand indication of overfishing in most of coastal fishing area in Indonesia. Nevertheless, applying these kinds of policies to fisheries communities or coastal societies will require a so called precautionary approach, given that capture fisheries control policies could directly restrict the business activities of fishermen (Setyohadi et al., 2005). The hairtail fish itself, is one of the demersal kinds of fishes abundantly found in Brondong Fishing Port. In current days, the hairtail fish is considered as a high demand and valuable export commodity compared to the domestic market. In the other hand, a massive large-scale fishing on hairtail fish has been recently ensued since the past few years. This occurrence has lead the digression of hairtail fish production per unit of fishing rod as a standard fishing catching tool utilized to wheedle hairtail fish aiming for export (Setyohadi, 2004). In consequence, the production forecast for hairtail fish landed in Brondong Fishing Port for some next periods is expected to importantly avails its management plans in order to preserve itself as one of fishery resources and advantageously generates high economy benefits for its capture business. This research attempted the use of order 1, 2, and 3 on MAR modeling. The purpose of this research is to form the best wavelet forecast model for Hairtail fish production data in Brondong fishing port, and forecast the Hairtail fish production for the next 12 month.

Wavelet Haar Filter

Haar the most unassuming filter wavelet with filter width (L)=2.
Equation scale :

$$\phi(t) = \sqrt{2}(g_0\phi(2t) + g_1\phi(2t-1)). \quad (1)$$

wavelet equation :

$$\psi(t) = \sqrt{2}(g_0\phi(2t) - g_1\phi(2t+1)). \quad (2)$$

(Percival & Walden, 2000)

Decomposition Using Maximal Overlap Discrete Wavelet Transform (MODWT)

MODWT is one of the developments of Discrete Wavelete Transformation. MODWT wavelet filter is $\tilde{h}_l = h_l/\sqrt{2}$, with condition :

$$\sum_{l=0}^{L-1}\tilde{h}_l = 0,\ \sum_{l=0}^{L-1}\tilde{h}_l^2 = \frac{1}{2},\ \sum_{l=-\infty}^{\infty}\tilde{h}_l\tilde{h}_{l+2m} = 0, \qquad (3)$$

and MODWT scale filter $\tilde{g}_l = g_l/\sqrt{2}$, with condition :

$$\sum_{l=0}^{L-1}\tilde{g}_l = 1,\ \sum_{l=0}^{L-1}\tilde{g}_l^2 = \frac{1}{2},\ \sum_{l=-\infty}^{\infty}\tilde{g}_l\tilde{g}_{l+2m} = 0. \qquad (4)$$

Used level is :

$$j < \log_2\left(\frac{N}{L-1}+1\right) \qquad (5)$$

(Percival & Walden, 2000)

The algorithm calculation of the scale coefficient and wavelet coefficient on 'j' level could be functioned by using pyramid algorithm for MODWT advanced by Mallat.

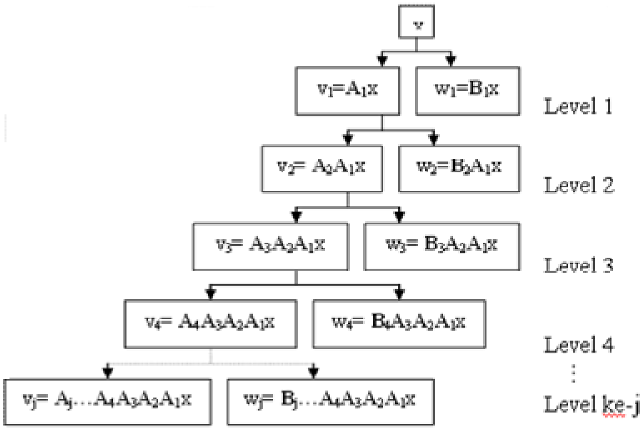

Figure 1. The scheme of MODWT pyramid algorithm (Popoola, 2007)

***Multiscale Autoregressive* (MAR) Modeling**

The AR prediction modified by Renaud et al. (2002) to MAR in the use of decomposition based on MODWT, is

$$\hat{Z}_{t+1} = \sum_{j=1}^{J}\sum_{k=1}^{A_j}\hat{a}_{j,k}w_{j,t-2^j(k-1)} + \sum_{k=1}^{A_j}\hat{a}_{J+1,k}v_{J,t-2^J(k-1)} \qquad (6)$$

From a stochastic process with weighter φ which was conducted by Box and Jenkins (1976), that finite moving average MA(1) process :

$$\tilde{Z}_t = (1-\theta_1 B)a_t\ ,\ |\theta_1| < 1 \qquad (7)$$

can be written as an infinite autoregressive AR(∞) process :

$$\tilde{Z}_t = -\theta_1\tilde{Z}_{t-1} - \theta_1^2\tilde{Z}_{t-2} - \cdots + e_t \qquad (8)$$

That, the MAR modeling on the moving average type data would need more order than the autoregressive type of data.

The best MAR model could be selected by comparing the biggest R^2 (the closest to one) in every order.

$$R^2 = \frac{\sum_{t=1}^{n}(\hat{Z}_t-\bar{Z})^2}{\sum_{t=1}^{n}(Z_t-\bar{Z})^2} \qquad (9)$$

(Makridakis et al., 2000)

Wavelet Forecast Model

For differencing stationing data:

$$Z_{t+1} = Z_t + \hat{Z}_{t+1}\ . \qquad (10)$$

For detrending stationing data:

$$Z_{t+1} = \sum_{j=0}^{k}\alpha_j t^j + \hat{Z}_{t+1}\ . \qquad (11)$$

The feasibility of wavelet forecast model is tested with *Ljung-Box* (Q) (Cryer, 2008).

2. RESEARCH METHODOLOGY

2.1. Data Source

The time series data that used in this research were particularly acquired from hairtail fish production data per month in Brondong Fishing Port (kg) from June, 2007 to September 2015. These data were non-stationer time series neither upon variance nor mean. These monthly data were typed as moving average, or more precisely ARIMA (0,1,1) model

2.2. Methods

The steps of research :

1. Stationary process of time series data (*differencing* and *detrending*)
2. Data decomposition using *Maximal Overlap Discrete Wavelet Transform* (MODWT) method on various levels (*j*).
3. The scale and wavelet coefficient had been selected from the result of MODWT decomposition by MAR order, then individual parameter significance test (*t*-test).
4. MAR modeling and the examination of residual assumption (normality and *white-noise*).
5. The MAR model selection by comparing R^2 values.
6. Wavelet forecast modeling formulation, and feasibility test of a model with *Ljung-Box* (Q).

3. RESULTS AND DISCUSSION

The previous explained methodological periods next applied on the monthly data of hairtail fish production in Brondong Fishing Port in a data plot as displayed on a figure below :

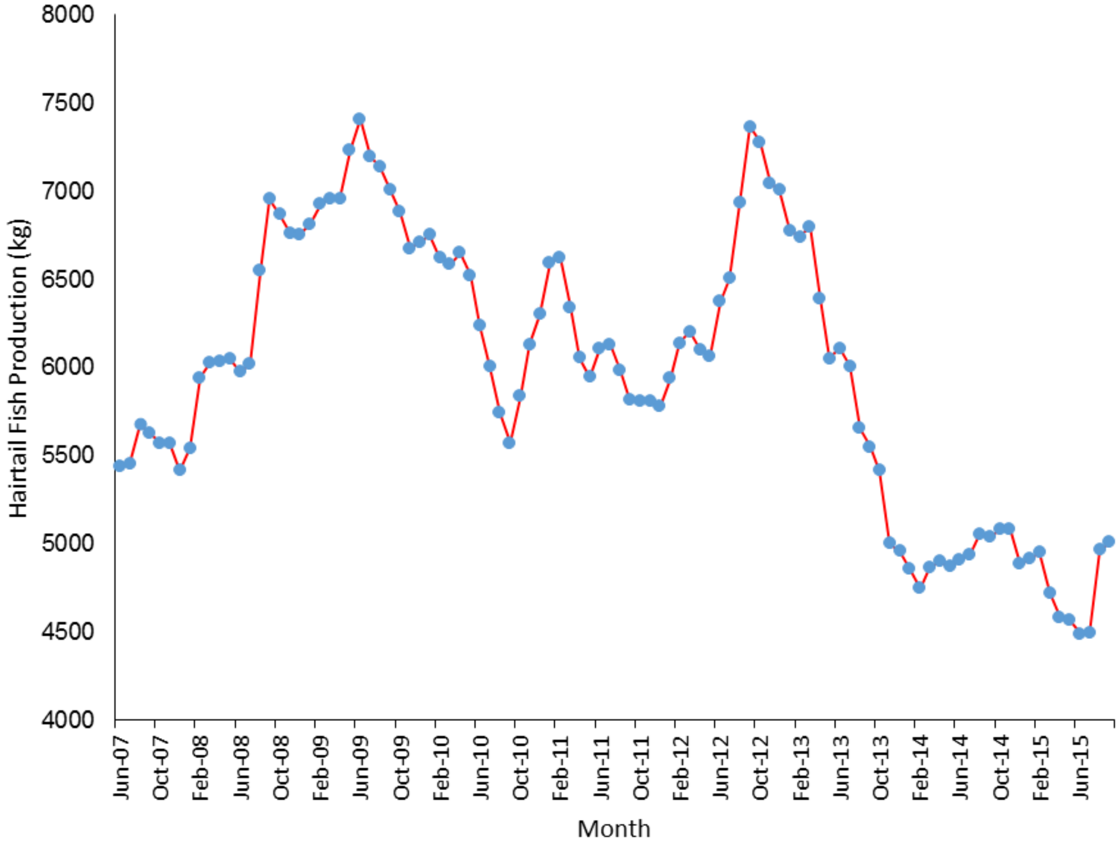

Figure 2. Data plot hairtail fish production in Brondong Fishing Port

Once the data had been stationed to the variance and mean (differencing and detrending), the MODWT decomposition should have been executed, with level (j) used are level 1, 2, 3 and 4. MAR modeling was held on every level and order. Every MAR models which met the normality assumption and *white-noise* on residual were gathered to had the R^2 value compared, as shown in Table 1.

Table 1. R^2 values on MAR models.

Model	R^2 value
Detrend+MAR(2)-I	0,937
Diff+MAR(2)-I	0,293
Diff+MAR(3)-I	0,349
Diff+MAR(2)-II	0,293
Detrend+MAR(3)-III	0,936
Diff+MAR(2)-IV	0,293
Diff+MAR(3)-IV	0,370

Table 1 indicates that the model of Detrend+MAR(2)-I is the best MAR model. The equation of Detrend+MAR(2)-I is described as

$$\tilde{Z}_{t+1} = 2{,}240 w_{1,t} + 0{,}854 w_{1,t-2} + 0{,}643 v_{1,t} + 0{,}283 v_{1,t-2}$$

that, the equation of wavelet forecast model is

$$Z_{t+1} = 0{,}012 + 1{,}8\text{x}10^{-5}\text{x}(t-1) + 2{,}240 w_{1,t} + 0{,}854 w_{1,t-2} + 0{,}643 v_{1,t} + 0{,}283 v_{1,t-2}$$

Ljung-Box Test (Q) appointed that the model was feasible to use. Eventually, the forecasting result for one year ahead of hairtail fish production in Brondong Fishing Port was obtained by calculating Z_{t+1} model.

4. CONCLUSION

Wavelet forecasting model for non-stationer time series data to variance and mean was established by MODWT decomposition through the process of data detrending. The forecasting result of hairtail fish production for the next 12 month (October 2015 to September 2016) will considerably fluctuate around 4,940 kg to 5,148 kg.

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