The estimation of nutrient limit for predicting eutrophication using quantile regression model (case study: aquaculture pond at IBAT Punten, Batu)

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Abstract. Aquaculture can be defined as the cultivation of aquatic organisms, and its systems are usually done in pond. Feeding management in aquaculture pond is very important since it will determine the yield of aquaculture production. Primary food source for most aquatic organism is phytoplankton, which its abundance in aquatic ecosystem is affected by nutrient such as nitrate and phosphate, light availability, temperature, and etc. The nutrient content must be maintained at the level that supports a beneficial phytoplankton abundance and a healthy fishery. Because when the nutrients increasing exceeds the desirable rate, the pond begins the eutrophication process. Eutrophic ponds are often undergo large algal bloom that will causing mass fish mortality and other environmental problem. The relationship between nutrients and phytoplankton abundance conventionally using simple linear regression. However, this method is less informative because it cannot provide the estimation limit of nutrient content to prevent eutrophication. This research proposes quantile regression to fix the flaw. The proposed method is applied to nutrient content and phytoplankton abundance of aquaculture pond at IBAT Punten, Batu. The result shows that the nitrate and phosphate limit are estimated at 0.731 mg/L and 0.022 mg/L respectively.

1. Introduction

The demand of fisheries commodity is very highly in the market. In order to fulfil the demand, the fisheries activity such as aquaculture must be carried out. Aquaculture can be defined as the cultivation of aquatic organisms. A successful aquaculture usually indicated by the high yield of production. To increase production yield of aquaculture activity, a good feed management is necessary. Although the used of artificial feed is common nowadays, but the need of natural feed cannot be replaced. The common natural feed for aquatic organisms is phytoplankton.

Phytoplankton are aquatic organisms that play an important role in aquatic ecosystems as a primary producer because they can carry out photosynthesis. The result of photosynthesis is the main source of nutrition for other groups of aquatic organisms that act as consumers. The abundance of phytoplankton in the aquatic environment is affected by several factors. These factors include physical-chemical factors (light intensity, dissolved oxygen, temperature stratification, and nutrient availability of nitrogen and phosphorus) and biological factors (grazing activity by animals, natural mortality, and decomposition). Phytoplankton abundance conditions in the waters can also be caused by nutrient intake from the land through the disposal of organic materials from residential areas and recreational or surrounding areas [1].
However, the concentration of nutrients that affecting phytoplankton abundance must be controlled at desirable level so that they does not cause eutrophication or algal blooms. Eutrophication is a serious environmental problem since it results in a degradation of water quality. Algal blooms limit light penetration, also high rates of photosynthesis associated with eutrophication can deplete dissolved inorganic carbon and raise pH to extreme levels during the day. Elevated pH can in turn ‘blind’ organisms that rely on perception of dissolved chemical cues for their survival by impairing their chemosensory abilities [2].

Moreover, within freshwater ecosystems, cyanobacteria are the most important phytoplankton associated with HABs or harmful algal blooms. Toxigenic cyanobacteria, including *Anabaena, Cylindrospermopsis, Microcystis, and Oscillatoria (Planktothrix)*, tend to dominate nutrient-rich, freshwater systems due to their superior competitive abilities under high nutrient concentrations, low nitrogen-to-phosphorus ratios, low light levels, reduced mixing, and high temperatures. Furthermore, cyanobacteria are responsible for several off-flavor compounds (e.g., methylisoborneal and geosmin) found in municipal drinking water systems as well as in aquaculture-raised fishes, resulting in large financial losses for state and regional economies. In addition to posing significant public health risks, cyanobacteria have been shown to be poor quality food for most zooplankton grazers in laboratory studies, thus reducing the efficiency of energy transfer in aquatic food webs and potentially preventing zooplankton from controlling algal blooms [3]. Therefore, the estimation of nutrient limit in aquatic ecosystem need to be conducted in order to prevent the ecosystem from eutrophication.

Unfortunately, most of the research related to nutrients content and phytoplankton abundance cannot performed the estimation of nutrient limit. They are only able to analyse whether there are any relationship between nutrients and phytoplankton abundance by using simple linear regression, such as Lv et al. [4]. Therefore, through this research we consider quantile regression method to estimate the nutrient limit of nitrate and phosphate that can be a warning state of eutrophication with case study in aquaculture pond at IBAT, Punten Batu. Quantile regression analysis has several advantages like it does not need any assumption, robust to outlier, and able to model the data more thoroughly [5]. Quantile regression able to describe or model the entire response variable, which depend on the chosen quantile to be modelled. Meanwhile, the classical linear regression is a conditional mean analysis, thus it is only modelling the response variable on its mean. Thus, the result of quantile regression model is more comprehensive than linear regression.

2. Materials and Methods

2.1. Materials

The objects of this research are nutrients content (mg/L) and phytoplankton abundance (ind/L) data in aquaculture pond in IBAT Punten, Batu which are collected during 2018. Generally, procedures of the study are comparison the result of simple linear regression and quantile regression, and estimation of nutrients limit related to high phytoplankton abundance. The analysis were conducted by using R version 3.4.3.

2.2. Method: Quantile regression.

Quantile regression is one of the regression analysis methods that can describe the relationship of one or several predictor variables to one response variable at various quantile points (conditional quantile) from the distribution of the response variable, so that this method can be used in heterogeneous data conditions. This is different from linear regression analysis which can only describe the causal relationship in the mean (conditional mean) response variable [6].

The following equation (1) shows the general form of quantile regression model [7].

\[ y_i = x_i \beta(\theta) + \varepsilon(\theta), \quad 0 < \theta < 1 \]  

where

\[ y_i = \text{response variable of the } i\text{th observation} \]
Parameter estimates of quantile regression can be defined as the solution of minimization of equation (2)

$$
\min_{\beta \in \mathbb{R}^p} \sum_{i \in \{i : x_i \geq \beta \}} \rho_\theta (y_i - f(x_i))
$$

Where \( \rho_\theta (u) = (\theta - 1_{(u<0)})u \) is a check function that illustrated as in Figure 1.

According to [8], equation (2) does not have fixed derivative form, so that a common numerical iteration cannot be performed to obtain the parameter estimation. Thus, an alternative method of linear programming was considered namely simplex method.

3. Results and Discussions

The analysis result of quantile regression and the comparison with simple linear regression can be seen in Table 1.

| Model             | Distribution | Phyto-abundance (ind/L) | Parameter estimates |
|-------------------|--------------|-------------------------|---------------------|
| Simple linear regression | Mean         | 9.2217 (10114.02)       | 0.157 0.175         |
| Quantile regression | q=0.05       | 9.0905 (8870.62)        | 0.151 0.180         |
|                   | q=0.50       | 9.2410 (10311.34)       | 0.187 0.190         |
|                   | q=0.95       | 9.2966 (10901.25)       | 0.029 0.143         |

Based on Table 1, the parameter estimates of quantile regression generally vary across quantile. Or in the other ord, the estimates are not equal between quantiles. If the results are compared to simple linear regression, then the result of quantile regression give a more comprehensive information of the data, since simple linear regression only produces one model on the mean. Moreover, if we will estimate the nutrient limit by using simple linear regression result, then the result will be misled because the
The parameter estimates of nitrate (0.157) and phosphate (0.175) from this analysis is way too different if compared to the parameter estimates of quantile regression on the upper quantile (q=0.95) where the estimate for nitrate is 0.029 and phosphate is 0.143.

The sign of parameter estimates for nitrate and phosphate are positive which indicate that in other the nitrate and phosphate content is high, it will cause the high abundance of phytoplankton. These results are suitable to [9] and [10]. However, the concentration of nitrate and phosphate must be controlled in order to prevent eutrophication. According to quantile regression results, the nutrient limiting to avoid eutrophication can be simply calculated based on upper quantile (q=0.95). The nitrate limit is 0.731 mg/L and the phosphate limit is 0.022 mg/L. If the concentration of nitrate and phosphate were above those values, then the handling efforts is needed.

4. Conclusion
According to the results of quantile regression analysis, it can be concluded that the parameter estimates for the relationship between phytoplankton abundance and nutrients content in aquaculture pond are vary across quantile. Therefore, the using of simple linear regression is not suggested because it is only modelled the response on its mean. Meanwhile, in order to estimate the nutrient limit for preventing eutrophication, it is required the upper quantile of phytoplankton abundance data. Based on quantile regression model for upper quantile (q=0.95), the nutrients limit for preventing eutrophication are estimated at the level of 0.731 mg/L and 0.022 mg/L for nitrate and phosphate respectively.

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