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REVIEW OF COMPARISON OF GROWTH MODELS IN VANNAMEI SHRIMP AND THEIR USAGE

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ABSTRACT

This paper contains a review of the use of several growth pattern models including von Bertalanffy, Gompertz, and Logistics in vannamei shrimp culture. Vannamei shrimp have several advantages, namely, responsive-ness to feed / high appetite, more resistance to disease attacks and poor environmental quality, relatively faster growth, higher survival rates than other shrimp, able to live with the stocking density is quite high and the maintenance time is relatively short, about 90-100 days per cycle. The use of the growth curve model can measure the optimization of growth and determine the right time to harvest, so that cultivator are expected to be able to optimize production factors efficiently, and get the maximum level of profit from vannamei shrimp cultivation. Many types of growth curve models have been written, but the best curve model for growth is characterized by a small standard error and the largest coefficient of determination. Based on the review, it can be seen that partial harvest can provide the maximum amount of biomass and the von Bertalanffy growth pattern model is the most suitable model for estimation because it has a small error rate, especially when combined with the Bayesian hierarchical model approach.

INTORDUCTION

Vannamei shrimp (Litopenaeus vannamei) is a marine fishery commodity that has a high economic value in both the domestic and global markets, 77% of which is produced by Asian countries including Indonesia. The Ministry of Marine Affairs and Fisheries (KKP) is targeting an increase in the value of shrimp exports in 2024 to reach 250%. To achieve this target, it is necessary to increase the export volume of farmed shrimp from 145,000 tonnes in 2018 to 363,000 tonnes in 2024.

Along with the increasing demand for seeds, high seed production is required. Good vannamei shrimp seeds must have good growth too. Change in body size is a good indicator and has a strong correlation value with the parameter of live weight. Therefore, it is important to identify the growth rate of body size through growth pattern curves to study growth in more depth. Growth curves have many models from simple ones, namely linear regression curves and non-linear curves. Non-linear model curves that are commonly used to estimate growth include von Bertalanffy, Gompertz, Logistic, and Richards. This growth pattern curve can be used to estimate biomass, age, and determine the right harvest time in shrimp culture.

Many types of growth curve models have been written, but the best curve model for growth is characterized by a small standard error and the largest coefficient of determination. This review provides an overview of the comparison of growth models and their uses in vannamei shrimp cultivation.

GROWTH

Growth is a change in fish size both in weight, length, and volume over a certain period which is caused by tissue changes due to the division of muscle and bone cells which are the largest part of the fish's body, causing additional weight or length of the fish [4]. Growth is a change in both the addition and increase of biomass of a living thing which is irreversible. Living things that grow will look bigger. Therefore, growth can be expressed in terms of length and weight. The characteristics of growth include:

1. There is a physical change in size and dimension
2. Increased number of cells
3. Increase the number of individuals
4. Can be expressed in terms of weight, length, and volume
5. Influenced by internal and external factors
6. Limited and irreversible (at a certain age living things no longer grow)

FIsh Growth

The study of fish growth in fish farming can use two types of growth, namely absolute growth and relative growth. Absolute growth is the growth in weight or body length of the fish at a certain age. Meanwhile, relative growth is the ratio between the size of the end of the interval and the size of the beginning of the interval. Absolute biomass growth can use the following formula [5]:

$$W = Wt - Wo$$

W is the absolute biomass growth of fish (grams), Wt is the weight of fish at time t in fish farming activities, and Wo is the weight of fish at the beginning of fish farming. Meanwhile, the daily growth rate or specific growth rate (SGR) can be measured by the formula [4] namely:

$$SGR = \frac{\ln W_t - \ln W_0}{t} x100\%$$

The notation t is the length of the cultivation period, Wt is the weight of the fish at the beginning of the fish farming activity, and Wo is the weight of the fish at the beginning of the fish farming activity, and ln is the logarithm of the natural number.

Fish growth rates vary between species. Each type of fish has genetic characteristics so that it has a certain growth pattern and a certain maximum length. Fish growth is influenced by various factors, including age, sex, water conditions (including temperature), season, reproductive cycle, and population size [10]. The following is an illustration of the length and weight growth of the fish in a series of time.

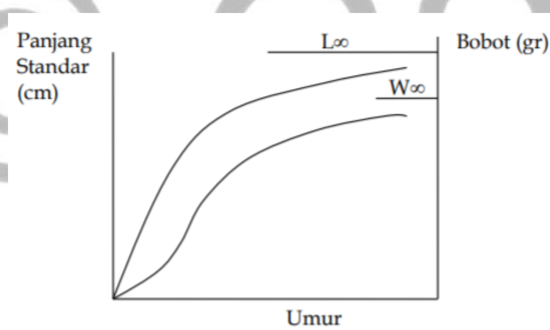

Figure 1. Fish Growth Graph [10]

This curve depicts the growth of fish from hatching to their maximum extent. Fish experience growth, both in weight and length, until they reach a certain maximum size limit, namely the length and weight of the infinity. Initially, fish grew slowly, because at that time they were still in the developmental phase of early life when growth was more focused on improving the body's organs. When the organs of the body are fully developed, the growth in length becomes rapid until maturity occurs. Furthermore, the amount of incoming energy is diverted from somatic tissue growth to gonad tissue growth. Although it is said that fish growth is unlimited, the growth rate is decreasing [9].

Fish Growth Model

Some of these alternative models can be an alternative reference for developing bioeconomic models of fish farming [16]. The model that produces the highest accuracy in terms of simulation results and empirical data can be chosen as the basis for developing a bioeconomic model of fish culture. Further description of some of these fish growth models can be seen in the following table:

Table 1. Fish Growth Model

Fish Growth Theory	Equation
Model von Bertalanffy	$W_t = W_\infty[1 - e^{-k(t-t0)}]^b$
Model Logistic	$F(W)=K(1 - W/W\infty)$
Model Gompertz	$F(W)=K(\ln W\infty - \ln W)$
Model Monomoleculer	$F(W)=K((W\infty/W) - 1)$
Model Richards	$F(W)=(1 - (W/ W\infty)^n)K/n$
Model Roff	$W_{t+1} = Wt + E - G_{t+1}$

Where: F (W) = growth as a function of fish weight (W), K = growth coefficient, n = constant, Winf = weight infinity, b = length-weight relationship exponential, t = time, to = hypothetical age, W = weight , E = energy availability (weight equivalent) and G = gonads [6].

Several studies that have studied the growth of living things using growth pattern models are described in the following table:

Table 2. Studies that study the growth of living things using growth pattern models

Species	Growth Curve Model	Method	Notable Findings	Authors
Mammals and birds	Von Bertalanffy, Logistic, Gompertz, Richards	The datasets are representative of 14 differents group of animals with the gain of body weight of with mature weights ranging from < 0.25 kg (Japanese quail) to > 1,000 kg (Holstein-Friesian bull)	In general, the Richards growth equation provided better fits to experimental data than the other models. However, for some animals, different models exhibited better performance.	Teleken *et al* (2017)
Diplodus annularis	Von Bertalanffy	Experimental fishing sessions were conducted at the Cabrera National Park located on the south coast of Mallorca Island	Conventional von Bertalanffy growth failed to fit the individual back-calculated lengths-at-age data well. A generalization of this model is proposed for accommodating one change in the growth rate at some moment of the lifespan of this species	Alos *et al* (2010)
Red, GIFT and Supreme Nile tilapia strains	Eksponensial Gompertz	Fish were cultivated in indoor recirculation systems in 0.5 m³ tanks with controlled temperatures of 22, 28 and 30°C. Random samples of 20 fish from each strain were weighed at day 7, 30, 60, 90 and 120.	Exponential model and Gompertz model were fitted and the estimates parameters were obtained by Weighted Least Squares. Temperature influences weight and age at the inflection point.	Santos *et al* (2013)
Fishes, crustaceans and molluscs	Von Bertalanffy, Logistic, Gompertz and Richards	16 data sets on wild and cultivated fishes, crustaceans and molluscs were used to test and compare conventional growth curves and a new growth mode	The poor statistical properties for estimation of conventional growth curves call for a critical reconsideration of their indiscriminate use to model growth of fishes, crustaceans and molluscs. The new model can be reliably used to analyze growth of organisms under a wide variety of situations and to derive statistical inferences of possible relations of its parameters with ecological or management variables.	Hernandez-Liamas *et al* (2004)
Tiger Prawns	Von Bertalanffy	Tiger prawns are kept in an aquarium measuring 50cm x 60cm x 40cm. Tiger prawns were reared in 3 treatments (15, 30 and 45). During the maintenance, measurements are made of the length and weight of tiger prawns. Measurements were taken every 2 weeks	Almost all errors or errors are close to 0.1 (both errors of biomass of tiger prawns are 15, 30 or 45), meaning that the error in the model data with the original data is small, so it can be said that the model data is close to the original data.	Sulanjari *et al* (2008)
White shrimp (P.	Gompertz, Von Bertalanffy,	Experimental observations of six initial densities (90, 130, 180, 230,	The modified von Bertalannfy function was the most effective of the three equations in	Araneda, Marcelo E

Species	Growth Curve Model	Method	Notable Findings	Authors
vannamei)	Pütter	280 and 330 shrimps m^2) in an intensive culture. Growth model (scenario of homogeneous sizes) and Growth model (heterogeneous size scenario)	predicting growth. The weight predictions, assuming homogeneity and variability of sizes, presented low Percentage Root Mean Square Errors (PRMSE). However, the inclusion of size variability in the fit produced better statistical results than when they were not included.	*et al* (2013)
White Shrimp (L. vannamei)	Logistic, von Bertalanffy	Cultivation harvesting is done in a partial way 2 times before total harvesting	Partial harvesting is able to show 78% more yields than a single harvesting system.	Alfan, Aris *et al* (2020)
White Shrimp (Litopenaeus vannamei)	Logistic model growth with the Bayesian hierarchy model approach	Shrimp growth function by relating average shrimp weight with age of shrimp, water temperatures, density, and feed supply. The data was provided by a commercial shrimp farming from 16 growout ponds of a commercial shrimp farm in Hawaii.	The Bayesian hierarchical model is found to fit the data better than the simple nonlinear model that neglects growth variability, with respect to the deviance information criterion, root mean squared error and mean absolute percentage error.	Yu, Run. *et al* (2010)

VANNAMEI SHRIMP GROWTH MODEL

Vannamei shrimp is called a superior variety because it is considered to have several advantages, namely, responsiveness to feed / high appetite, more resistance to disease attacks and poor environmental quality, relatively faster growth, higher survival rates than other shrimp, able to live with The stocking density is quite high and the maintenance time is relatively short, about 90-100 days per cycle [8]. Also, the Ministry of Marine Affairs and Fisheries (KKP) is targeting an increase in the value of shrimp exports in 2024 to reach 250%. To achieve this target, it is necessary to increase the export volume of cultured shrimp from 145,000 tonnes in 2018 to 363,000 tonnes in 2024. Knowing the growth model can be used as a basis for farmers' decision making to determine harvest time to obtain maximum biomass. Factors affecting growth are divided into internal and external factors. Internal factors that affect growth include genetic and physiological factors such as health levels, while external factors include feed, stocking density, and water quality. Based on the Table 2. It can be seen that the Logistic, von Bertalanffy, Gompertz, and Putter growth models can be used in vannamei shrimp culture.

The von Bertalanffy growth curve model is the most suitable model to represent growth rates with different initial culture densities[3]. The determination coefficients of homogeneous weight explained between 95% and 99% of the variation of the model for the observed values of weight. The mean square error (MSE) estimated values of 0.20–0.70 g, which in percentage terms represent prediction errors below 20% (8.6% and 16.3%). In each initial density, the percentage variation of heterogeneous growth explained by the model was between 70% and 97%. In the different treatments, the mean square error (MSE) produced values between 0.21 g and 0.67 g, which in terms of percentages meant prediction errors of less than 20% (between 4% and 12.5%). The growth rates of the model decreased with increasing initial density. The greater the density of fish we provide, the smaller the growth rate per individual [14]. With high density, it will cause limited space and lack of feed, as a result, competition between individual shrimp for food and oxygen will be tighter so that the shrimp growth process will slow down and even cannibalism occurs [1].

To anticipate the occurrence of food shortages and cannibalism, partial harvesting can be one solution. Partial harvesting is used to control shrimp biomass that does not exceed the carrying capacity of the pond environment and provides opportunities for lagging shrimp to grow better due to a reduction in cramming conditions and a reduction in waste load so that the shrimp live more comfortably [13]. Determination of the optimal partial harvest time in order to produce the greatest amount of biomass can be decided by knowing the growth curve model first. Based on the equation of weight, length, and biomass, it is found that the partial harvest biomass is 78% more than in a single harvest scenario[1]. Harvesting time in the first period is on the 33rd day with 81962 gr of biomass, the second period is the 21st day with 101464 gr of biomass, and the third period is 111359 gr. Whereas in single harvesting, optimal harvest time is on day 51 with only 165571.5 gr of biomass.

If we want to estimate the growth using limited observational data for each pond individually, it can be done by adjusting the growth curve and the data assuming the value of the growth function parameter is the same for all ponds. The Bayesian hierarchical model, as an alternative method for forecasting shrimp growth for commercial shrimp farms [17]. They tried to improve growth prediction by incorporating the across-ponds variability into the shrimp growth model. The value of root mean squared error of the Bayesian hierarchal model is 1.05 which is much smaller than the value of root mean squared error 1.11 of the simple nonlinear model. It means the Bayesian method is capable of improving the quality of growth prediction for shrimp aquaculture through incorporating the variability in growout ponds, using the hierarchical structure. As an illustration, the simple nonlinear model predicted a uniform weight of 4.27 g in the 3rd week, the predicted weights from the Bayesian hierarchical model vary from 3.02 g to

5.64 g with a mean weight of 4.32 g. Results from the Bayesian hierarchical model clearly exhibited growth variation in the growout ponds.

Conclusion

The von bertalanffy growth pattern model shows that harvesting done partially can produce the most optimal biomass, but the use of high initial stocking density can cause a decrease in growth. This model is considered to be the most suitable growth pattern model with an error rate of below 20%. But with the application of the Bayesian model the hierarchy of the model can give the standard error to be below 1.05%. The author suggests that shrimp farming entrepreneurs, especially those that produce their shrimp seeds, can make a growth standard curve based on the most suitable growth pattern model. This can help shrimp seed buyers to estimate the proper growth, biomass, and harvest time.

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