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Abstract. The research purpose was to develop a model bioeconomic of profit maximization that can be applied to red tilapia culture. The development of fish growth model used polynomial growth function. Profit maximization process used the first derivative of profit equation to time of culture equal to zero. This research has also developed the equations to estimate the culture time to reach the target size of the fish harvest. The research proved that this research model could be applied in the red tilapia culture. In the case of this study, red tilapia culture can achieve the maximum profit at 584 days and the profit of Rp. 28,605,731 per culture cycle. If used size target of 250 g, the culture of red tilapia need 82 days of culture time.

1. Introduction

Red tilapia (*Oreochromis* sp.) is one of the major aquaculture commodities in Indonesia. Red tilapia culture is the main production of red tilapia with several types of culture methods. Red tilapia could be cultured use cages, floating cages, ponds and brackish water ponds. Red tilapia is relatively easy to adapt to the aquatic environment. However, culture of red tilapia should be careful because red tilapia is classified an invasive species in Indonesia. The growth average of tilapia production (including red tilapia) in Indonesia was 21.41 percent per year in the period of 2010–2014.

Table 1. The progress of tilapia production in Indonesia [1].

Years	Tilapia Production (Tonnes)
2010	461,191
2011	567,078
2012	695,063
2013	924,772
2014	999,615

Red tilapia culture has a strategic role in fisheries development of Indonesia, so the study of optimization to red tilapia culture is important, including profit maximization. In this research, the optimization of red tilapia culture was focused on monoculture and intensive culture. Research to learn the profit maximization of red tilapia culture could use the bioeconomic approach.

Fisheries bioeconomic is a combination of fisheries biology and economics science. The function of fish growth and the fish stock could be estimated using fisheries biology. While the maximization of profit could be estimated using economics, especially microeconomics (profit maximization). Research

on aquaculture bioeconomics has been done by several researchers [2, 3, 4, 5, 6, 7]. Study of harvest optimization by [2], using the Beverton-Holt growth model and then further developed by [3, 5, 6]. A study of harvest time optimization using the von Bertalanffy growth model with the assumption of length exponent equal to three (isometric) [4, 7]. While this research using the polynomial growth model. The polynomial models have proven to be more accurate than the von Bertalanffy models in fish growth modeling [7, 12, 13].

2. Materials and Methods
This research object was focused on red tilapia culture to produce the fish consumption size. In this research, red tilapia growth model used polynomial function degree two for simplifying the model but still not ignoring the accuracy of the model. Stages of research have been including data collection and continued with data analysis using some of the equations described in the description below.

2.1. Data collection
This research used primary and secondary data. The primary data includes prices and costs by a survey to the red tilapia farmers in Magelang, Klaten and Wonosobo Regency. Secondary data includes statistical data and relevant references, including the biology of red tilapia.

2.2. Fish growth
The growth of red tilapia follows this polynomial equation:

$$W_t = at^2 - bt \tag{1}$$

Wt is the size of fish (g) at age t day, 'a' is intercept and 'b' is slope.

2.3. Costs, revenue and profit
In general, profit was the revenue minus cost. Revenue was influenced by the selling price and biomass of the harvested fish. Fish biomass was affected by the weight of individual fish and the number of fish still alive in the process of aquaculture. While the cost component includes the cost of seed procurement, labor costs, feed costs and procurement cost of facilities and production equipment. The cost component was converted to IDR per day. The quantity of artificial feed was influenced by food conversion ratio (FCR) and growth of fish biomass.

$$\pi = TR - TC \tag{2}$$
$$TR = Btb.Pi \tag{3}$$
$$Btb = Wtb.Ntb \tag{4}$$
$$Ntb = No - M.tb \tag{5}$$
$$TR = Wtb.Pi.(No - M.tb) \tag{6}$$
$$TC = Cp + Cb + Ctk + Cd \tag{7}$$
$$Cp = Pp.Qp \tag{8}$$
$$Qp = (Btb - Bo).FCR \tag{9}$$
$$Bo = No.Wtbo \tag{10}$$
$$Ctk = Ptk.tb \tag{11}$$
$$Cd = Pd.tb \tag{12}$$
$$tb = t - tbo \tag{13}$$

Notes:
- π : profit at tb (IDR per culture cycle)
- tb : culture time (days)
- tbo : age of fish at initial culture (days)
- TR : total revenue at tb (IDR per culture cycle)
- Btb : fish biomass at tb (g)

Wtb : fish weight at tb (g per ind)
Pi   : fish price (IDR per g)
Ntb : number of fish at tb (ind)
No   : initial number of fish (ind)
M   : average rate of mortalitity (ind per day)
TC   : total cost at tb (IDR per culture cycle)
Cp   : feed cost at tb (IDR)
Cb   : seed cost (IDR per culture cycle)
Ctk : labor cost at tb (IDR)
Cd   : depreciation cost of assets at tb (IDR)
Pp   : feed price (IDR per g)
Qp   : quantity of feed accumulation at tb (g)
Bo   : initial fish biomass (g)
Wtbo: initial individual fish weight (gram/ekor)
FCR: feed convertion ratio
Ptk : labor cost per day (IDR per day)
Pd   : asset depreciation per day (IDR per day)

2.4. Profit maximization

The first derivative of equation (2) to tb equal zero is be used to the profit maximization process as the first order condition or FOC ($d\pi/dtb = 0$) and the second order condition or SOC ($d^2\pi/dtb^2$) was negative. If we use equation (1) to (13), so could be solved the equation (14) and (15).

$$\pi = Btb.Pi - Cp - Cb - Ctk - Cd \tag{14}$$

$$\pi = g.tb^3 + h.tb^2 + i.tb + j \tag{15}$$

Notes:
$g = a. (Pp.FCR.M - Pi.M)$
$h = Pi.a.No + Pi.b.M + 2.Pp.FCR.a.tbo.M - 2.Pi.a.tbo.M - Pp.FCR.a.No - Pp.FCR.b.M$
$i = 2.Pi.a.tbo.No + Pi.b.tbo.M + Pp.FCR.a.tbo^2.M + Pp.FCR.b.No - Pi.a.tbo^2.M$
$\quad - Pi.b.No - 2.Pp.FCR.a.tbo.No - Pp.FCR.b.tbo.M - Pd - Ptk$
$j = Pi.a.tbo^2 No - Pi.b.tbo.No - Pp.FCR.a.tbo^2.No + Pp.FCR.b.tbo.No + Pp.FCR.Bo - Cb$

The first derivative to equation (15) could be solved the equation (16):

$$d\pi(dtb)^{-1} = 0 = 3.g.tb^2 + 2.h.tb + i \tag{16}$$

Then, equation (16) could be used to find the optimal of tb by use the quadratic solution [8]:

$$tb_{1,2} = \frac{-(2h) \pm \sqrt{(2h)^2 - 4.(3g).i}}{2.(3.g)} \tag{17}$$

$$tb_1 = \frac{-(2h) + \sqrt{(2h)^2 - 4.(3g).i}}{2.(3.g)} \tag{18}$$

$$tb_2 = \frac{-(2h) - \sqrt{(2h)^2 - 4.(3g).i}}{2.(3.g)} \tag{19}$$

2.5. The Target of fish size

In research, we also study about harvest size base on market demand. If the market demand size is set as Wt, so by using equations (1) and (3), we can modify the equation as follows:

$$Wtt = a\ (tbo + tbt)^2 - b.\ (tbo + tbt) \qquad (20)$$

Note:

Wt$_t$: target of fish size (g per ind)

tb$_t$: time culture to generate Wt$_t$

If Wtt could be found, so tbt also could be found. Equation (20) could be modified as follows:

$$Wtt = a.tbo^2 + 2.a.tbo.tbt + a.tbt^2 - b.tbo - b.tb \qquad (21)$$

$$0 = a.tbt^2 + (2.a.tbo - b).tbt + a.tbo^2 - b.tbo - Wtt \qquad (22)$$

$$tb_{t(1,2)} = \frac{-(2.a.tbo-b) \pm \sqrt{(2a.tbo-b)^2 - 4.a.(atbo^2 - b.tbo - Wt_t)}}{2.a} \qquad (23)$$

3. Results and Discussion

3.1. Estimation of growth function

In this research, fish growth function could be estimated using the growth data of red tilapia in table 2. The result of growth estimation can be seen in figure 1.

Tabel 2. The growth of red tilapia [7, 9].

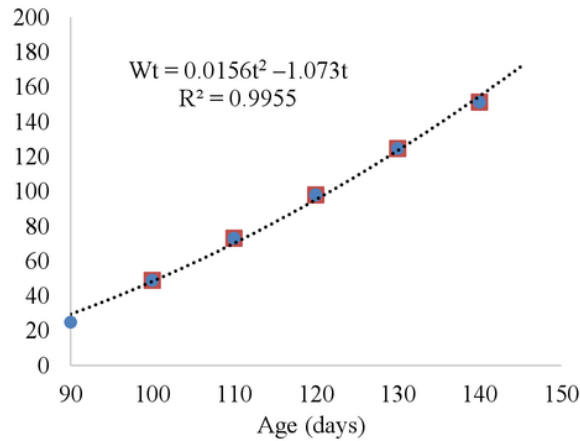| Age (days)	Individual weight (g)
90	24.83
100	48.97
110	73.10
120	98.00
130	124.67
140	151.30

Figure 1. The growth estimation of the red tilapia.

The estimation of red tilapia growth is follow this equation:

$Wt = 0.0156t^2 - 1.073t$

$R^2 = 99\ \%$

4

Subject to:

$Wt, t > 0$

$Wt \leq W_{inf}$

Winf (maximum weight) is 3,744 g, Linf (max length) was 60 cm, and the relationship of length and weight follows the equation *0.02042 $L^{2.96}$* [10, 11].

In this research, red tilapia proved to be growing rapidly. On the red tilapia culture with a harvest target size of 250 g, the red tilapia fish was in a fast growth phase, so the use of polynomial growth model in this research was relatively suitable. The growth of red tilapia was slowing as it toward the weight of infinity.

The growth of red tilapia was influenced by water quality, artificial feed, seed quality, fish density, the age of fish and gender. Male red tilapia grow faster than female red tilapia. Red tilapia fish culture using floating cages can result in faster fish growth compared to red tilapia culture using ponds. It was caused by an adequate supply of oxygen to the floating cages. Dissolved oxygen was required for fish metabolism, including to support the growth of fish [7].

3.2. Optimal profit

In the application, there are diversity of red tilapia culture depend on the behavior of fish farmers. Several assumptions were be used in this research as follows the table 3.

Table 3. Research assumptions.

Assumptions	Values
a	0.0156
b	1.073
Initial weight (*Wtbo*)	20 g
Seed age (*tbo*)	84 days
Initial number of seeds (*No*)	6,000 ind
Mortality rate (*M*)	6 ind per hari (SR of 120 days is 88 %)
Fish price (*Pi*)	Rp. 17,500 per g
FCR	1
Feed price (*Pp*)	Rp. 10,000 per g
Depreciation (*Pd*)	Rp. 42,000 per days
Labor wage (*Ptk*)	Rp. 7,000 per days

Note: USD 1 equal to Rp. 13,343 at 30 April 2017

Based on the simulation, it was estimated that maximum profit at 584 days of culture with profit per cycle of Rp. 28,605,731 for 6,000 seeds. However, Indonesia fish farmers have the limited capital, so it was difficult for the fish farmer to applied 584 days of culture.

Table 4. Optimal culture of red tilapia.

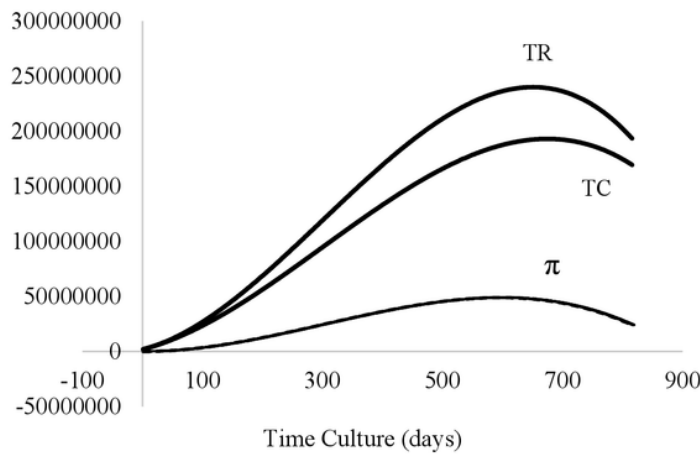| Notes	Values
Profit equation	$\pi = -0{,}47.tb^3 + 422.tb^2 - 3.164.tb$
The first derivative of profit equation ($d\pi/dtb = 0$) as FOC	$d\pi/d\,tb = -1{,}404.tb^2 + 843.tb - 3.164 = 0$
Optimal time of culture (tb) use equation (19)	597 days (t = 681 days)
The second derivative of profit equation ($d^2\pi/dtb^2 =$ negative) as SOC	$-2{,}808.tb + 843 = (-2{,}8080 \times 597) + 843 = -832{,}53$ (negative, proven)
The fish weight at optimal profit	6,504 g (SR 40 %)
The fish biomass at optimal profit	15,726,572 g or 15.7 tonnes
The maximal of fish biomass	15,995,762 g (SR 35 %; tb = 651 days, t = 735 days)

Figure 2. TR, TC and profit.

After reaching the maximum profit level, the red tilapia culture was still experiencing revenue growth. However, this revenue growth was smaller than the cost growth, so it caused a decrease in profits. We also applied this bioeconomic model to giant-gouramy and catfish culture [12, 13]. The giant-gouramy culture generated the maximal profit at 324 days and catfish (*Clarias* sp.) culture generated the maximal profit at 345 days.

3.3. Size of market

By applying equation (23), it could be estimated the culture time to produce a target of fish size. If the target size was 250 g, seed size of 19.9 g and seed age of 84 days, then the estimated culture time (tb_t) was 82 days (2.7 months). By using the equation (15), we could estimate the profit of Rp. 2,317,101 per culture cycle.

Fish farmers tend to prioritize faster turnover of capital with fewer profits than the maximum profits but slow in capital turnover. It caused by the limited capital of fish farmers and opportunity costs. If using 597 days of culture time to achieve the maximum profit, fish farmers will lose the opportunity to

take seven cycles of cultures with an assumption of culture time per cycle was 82 days. Fish farmers will also had difficulty selling fish in the local market with a size too large compared to the target size.

4. Conclusion

Based on this research, we proved that this model could be used to estimate the optimal time culture of red tilapia. The profit of red tilapia culture follow the equation: $\pi = g.tb^3 + h.tb^2 + i.tb + j$. While the culture time at optimal profit to follow the equation: $tb = (-(2h) - (2h)^2 - ((4.(3g).i)^{1/2}))(2.(3.g))^{-1}$. In case of this study, red tilapia culture can generate the maximum profit at 597 days, with a profit of Rp. 28,605,731 per culture cycle. Then if the target of fish size is 250 g, it takes 82 days culture time.

Acknowlegements

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