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The Production Model of Tilapia (*Oreochromis niloticus*) Cultivation with System Dynamics Approach

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Abstract

The purpose of this study was to determine the survival rate (SR), the Average Daily Growth (ADG), and the Feed Conversion Ratio (FCR) of Nile tilapia (*Oreochromis niloticus*) with a dynamic system model. The dynamic system model is used to determine the optimal value of the three variables. The results showed that the survival rate, average daily growth, and feed conversion ratio of tilapia cultivation were 93% (SR), 3.2gr/day (ADG), and 0.73 (FCR). In this research, tilapia production was 14,199gr, the amount of feed was 10.344 gr and the length of cultivation was 65 days. It was hoped that the dynamic system model design could have tilapia farmers develop aquaculture businesses that were more environmentally friendly, effective, and efficient.

INTRODUCTION

Nile Tilapia (*Oreochromis niloticus*) is a fast-growing, high stocking density, and salinity tolerant, and easily adaptive fish (Pervin *et al*., 2020). The Nile tilapia in Jayapura - Indonesia is a species that is widely consumed by the community and many traders of Java and Sulawesi to be traded. In Argentina, tilapia culture is still incipient but has great potential due to the great freshwater resources (Castellini *et al*., 2020). Grammer *et al*. (2012) said that the species is favored among aquaculturists due to its ability to tolerate a wide range of environmental conditions, fast growth, successful reproductive strategies, and ability to feed at different trophic levels. It is widely cultured in many tropical and subtropical countries of the world.

Herawati *et al*. (2015) stated that *O. niloticus* has excellent faster growth and tolerance even in bad environmental water conditions. The temperature of cultivation influences the description growth of Red, GIFT, and Supreme tilapia strains (dos Santos *et al*., 2013). Rapid growth rates, high tolerance to adverse environmental conditions, efficient feed conversion, ease of spawning, resistance to disease, and good consumer acceptance make it a suitable fish for culture (Mensah and Attipoe, 2013). Workagegn *et al*. (2014) said that variations in growth performance and feed utilization efficiency were caused due to differences in the quality of supplemental diets in terms of nutrient composition.

System Dynamics (SD) is an established discipline to model and

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simulate the complex dynamic system, the primary goal of SD is to evaluate and design new policies that can impact the system under study in the desired way (Schoenenberger *et al*., 2021). According to Sapiri *et al*. (2017), the main focus of system dynamics is to comprehend how the elements in a system interact with one another. System Dynamics modeling offers an approach to the explicit representation of the structure that leads to dynamic complexity (Yearworth, 2014). The System Dynamics approach focuses on how problem happens within the system because it favors an operational viewpoint (Martinez-Moyano, 2018).

System Dynamics modelling is a problem – oriented modelling approach pioneered by Jay Forrester in the late 1950's to help corporate managers better understand industrial problem (Forrester, 2012). System Dynamics were used in the present paper for analyzing the interrelations of the factors. Causal loop diagrams were developed based on a thorough literature review that were then transferred to stock and flow diagrams for the mathematical simulation (Alefari *et al*., 2020). The function of Causal Loop Diagrams (CLD) is to map out the structure and the feedbacks of a system in order to understand its feedback mechanisms (Haraldsson, 2018). Causal loop diagram were used towards the end of a study to represent and communicate the structure of the dominant loops that had been determined using simulation (Bureš, 2017).

The lack of management in aquaculture activities and the lack of scientific understanding of aquaculture in the community is a problem that occurs in Jayapura. The impact will result in aquaculture activities by the community being immeasurable. This situation will affect every aspect, namely the environmental aspect and the economic aspect. The purpose of this research is to obtain a design of a dynamics system model of tilapia cultivation and this dynamics system model of tilapia cultivation is a scientific novelty.

METHODOLOGY

Place and Time

This research was conducted from February to May 2021. The research was conducted in an aquaculture pond at the Faculty of Fisheries and Marine Science, Yapis University, Papua, Indonesia.

Research Materials

The devices and equipment used in the research were a pH Meter (Model pH-03, Changzhou, China), Refractometer (ZS-HT711ATC, Zhejiang, China), Aerator (Resun, LP-100, Guandong, China), DO Meter (LT Lutron DO-5510). The material used in the research was Feed Pellets (HI PRO-VITE 788) with 26 – 28% protein content and Tilapia Fish with a population of 60 individuals and an initial weight of 50 g/individual.

Research Design

Data collection in the field was data collection of aquaculture production. Production data was taken by recording the variables in the process of rearing tilapia. These variables include initial stocking density, final stocking density, amount of feed, initial biomass, final biomass, and duration of cultivation. The number of fish used in this study was 60 Tilapia and the number of fish used during the sampling process was 10 tilapia. The method of data collection was by doing the sampling method.

We used to catch tilapia then the fish was measured to fill in the values of predetermined variables. The purpose of taking the data was to determine the production result during rearing tilapia with 3 benchmarks, namely Survival Rate (SR), Feed Conversion Rate (FCR), and Average Daily Growth (ADG).

Work Procedure

The process of Tilapia cultivation was carried out with the following step: First, preparation of aquaculture ponds. Ponds preparation includes cleaning aquaculture ponds, filling water, and installing aerators. Second, stocking tilapia seeds.

Stocking of tilapia seeds was carried out when pond preparation has been carried out. Before stocking, acclimatization treatment was applied to tilapia. Acclimation is a key technology involved before stocking transported post-larvae into the culture pond (Sebastian *et al.*, 2021). Third, the tilapia rearing process. The process of rearing tilapia was carried out for 3 months and sampling of tilapia was carried out every week to determine the development of tilapia. Several variables were measured at the time of sampling tilapia, namely fish weight and fish length to determine the average daily growth (ADG) and feed conversion ratio (FCR). Then, sampling the number of dead fish. This was done to determine to survival rate (SR).

Feeding management was carried out during the enlargement process according to the feed percentage method. Feeding management was a way to regulate the diet of fish by consuming fish feed. As for the feed management applied, namely determine the time of feeding per day. Determination of feeding time per day was done by looking at the behavior of fish in consuming feed. After that, the amount of feed given per day was determined by connecting the feeding rate with tilapia biomass. Determination of the feeding rate based on 2 phases, namely the initial phase of tilapia cultivation by 50% (day 1 to the middle of the tilapia cultivation process cycle) and the final phase of tilapia cultivation by 10% (Mid-cycle of tilapia cultivation to the end of cultivation). Fourth, tilapia production. Tilapia production was carried out by taking into account the SR, ADG, and FCR during the tilapia (*O. niloticus*) rearing process.

Data Analysis

The data analysis used in this research was quantitative analysis and qualitative analysis. Quantitative analysis was presented in the form of calculation, table, graph, and picture. Qualitative analysis was carried out with a descriptive approach which was a method or a system of thought. The purpose was to make a descriptive, factual, and accurate description of the facts of causality. Qualitative analysis used dynamic system analysis by Stella Software. The following formulation in analyzing production, namely:

$$FCR = \frac{F}{(Wt+D)-W0}$$ (Augustine *et al.*, 2020)

Where:
FCR = Feed Conversion Ratio
Wo = Weight of animal tested (g)
Wt = Weight of animal tested at the end of study (g)
D = Total Weight of dead Fish (g)
F = Amount of Feed (g)

$$SR = \frac{Nt}{N0} \times 100\%$$ (Stejskal *et al.*, 2021)

Where:
SR = Survival Rate (%)
No = Number of Species at the beginning of the cycle
Nt = Number of Species at the end of the cycle

$$ADG = \frac{(ABW2-ABW1)}{\text{1st and 2nd sampling period}}$$ (Kurniawan *et al.*, 2014)

Where:
ADG = Average Daily Growth (g)
ABW_1 = Initial Weight (g)
ABW_2 = Final Weight (g)

Dynamic System Approach

Model development was done using a dynamic system approach. System Dynamics modeling offers an approach to the explicit representation of the structure that leads to dynamic complexity (Yearworth, 2014). For this reason, STELLA™ Software was used in this research. The conceptual model was made and then translated into a dynamic system model (Stella™) through Stock and Flow maps.

RESULTS AND DISCUSSION

Causal Loop Diagram(CLD)

The causal loop diagram of tilapia cultivation was presented in Figure 1.

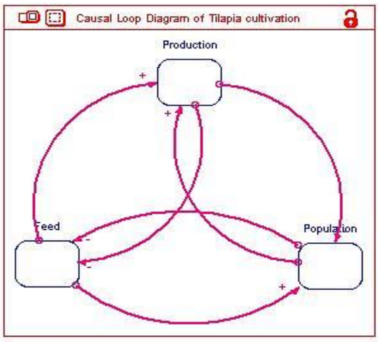

Figure 1. Causal Loop Diagram (CLD) of tilapia cultivation.

The result of this study obtained a causality in a dynamic system model which shows that three variables influence tilapia cultivation, namely production variable, feed variable, and population variable. The causality model that has been obtained is a rationale. Furthermore, the rationale was developed to obtain an aquaculture model for tilapia. Figure 1 explained that there was a visible relationship between variables and influences each other.

Relationship between population and feed, the increase in population will affect the amount of feed, namely the feed reduced (-) and the available feed will increase the population (+). Relationship between feed and production, the increasing feed will have an impact on increasing production (+) and conversely increasing production will reduce feed availability (-). Furthermore, the relationship between production and population. Increased production will result in a reduced population (-), this was due to food competition for growth. And if the population increase, production will also increase (+).

The function of Causal Loop Diagrams (CLD) is to map out the structure and the feedback of a system to understand its feedback mechanisms (Haraldsson, 2018). The CLDs comprise variables connected with arrows representing causal relationships (Dhirasasna and Sahin, 2019). Causal loop diagrams (CLDs) constitute a schematic description of the considered system depicting its components and the (Causal) relations between them (Strelkovskii and Rovenskaya, 2021). The quantitative modeling in the next stage of research will be conducted to estimate the parameters in a comprehensive and update causal loop diagram and stock and flow diagram, rum simulation of the parameters to get the similar behavior of the reference model, conduct sensitivity analysis, and finally test the impact of policies/variables on the future growth of the industry (Xia *et al*., 2021).

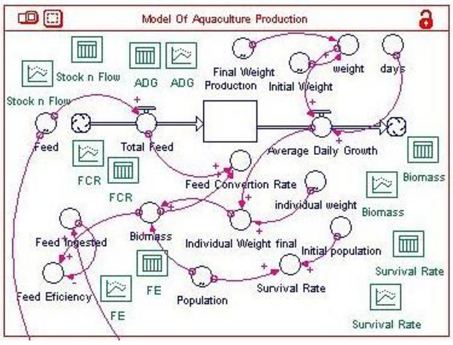

Figure 2. Aquaculture production model of tilapia.

The picture above is a production model for tilapia fish. The dynamic system model that has been formed is a development of the causal loop diagram

(CLD) of tilapia (*O. niloticus*) cultivation that has been made previously. We made a causal loop diagram of tilapia cultivation as the basis for our thinking in developing a dynamic system model for tilapia cultivation.

In Figure 2, the total feed is an input, Average daily growth (ADG) represents the output and several sub-variables affect inputs and outputs to produce optimal aquaculture production. As for the sub-variables that affect the input and output, namely the amount of feed given, final population, initial population, biomass, initial weight, final weight, and the total days the aquaculture process takes place.

Average Daily Growth (ADG)

The results of the average daily growth of tilapia were presented in Figure 3 and Table 1.

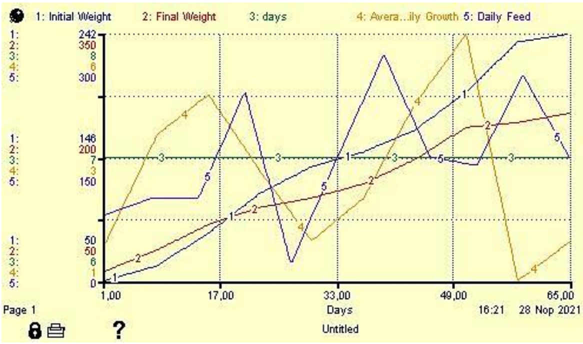

Figure 3. Average daily growth graph pad.

Table 1. The average daily growth value during tilapia cultivation.

Days	Individual Weight (g)	ADG (g)
1-9	50 – 64.9	1.9
10-16	64.9 - 95,7	4.4
17-23	95.7 – 134.8	5.6
24-30	134.8 – 141.8	1
31-37	141.8 – 161.6	2.8
38-44	161.6 – 181.7	2.9
45-51	181.7 – 235.8	7.7
52-58	235.8 – 240.6	0.7
59-65	240.6 – 253.6	1.9

As for the average daily growth results in different tilapia, the production system model in Figure 2 shows that the daily feeding input affects the average daily growth of tilapia. This causes the average daily growth value of tilapia to be different from the first day of the cultivation process to the last day of the cultivation process. According to Suwardi and Suwoyo (2012), the growth that occurs in fish is influenced by internal and external factors. An increase in biomass was feeding which was converted into fish biomass (Widyatmoko *et al*., 2019). Growth occurs when there is a surplus input of energy and amino acids (proteins) derived from feed (Rostika *et al*., 2017).

Survival Rate (SR)

The results of survival rate of tilapia were presented in Figure 4 and Table 2.

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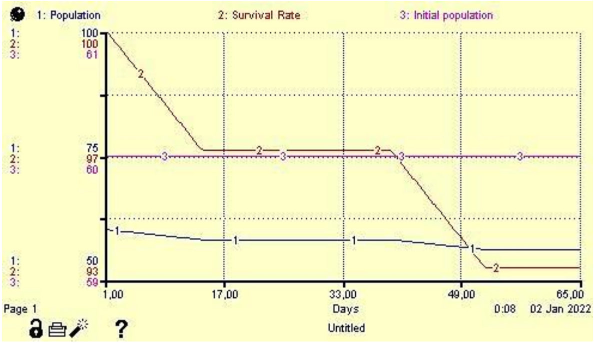

Figure 4. Survival rate graph pad.

Table 2. The survival rate during tilapia cultivation.

Days	Population	Survival Rate (%)
1 – 6	60	100
7 – 13	59	98
14 – 19	58	97
20 – 26	58	97
27 – 32	58	97
33 – 38	58	97
39 – 45	58	97
46 – 51	57	95
52 – 58	56	94
59 – 65	56	94

The survival rate results indicated that tilapia had a good level of tolerance and adaptation to the environment. According to Nurazizah *et al.*(2021), the temperature below 24 °C is too cold, which may cause the fish seeds to fail to adapt and many died at the beginning of stocking.

Feed Conversion Ratio (FCR)

The results of the feed conversion ratio were presented in Figure 5 and Table 3.

Table 3. Feed conversion ratio during tilapia cultivation.

Days	Amount of feed (g)	Biomass (g)	FCR
1	80	3,000	0.03
7	558	3,609	0.15
14	1,426	5,040	0.28
20	2,853	6,845	0.41
27	4,071	8,048	0.51
33	5,216	8,714	0.55
39	6,496	9,704	0.67
46	7,446	11,236	0.66
52	8,551	13,241	0.65
59	9,894	13,575	0.73
65	10,344	14,199	0.73

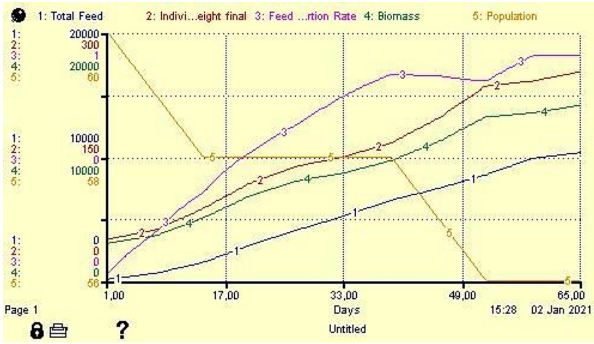

Figure 5. Feed conversion ratio graph pad.

Figure 5 illustrated that the FCR value increases from the first day of the cultivation process to the last day of cultivation. This was also influenced by the value of biomass and the amount of feeding which also has a perpendicular (Linear).

In Figure 5 of the dynamic system, increasing the amount of feed was followed by an increase in biomass, the statement would affect the FCR value. The FCR value on the last day of the cultivation process was 0.73. This indicates that there was management in feeding which caused the amount of feed to be very efficient. The lower the feed conversion value, the more efficient the fish is in utilizing the feed they consume for growth so that the fish's body weight increases because the feed can be digested optimally (Nurazizah *et al*., 2021).

The ability to convert feed intake into body weight gain can be measured by the feed conversion ratio (FCR) which is the ratio between feed intake (FI) and body weight gain (BWG) over a given period (Rodde *et al*., 2020). Improving the ability of cultured fish to convert feed intake into biomass could play a significant role in reducing feed use in aquaculture and improving its sustainability through reduced costs and environmental impacts (Besson *et al*., 2014). The management of feeding regimes during the growth process of fish can reduce feed consumption and its costs (Poot-López *et al*., 2020).

CONCLUSION

The final result obtained during the rearing period were 94% survival rate, 3.2 g Average Daily Growth, and 0.73 Feed Conversion Ratio. Then, a dynamic model system design was obtained in the development of tilapia cultivation, which was a system that connects several variables in the production aspects of tilapia. The production aspects were average daily growth, survival rate, feed conversion ratio, and several sub-variables namely total daily feed intake, biomass, population, initial weight and final weight. It was hoped that the dynamic system model design could help farmers to develop aquaculture businesses that more environmentally friendly, effective, and efficient.

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