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Characteristics of Using Feed Impact on Tilapia (*Oreochromis niloticus*) Culture Using a Dynamics System Approach

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Abstract

Feed was the most important part of aquaculture. Not only affecting growth, but the feed also impacted the cultivation environment. Poor feeding management in the use of feed will harm the cultivation process. The purpose of the research was to create a dynamic system model. In the model a systemized algorithm was structured that would assist cultivators in carrying out aquaculture activities and with this model, problems that occurred were immediately resolved. The dynamic system model was the method used in this research. This model was used to determine the optimization of feed use based on several variables that support the process of using the feed. In this research, the production of *Oreochromis niloticus* was 14 kg, and the amount of feed used was 10 kg, which affects the increase in the amount of organic matter, which was 3626.4 g (total feces + uneaten feed) in 65 days of cultivation period. The result showed that the total feed was connected with organic waste, namely total N, total P, total feces, and total uneaten feed. The results obtained from this research were then poured into a dynamic system and the results were found, namely the relationship between feeding and organic waste, namely linear or perpendicular. The design of this dynamic system model was expected to enable tilapia cultivators to develop aquaculture businesses that were more environmentally friendly, effective, and efficient.

INTRODUCTION

The Nile tilapia (*O. niloticus*) in Jayapura - Indonesia was a species that is widely consumed by the community and many traders of Java and Sulawesi. Tilapia

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farming was one of the most popular activities in Jayapura. In Bangladesh aquaculture practice is expanding very rapidly due to meeting the increasing demand for fish (Pervin *et al*., 2020). Nile tilapia culture in earthen ponds in Thailand is expanding (Sriyasak *et al*., 2015). 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. (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.

Besson *et al*. (2019) restrict the feeding rate to 50% of the optimal feeding rate. 100% of feed was given to fish, 10% was uneaten feed, 10% was solid waste, 30% was liquid waste produced by fish and the remaining 25% was used for growth, and the other 25% for metabolism (Setiawan *et al.*, 2016). Bambaranda *et al*. (2019) stated that aquaculture effluents originate from pond fertilization, feed, and metabolic processes. Global population growth and increased food consumption have led to questions regarding the environmental sustainability of the food production system (Fialho *et al*., 2021). This situation would have an impact on environmental conditions, if good management was carried out, it would have a good impact on the environment.

Pattillo *et al*. (2020) said that aquaculture production systems are typically designed to process waste. Nitrogenous compounds accumulated in aquaculture systems have a lethal effect on aquatic animals especially when they are reared at higher stocking densities (Preena *et al*., 2021). A sustainable aquaculture with effluents of low environmental impact (Sadeghi-Nassaj *et al*., 2018). Disposal of waste with a high polluting capacity threatens the growth of the species (Coldebella *et al*., 2018). Waste resulting from the aquaculture process was a factor that could affect the environment. Minimal or unavailability of waste in waters could also be a problem. Otherwise, the abundance of waste concentrations could also damage the aquatic environment. The problem experienced by cultivators in Jayapura was the lack of knowledge about cultivation management which results in increased waste production that could also directly affect aquaculture production, namely the growth and survival rate of the species that were cultivated.

System Dynamics (SD) is an established discipline to model and simulate complex dynamic systems, the primary goal of SD is to evaluate and design new policies that can impact the system under study in a desired way (Schoenenberger *et al*., 2021). A previous study said that the main focus of system dynamics is to comprehend how the elements in a system interact with one another (Sapiri *et al*., 2017). Made a causal loop diagram of tilapia cultivation as the basis for thinking in developing a dynamic system model for tilapia cultivation (Kurniawan *et al*., 2023). 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 problems happen within the system because it favors an operational viewpoint (Martinez-Moyano, 2018). System Dynamics modeling is a problem–oriented modeling approach pioneered by Jay Forrester in the late 1950s to help corporate managers better understand industrial problems (Forrester, 2012).

System dynamics were used in the present paper for analyzing the interrelations of the factors. Causal loop diagrams

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were developed based on a thorough literature review that was then transferred to stock and flow diagrams for the mathematical simulation (Alefari *et al*., 2020). The function of CLD is to map out the structure and the feedback of a system to understand its feedback mechanisms (Haraldsson, 2004). The causal loop diagram represents how a system works (Kiani *et al*., 2009). The dynamic system approach was used as a method of overcoming the problems experienced. In this approach, each variable from aquaculture activity would be linked and a causal loop would be formed.

This model would describe a causal relationship. Then, the model was also supported by quantitative results that strengthen the causal relationship that had been obtained. The purpose of this research was 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

Ethical Approval

This research was approved by The Research and Community Service Institute, Yapis University of Papua. The use of the species was approved by The People's Hatchery Unit under The Maritime Affairs and Fisheries Service, Keerom Regency, and has fulfilled the guidelines for the maintenance of cultivated species from The Fish Hatchery Office, Marine and Fisheries Service, Jayapura City. Furthermore, after the research is complete, the species will be handed over to the Faculty of Fisheries and Marine Science, Yapis University of Papua to be maintained.

Place and Time

This research was conducted from February to August 2022. The research was conducted in the Faculty of Fisheries and Marine Science aquaculture ponds, Yapis University, Papua, Indonesia.

Research Materials

The materials used in the research were Feed Pellets Hi Pro Vite F999 which was produced by PT. Central Proteina Prima with a protein content of 35% was used for rearing age 1 – 20 days and the nature of the feed was floating fish feed. After that, the Hi-Pro Vite 788 pellet feed produced by PT. Central Pangan Pertiwi to the time of production and the properties of the feed, namely floating fish feed and the Tilapia used came from The People's Hatchery Unit, Maritime Affairs and Fisheries Service, Keerom Regency with the number of fish stocked which was 60 and had sizes 5 – 7 cm; individual weight 50 g.

Research Design

Data collection in the field was data collection of aquaculture production and feed. 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 and the data collection method used was the sampling method. The purpose of taking the data was to determine the production result during rearing tilapia with 3 benchmarks i.e., Survival Rate (SR), Feed Conversion Ratio (FCR), and Average Daily Growth (ADG).

The feed data was taken to analyze the impact of the feed on the environment. The data was the nutritional composition of the feed, the amount of feed given every day and the total feed given during the tilapia culture process. From these data, it could be seen the impact of feeding on the environment.

Work Procedure

The research procedure began with the culture process with tilapia. Then, the amount of feed with a protein content of 26 – 28% given was adjusted for the tilapia biomass and feeding rate. After getting the amount of feed to be given, then the feed was given to the species being cultivated

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through the specified amount of feed divided by the frequency of feeding. The frequency of feeding was 3 times per day, i.e., 07.30; 15.30; 19.00. El-Hack *et al*. (2022) said that the feeding frequency is three times a day. The feeding process was carried out by spreading the feed evenly and sampling tilapia every 10 days to obtain biomass. Using the aerator only at night was done because at night there was a deficit of oxygen. After the data had been collected, then the data was converted to dynamic system modeling using STELLA™ software for analysis.

Feeding per day was carried out per day based on observations of the behavior of fish in search of food. All the feed that was given during cultivation would be calculated. Furthermore, this data was used to analyze wasted feed and feed consumed by tilapia. Then, the feed consumed will be analyzed to see if the feed was absorbed by the fish's body and wasted through the feces. All variables would be analyzed to obtain causality through a dynamic system approach. To overcome the accumulation of organic waste in aquaculture ponds, a siphoning process and regular water changes were carried out.

Data Analysis

The data analysis used in this research was quantitative analysis and qualitative analysis. 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 analysis of feeding refers to the percentage of feed that relates the biomass to the feeding rate. The feeding rate was adjusted to the age of tilapia during the enlargement process for tilapia culture. The following was the formula for analyzing feed conversion data, namely:

$$\mathrm{FA} = \mathrm{FR} \times \mathrm{B}$$

Where:

FA = feed amount (g)
FR = feeding rate (%)
B = biomass (g)

$$\mathrm{FCR} = \frac{\mathrm{F}}{(\mathrm{Wt} + \mathrm{D}) - \mathrm{W0}}$$

FCR = feed conversion ratio
W0 = initial fish weight (g)
Wt = final fish weight (g)
D = total weight of dead fish (g)
F = feed amount (g)

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 through Stock and Flow maps. The use of this dynamic system aims to detect a causal relationship between several variables that contribute to each other in aquaculture production and waste production in tilapia aquaculture processes. Then, a simulation was then carried out to find out the real situation in the field. Dynamic systems provide an effective way of modeling, simulating, and studying complex systems.

The theory of system dynamics gives the fundamental guidelines to structure the model that describes the system through the employment of feedback loops, stocks, and flow (Bottero *et al*., 2020). Dynamic system models are not data-focused in the statistical sense of the word, but they describe the mechanisms of the system studied (Roppolo *et al*., 2015). Koot and Wijnhoven (2021) described that small changes in the system can have a marked effect, whereas large stimuli do not always cause drastic changes. A preliminary system dynamic model is developed to understand and analyze the implementation dynamic of key productivity factors affecting productivity in manufacturing industries (Kamble and Wankhade, 2021).

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RESULTS AND DISCUSSION

Organic Waste Causal Loop Diagram (CLD)

A Causal Loop Diagram (CLD) was a causal relationship that influenced each other and formed a system model. CLD constitute a schematic description of the considered system depicting its components and the (causal) relations between them (Strelkovskii and Rovenskaya, 2021). Developing CLD involves identifying stakeholders and endogenous variables and formulating variable causal relationships (Dhirasasna and Sahin, 2019). Figure 1 was a CLD that explained a systematic scheme of the impact of using the feed on tilapia culture.

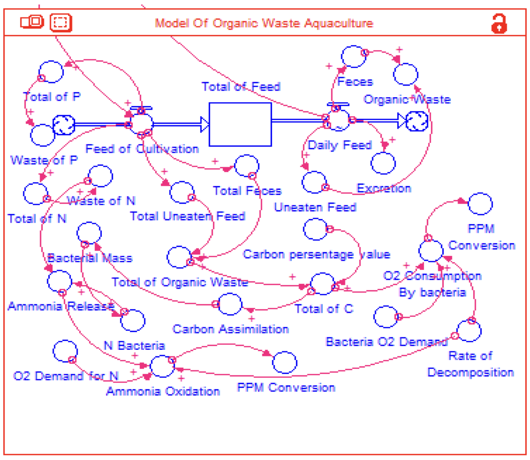

Figure 1. Organic waste model of tilapia cultivation.

Figure 1 was a dynamic system model that forms a systemized thinking algorithm and this was the result of data analysis using Stella™ Sofware. The padlock, the box on the top left, and the belt was pictures of the Stella™ Sofware. Which for locks, describes the system that can be locked or unlocked by the creator of the dynamic system model. Then, the box on the top left was the part that was used to block all variables. Meanwhile, the belt was a part that serves to hide the model.

In the CLD model above, there was a causal relationship for each variable to form a modeling system. In the above model, the results obtained were that feed was the main factor in waste production in tilapia (*O. niloticus*) aquaculture activities. This was illustrated in the model because the feed given to the species will increase the waste of P, waste of N, Total uneaten feed, and Total feces. The increase in organic matter was indicated by (+). Furthermore, in the above model, the increase in organic matter, results in an increase in the total C in the culture ponds. In the model that has been made, the results also explain that the increase in organic matter increases the need for oxygen which was used to decompose organic matter by aerobic bacteria.

Kurniawan *et al.* (2023) show that one of three variables that affect tilapia cultivation was the feed variable. Thus, if the feed variable was not managed properly, it will result in the accumulation of organic matter in the culture ponds. Furthermore, Stocking density was also a factor in determining the amount of feed to be given to the culture species. According to Prüter *et al.* (2020), the stocking density influenced feed input. In addition, the feed also serves to increase growth. If mishandled feeding of fish, it will have an impact on environmental conditions and growth. Fish farms generate nutrients and organic matter, consisting of metabolic products, feces, and uneaten feed, which have the potential to modify the bottom environment (Ji *et al.*, 2021). The

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nutrients for the plants come from compounds excreted by the fish as a product of their metabolism and from the bacterial decomposition of organic waste (feces and uneaten feed).

In addition to maintaining environmental conditions to remain stable and to increase growth, the feed was also one of the factors in cultivation that incur the largest production operational costs in 1 cycle of cultivation. According to Salger *et al*. (2020), feed is a major expense in aquaculture, comprising up to 50 – 70% of the total production cost for tilapia. Accumulation of organic matter in both farming and adjacent waters should be prevented because it can bring about a series of harmful issues including oxygen depletion, eutrophication, and toxicity of ammonia and nitrite. Therefore, real–time detection and monitoring of uneaten feed can effectively reduce the occurrence of overfeeding (Hu *et al*., 2021). For the detection of excess feeding, it is necessary to determine the behavior of fish in the cage during the feeding process (Parra *et al*., 2018).

The feed wasn't only used for the production of tilapia but also produced organic waste as previously explained. In the model above, the organic matter derived from the feed given to the species in cultivation was described, and divided into several parts, namely uneaten feed and total feces which were the results of metabolic activity in the fish's body. Then, the total feces and uneaten feed by fish settle at the bottom of the waters into waste which would damage the cultivation environment. Setiawan *et al*. (2016) explained that of the 100% of feed was given to fish, 10% was uneaten feed, 10% was solid waste, 30% was liquid waste produced by fish and the remaining 25% was used for growth, and the other 25% for metabolism. The majority of this waste will, depending on bottom topography and ocean currents, slip through the open–cage net pens and accumulate in sediments beneath the fish farm (Olsvik *et al*., 2019). Uneaten feed, feces, and death of phytoplankton are the main element in the formation of organic matter in the rearing waters (Jefri *et al*., 2020).

The amount of feeding given to the species would have a negative impact, namely the accumulation of organic waste. From the organic waste model discussed earlier, total N, P, and C were obtained. Then, the total N, P, and C were then separated to obtain the retention and waste value of N, P, and C. The models above obtained and described the causal relationship between total feed and concentration of N, P, and C. The waste from feed and feces containing nitrogen and phosphorus can decrease fertility and the feasibility of water quality (Marda *et al*., 2015). The regulation defines much more N and P concentrations and the threshold N:P ratio at which eutrophication occurs, but there is no clear information on the P:N ratio (Diatta *et al*., 2020).

From the above model, total C derived from total organic waste would be assimilated by heterotrophic bacteria while releasing N and P into the waters. This is in accordance with the explanation of Letscher *et al*. (2015) which explained that remineralization of DOM in the ocean's interior is carried out by heterotrophic microbes, respiring C while releasing inorganic N and P nutrients back into the water column. The process took place causing the growth of phytoplankton to increase (bloom). Organic matter input from feed and waste is high, resulting in high concentrations of phytoplankton; which consume a lot of oxygen at night (Sriyasak *et al*., 2015). Nitrogen (N) and Phosphorus (P) are critical elements that control primary production in large portions.

Feed of Tilapia Cultivation

Feed was the most important part of aquaculture and besides affecting growth, the feed also had an impact on the cultivation environment. Alemayehu *et al*.

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(2018) said that aquaculture feeds are formulated to the nutritional needs of the species being cultured, including maintaining a highly effective natural immune system and growth. The output of the Daily feed of tilapia culture would be explained in Figures 2 and 3 as follows.

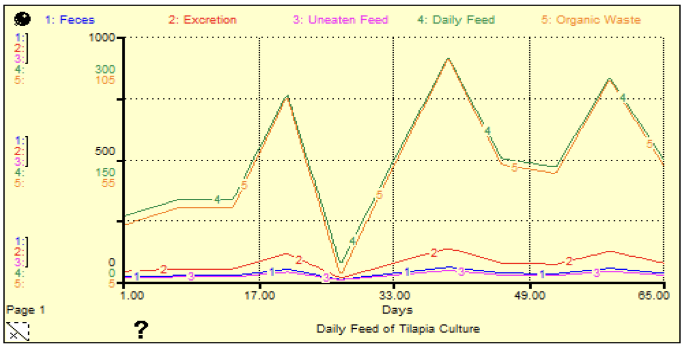

Figure 2. Daily feed of tilapia culture.

The picture above was a graph of the dynamic system model. The X-axis was Days, while the Y-axis was the related variables (Feces; Excretion; Uneaten Feed; Daily Feed; Organic Waste). The reason the Y-axis was not displayed on the left side of the graph was that the values and units of each variable were different. To distinguish the five variables above, Stella™ Software provided a sign that was a different color. Which, each color represents the variable in question.

The graphic figure above explains the condition of the organic matter found in tilapia fish farming ponds. This condition comes from the amount of daily feed given to the species being cultivated. The amount of feed given every day, in addition to producing growth, the feed given can also produce organic waste. In the figure above, you can see a graph of the daily feed given on the first day, the graphs look up which means the amount of feed given has increased. This was because the fish that was kept was still small and their immune level was still low they must always be given food according to their body weight and fasting is not permitted. It is at this time that the FCR value will increase.

Then on the 20th day, the amount of feed would be reduced because the condition of the tilapia is growing and the immune condition of the tilapia was quite good. For the detection of excess feeding, it is necessary to determine the behavior of fish in the cage during the feeding process (Parra *et al*., 2018). This was done to reduce the FCR value, which increases at the beginning of the ongoing cultivation process. On the 20th day until the end of the cultivation process, the feed treatment given must refer to growth and FCR values. This was done because it was not only growth that was prioritized but also the FCR value that must also be adjusted. So, on the 20th day until the completion of the cultivation process, feeding arrangements were made by looking at the biomass and the condition of tilapia.

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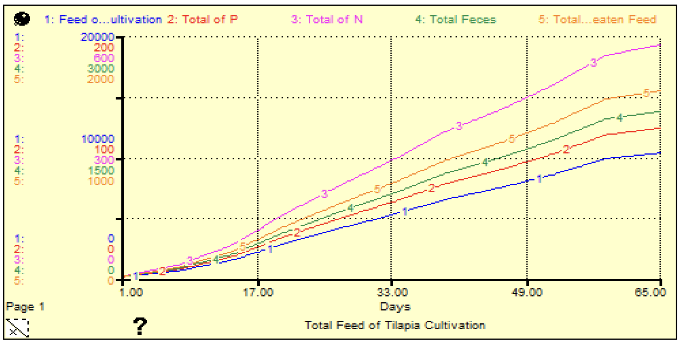

Figure 3. Total feed of tilapia cultivation.

The picture above was a graph of the dynamic system model. The X-axis was Days, while the Y-axis was the related variables (Feed of Cultivation; Total of P; Total of N; Total Feces; Total Uneaten Feed). In contrast to the daily feeding that has been described previously, Figure 3 above was the total feeding during the tilapia cultivation process. In total feeding, here would add up the feed that has been given per day until the last day the cultivation process takes Table 1. Then, the total feed was connected with organic waste, i.e., total N, total P, total feces, and total uneaten feed.

The results obtained from this research were then poured into a dynamic system and the results were found, namely the relationship between feeding and organic waste, namely linear or perpendicular. Where, the more feed given, the more organic waste in the waters and this would have a bad impact on the environment if not managed properly. Good management is needed to get good growth with nutritional intake and on the other hand it will damage the environment. So, there must be good management.

Table 1. Total feed value during tilapia cultivation.

Days	Total Feed (g)	Feces (g)	Uneaten Feed (g)	Total N	Total P	Waste N	Waste P
1-9	608	121.6	91.2	34.0	7.3	22.9	6.1
10-16	1909	381.8	286.4	106.9	22.9	71.9	19.0
17-23	3497	699.4	524.6	195.8	42.0	131.7	34.8
24-30	4071	814.2	610.7	228.0	48.9	153.4	40.5
31-37	6021	1204.2	903.2	337.2	72.3	226.8	60.0
38-44	7076	1415.2	1061.4	396.3	84.9	266.6	70.5
45-51	8411	1682.2	1261.7	471.0	100.9	316.9	83.8
52-58	9644	1928.8	1446.6	540.1	115.7	363.3	96.1
59-65	10344	2068.8	1551.6	579.3	124.1	389.7	103.0
Total	10344	2068.8	1551.6	579.3	124.1	389.7	103.0

Table 1 above shows the total amount of feed, which was 10,344 g, which affects the increase in the amount of organic matter, which was 3,626.4 g (total feces + uneaten feed). With so much waste production, this will have an impact on the environment. By accumulating organic waste due to the amount of feed given, it is necessary to provide oxygen. In addition to providing oxygen for the respiration process in the species being kept, which functions to carry out the nitrification process. Aeration aims to degrade organic matter found in waters (Kurniawan *et al.*, 2021). The biological process occurs naturally in environments such as surface water, but it requires sufficient dissolved oxygen to degrade organic matter (Gnowe *et al.*, 2020). Which is the

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composition of organic matter regulated by oxygen (Buda *et al*., 2021).

CONCLUSION

The results of the design of the dynamic system model provide a systematic picture of causality. From the design model, the feed given influences the environment, i.e., organic matter produced from tilapia aquaculture activities. The amount of feed given was directly proportional to the total N and P, total feces, and uneaten feed. Feed management must be carried out to minimize the increase in organic matter. The dynamic system approach for tilapia was very good for aquaculturists to be able to manage feeding in aquaculture activities.

CONFLICT OF INTEREST

The authors declare there is no conflict of interest.

AUTHOR CONTRIBUTION

Ade Kurniawan and Abdul Gani contributed as drafters for the technical, methodology, data analysis, and primary and secondary data collectors in the fields; Endang Muhammad contributed as drafters for the management section collected primary and secondary data in the field; George M. Numberi, Endang Y. Papare, Asti, Otto Sada contributed as policy drafters to the government regarding research results and provided cultivator data as well as primary and secondary data collectors in the fields.

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