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OPTIMIZATION OF WHITELEG SHRIMP INTENSIVE PONDS PRODUCTION WITH DYNAMIC SYSTEM APPROACH OF LEMAH KEMBAR VILLAGE PROBOLINGGO EAST JAVA

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ORIGINAL ARTICLE

ABSTRACT: *The aims of this research was to assess the activities of that occur in ponds culture production intensive vanname shrimp in Lemah Kembar village, Sumberasih, Probolinggo regency, is based of production aspects. In this research, shrimp production was 4182.9 kg/plot, with a cultivation period of 98 days, the amount of 5621.5 kg of feed, with the results of analysis of aquaculture production as follows: Feed convention rate 1.34, Survival rate 75%, Specific growth rate 0,22 gram/days, Final weight 19.23 grams/individuals and 68% Feeding efficiency. The current research conducted a review on the process of intensive shrimp aquaculture production for 98 days, with a stocking density 102 individuals/m³ and evaluation of aquaculture production that occurs in the field. Based on optimization model which is applied, there are two options, the first is by partially harvest 45% (PR 2) so the harvest crop reached 4165.4 kg, total feed 5148 kg, FCR 1.24 with dissolved oxygen 0.4 ppm in the early days and 0.7 ppm in the end of the production. Second option is using non-partial model, harvest crop is 4,456 kg, total feed 5,862 kg, FCR was 1.21. It showed that the optimization model can increase production and significantly decrease FCR.*

Key words: *Pond Aquaculture, Whiteleg Shrimp, Optimazion Models*

INTRODUCTION

East Java is one of prominent contributors of Indonesian shrimp production. About 30% of national shrimp production, out of approximately 5 – 8 tons of national production from every harvesting time, is produced by some production centers in Sidoarjo, Pasuruan, Probolinggo, Situbondo and Banyuwangi (*Bisnis Indonesia,* December 7, 2012). Particularly in Probolinggo Regency, based on the data of Department of Maritime Affairs in 2011, there are 878.4 Ha intensive ponds to produce Giant tiger Shrimp from 1983 to 1995. In the early 2000s they stopped producing for five years because they fail to harvest due to bacterial and viral disease as a result of practical aquaculture which did not concern with the environmental support capability. Until now, there are approximately 223.10 Ha intensive ponds being developed to produce Whiteleg Shrimp (*Litopenaeus vannamei)*.

The problem with this intensive Whiteleg Shrimp aquaculture system is the mortality rate which is increasing with the decreasing pond water quality in the growing period. This decreasing water quality is caused by biomass activities like feces, uncontrolled feed and ammonia residue, which is possibly happened due to inappropriate/uncontrolled feed management. One indication of inappropriate feed can be seen by analyzing biomass ratio based on feed consumption ratio (FCR) and feed efficiency (FE). Significantly excessive feed amount will increase biomass ratio. It is said that 15% of the feed will dissolve and 20% of it is the primary contributor of biomass ratio (Primavera, 1994). Significant increase of biomass during the aquaculture will also increase the dissolved oxygen need in the water. Based on research of Boyd (2000), dissolved oxygen need for degradable process is 0.2 kg for a kilogram biomass. The high need of dissolved oxygen for the degradable process will affect biomass survival rate, which with significant increase of biomass will decrease the survival rate of the shrimps which also decrease the production. The solution to this problem is by analyzing feed supply efficiency (FCR improvement), so that production can be optimized with appropriate pond support capability and capacity.

Dynamic system is a metal concept, empirical relationship or collection of mathematical statements or can also be stated as simple representation from a complex system (natural system). For that reason, the model is an abstract illustration from a system where the variables are in the cause and effect relationship. The model can also be defined as a simplification of a system or a subsystem. The system is the illustration of a process or some well-regular processes. According to Jeffer (1978), a system can be seen so complex because of the processes involved, but the system is still a regularity.

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Based on the objectives, the simulation model can be divided into 3 (three) types: for process understanding, for prediction and for management need (Jeffer, 1978). The simulation model as a scientific method has some plus points, for example to support the definition and the classification of existing knowledge, to localize the gap in a certain field study and to explicitly make hypothesis in order to support in deciding the research priorities, as a mean to make standard operational information, as an effective cooperating medium among scientists of different discipline and scientific levels and also the model development as a sign of scientific advancement and accurate prediction improvement. A good model must illustrate the actual function of the system (Jeffer, 1978).

The model is a tool which can be used to support in illustrating the complex system conceptually and measuredly and even to predict the consequences of an activity which is if applied to the actual system will be very expensive and take long time or even damage the system itself. A good and correct model is the one which includes the essential part or an important functional component from the actual system. Modelling is necessary in order to understand the complex nature and its difficulties to be comprehended thoroughly. It means that modelling can be defined as a technique to conceptualize and measure a complex system or to predict the system response from human intervention.

The objective of this study is to analyze aquaculture production which consists of specific growth rate, survival rate, feed consumption ratio, feed efficiency and final weight so that total production and total feed can be measured and then we can analyze the optimization of the production with the dynamic approach. This research is expected to be able to create a complete model in optimizing production based on the existing aquaculture management, so that the model can be used to predict the expected optimization in the next aquaculture process.

MATERIALS AND METHODE

Material used in this research is an intensive pond, Whiteleg shrimp sample, the feed supply. The equipments used are digital weightscale, sampling net, daily feed log book and plastic bucket for biomass calculation. Method used is purpose sampling with quantitative approach, based on ex post facto (by following activities of the aquaculturist) so the known result is achieved by activities done for 4 months (from February to May 2013) in the intensive shrimp pond of Lemah Kembar village, Sumberasih subdistrict, Probolinggo regency, East Java.

Statistical analysis

Quantitative analysis approach: In production pond analysis, feed efficiency is the primary objective, because the success of the production depends on it. The most important factor in this matter is daily biomass estimation, absolute growth, growth rate and survival rate and the feed consumption rate to increase biomass weight (FCR), as shown in mathematical formula according to Cordova - Murueta, et al. (2003), as follows:

$Wt = W^{o} \times (1 + SGR/100)\ t$ .....

$SGR = \ln (W_t/W_0)/t \times 100$....

$JPt = Wt \times F$....

Discription:

Wt = Biomass in the day - t (g)

Wo= Biomass early (day - 0; g)

SGR= Specific growth rate (% / h)

JPt= The number of days to feed on - t (g)

Ep = efficiency of feed

F = Percentage of feeding (%)

t = Rearing periode

And then according to Haetami in 2012 feed efficiency ratio is the percentage of well-digested feed, whch is then transformed and added the shrimp weight. To measure the feed efficiency formula used is:

$Ep = GA/F \times 100\%$

Description:

Ep = Efficiency of feeding (%)

GA = Growth absolute (g)

F = The amount of feed given (g)

According to Smith *et al*., (2002), to know the amount of feed used to add the shrimp weight use FCR and shrimp weight addition by using this formula:

$AFI = FCR \times WT_w$

Description:

AFI = Feed given for a specific period (kg)

FCR = feed conversion ratio

WT_w = weight of added biomass (kg)

Dynamic system approach: Model development is done by using dynamic system approach. This method can reinforce our inquiry skill in the complex system (Sterman, 2000). To model the dynamic system issues, tools *Vensim, Stella, Powersim*, and other simulation software are needed. For that reason, *Stella 9.1.4* software is used in this research.

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Model development starts with system conceptualization which is done by making conceptual model which is illustrated by causal loop diagram. System conceptualization is used to illustrate generally the simulation of dynamic system being done. The conceptual model is then translated into dynamic system model through stock and flow maps. Formulation on the model is done by understanding and testing the model consistency whether it is appropriate with its objective and limitation. After the model is made, then verification phase is carried out. In this phase, the model is checked whether it is appropriate, sensible and there is a consistent formulation or the measuring unit. Then the system model is simulated and the result then is validated to ensure that the model can represent the actual system. Dynamic system analysis is conducted to optimize the production of Whiteleg shrimp culture, in accordance with the achieved data based on quantitative analysis with the concept of Grant et al. (1997), Sterman (2000), as follows:

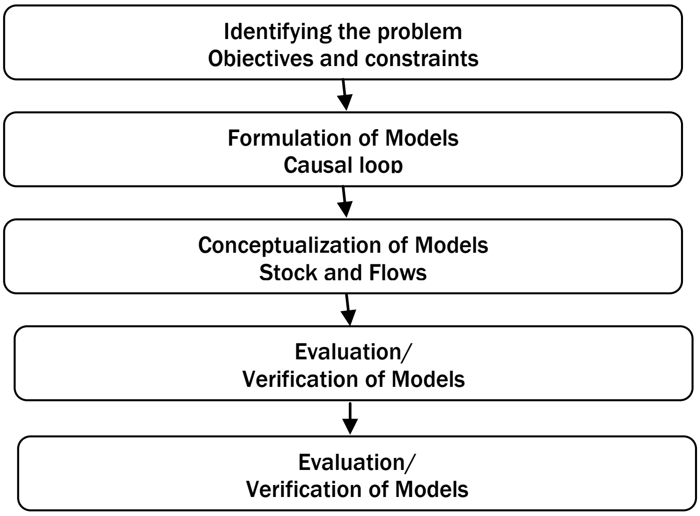

Figure 1. Framework of System Modeling Operational Phases; (Source: Grant et al., 1997; Sterman, 2000).

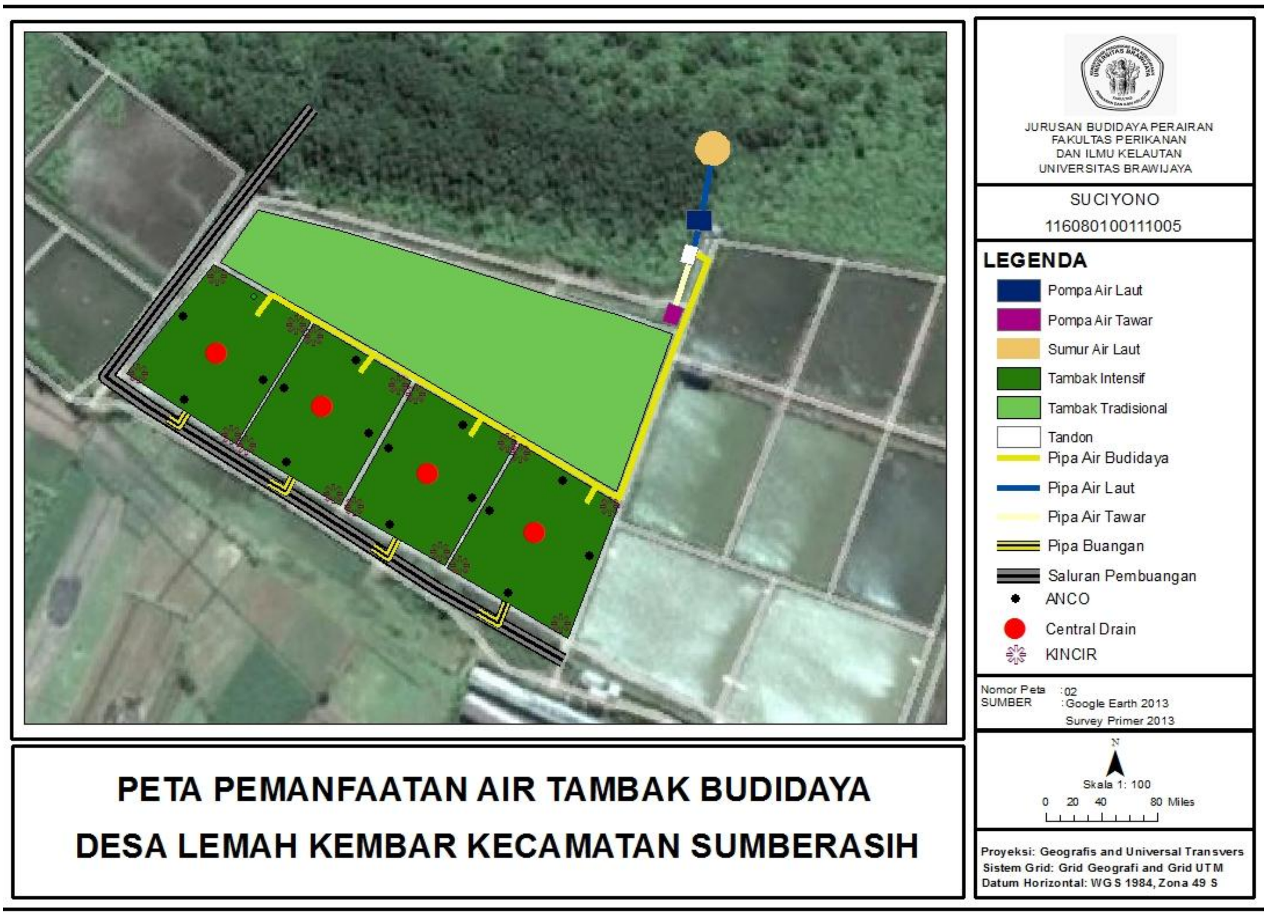

Figure 2. Pond Aquaculture Spatial Location. (Source: Results of the data if the GIS Image 2013)

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DISCUSSION

Research Pond Area Condition

Geographically Lemah Kembar village is in the coordinates of 7° 40' to 8° 10' S dan 112° 50' to 113° 30' E. Administrative line of Sumberasih subdistrict ends on Madura strait in the north. In the east it is adjacent to Probolinggo subdistrict, in the south is adjacent to Wonomerto subdistrict and in the west with Tongas subdistrict with total area of 30,25 km². (Statistics Indonesia Probolingggo Regency, 2011). The lay out of the culture pond is positioned in the traditional aquaculture and farming area, and this pond was actually a part of traditional ponds which method is changed to intensive aquaculture since 2010. The construction of the culture pond is using cast concrete for the side but not for the pond base. Every pond uses six watermills as the oxygen suppliers, four feed sampling and shrimp growth cross nets, with outlet system in the central drain and the effluent is directed to the waste drainage as seen in Figure 2.

Culture Production Analysis

Culture production analysis is the total shrimp biomass in the harvesting time. Some parameters supporting production are initial biomass average weight, culture's length period, feed amount, seed number, etc. Based on the quantitative calculation, specific growth rate (SGR), survival rate percentage (SR), absolute growth rate (GR), feed consumption ratio (FCR) and feed efficiency (Ep%).

Table 1 - Vannamei shrimp aquaculture production for 98 days

Parameters	Value
Number of initial biomass (Individual)	362400
Extensive ponds (m²)	3200
Number of final biomass (individual)	244.929
Initial weight biomass (gram/individual)	0.005 - 0.007
Final weight biomass (gram/individual)	19.23
Rearing periode of aquaculture (day)	98
Total of feed (kg)	5621.5
Total of harvest (kg)	4182.79

Sources: Data analysis of aquaculture production in 2013

Survival Rate: Based on quantitative analysis which is done by counting initial shrimps (No): 326.400 shrimps and the total number of shrimps in the end (Nt): 224.929 shrimps, we achieve final SR in the percentage of 75% for the 98 days of Whiteleg shrimp culture with approximate density about 102 /m². Widiasa (2005) reported culture result of Whiteleg shrimp in Barru regency with density of 57/m², length period of 100 –105 days, the harvest shrimps were 17.5–19.2 g for each individual shrimp with survival rate about 81– 87 % and the production reached 2.9 – 3.2 tons/3.500 m².

Specific Growth Rate: The observation on the specific growth rate for 98 days of culture period showed significant improvement along with the increase of feed and the culture period, in the beginning of the culture Day 1 – Day 49 the weight reached 0.167 g for each individual shrimp, Day 49 – Day 60 is 0.324 g for each individual shrimp, then Day 60 – Day 72 is 0.245 g for each individual shrimp. The weight on Day 73 – Day 81 is 0.158 g for each individual shrimp, on Day 82 - Day 90 is 0.192 g for each individual shrimp, on Day 90 – Day 98 is 0.152 g for each individual shrimp. The highest growth rate is on Day 49 – Day 60, followed by growth on Day 60 - Day 72, and it decreased significantly along with the length period, even though there is an increased growth on Day 81 – Day 90 due to density declining at the age of 72 days. The average specific growth rate in this research is about 0.20 ∂ 0.061 g for each individual shrimp.

Growth Rate: Average of total growth rate is 18.87 ε 0.503 g for each individual shrimp (size 54 – 52), quantitative analysis result by measuring final weight (W_t) and growth early (W_o) of Whiteleg shrimp, resulted final weight about 19.02 gram for each individual shrimp with total production 4182.79 kg/3200m². Final weight for each individual shrimp is 19.23 gram, as shown in Figure 3.

Final individual weight of Whiteleg shrimp achieved in this research is bigger than the research by Haliman and Adijaya in 2005, which reported about Whiteleg shrimp culture in Situbondo, East Java with 150 shrimps/m² density, 85 % of survival rate, final weight of 14.28 g for each individual shrimp, produced 5.465 kg/3000 m² with 1.5 FCR. This agreed with Sugama statement (2002) that some aquaculturists succeed in culturing Whiteleg shrimp with production result ranged from 6 – 12 tons/ha, 65 – 85% of survival rate, 1.0 – 1.2 FCR in a culture period of 100 – 110 days, and the harvested shrimps were about 12.5 – 17.0 g for each individual shrimp (size 60 – 80).

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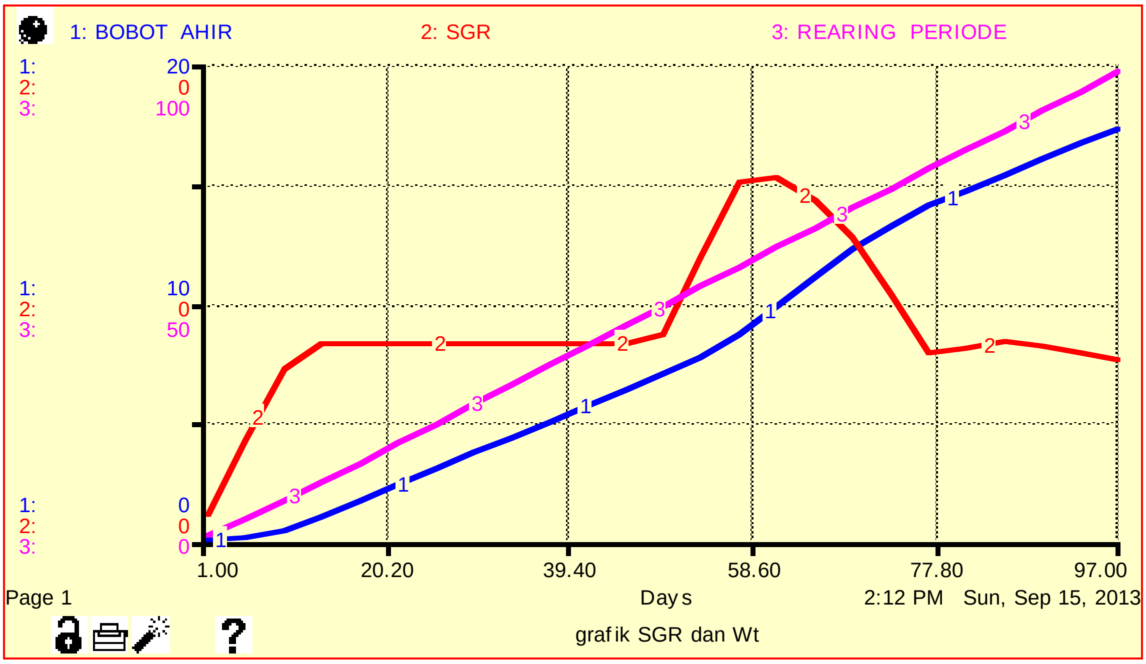

Figure 3 - Specific growth rate graphic vanname shrimp. (Source: analysis of production data @ stella 9.1.4)

Food Convention Rate: Based on the data in Table 1 Food Convention Rate or the amount of feed in kilograms which is need to produce 1 kilogram biomass/shrimp, in this research, the result achieved is 1.34 kg feed is needed to produce 1 kg of shrimps with regression equation Y=1254.65+0.532X+e with determination coefficient R^2= 0,98. Biomass increase fluctuation is significant with the feed increase in the beginning of the production until Day 72, but it decreased relatively in the end of the culture and the harvesting time in line with the decreasing growth rate and feed as shown in Figure 4.

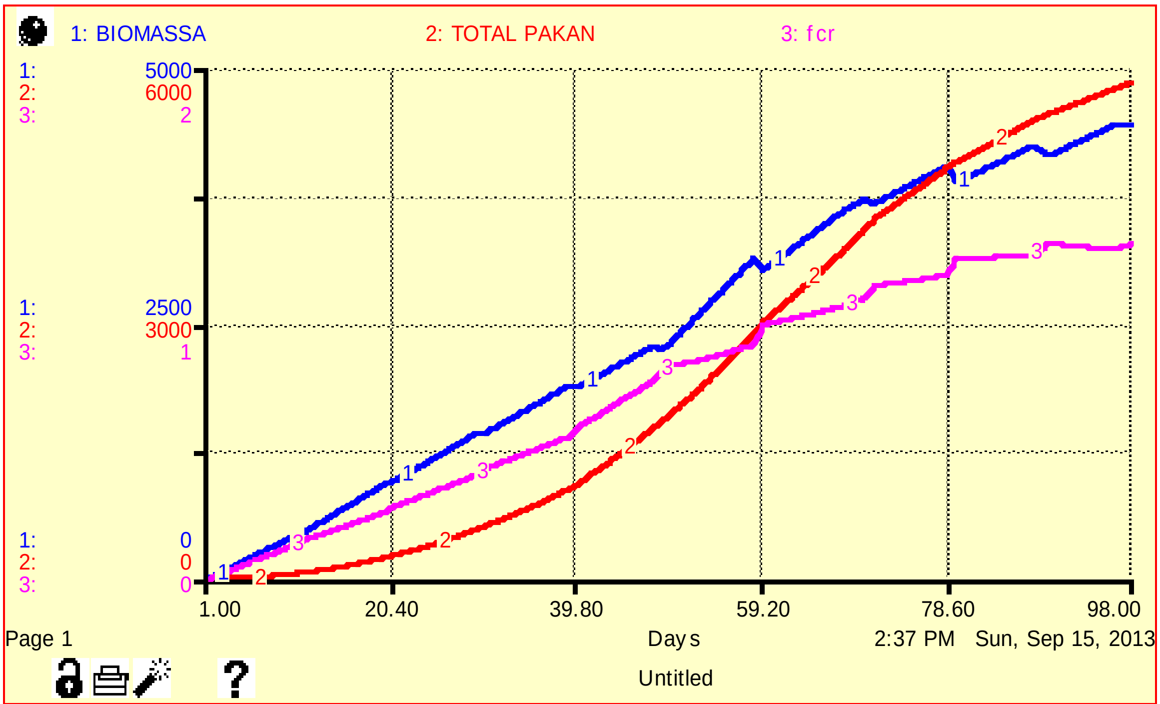

Figure 4 - Relationship graph of feed utilization and weight of shrimp during cultivation @ stella 9.1.4

Feed percentage in this research is higher in comparison with the anonymous research in 2003 which resulted 1.3 FCR for Whiteleg shrimp culture with 90 shrimps/m² for 110 days, but is lower than Trenggono's research which with the same length of period and density had achieved 1.4 FCR. Haliman and Adijaya (2005) reported about Whiteleg shrimp culture in Situbondo, East Java with 150 shrimps/m² density, 85 % survival rate, 14.28 gram final weight for a shrimp and produced 5,465 kg shrimps/3000m² with 1.5 FCR.

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Feed Efficiency: According to Haetami (2012), feed efficiency is the percentage of well-digested feed which is then add the weight of an individual shrimp. Quantitative analysis result conducted in this research by calculating absolute growth (GA) with the feed given (F) in grams, achieved 14.70 gram for each individual shrimp and need 17.49 g for each individual shrimp so that Ep (feed efficiency) got is 84% at the age of 72 days, then the feed efficiency kept decreasing until harvesting time with details as follows: on Day 81 the Ep is 46%, on Day 90 and Day 98 the Ep is 52% and if accumulated the Ep is 68%. The result was caused by excessive feeding in the final period of culture, which caused by inappropriate biomass sampling management with the survival rate of 78% at the age of 72 days, and with mortality rate of 7% after 72 days until harvesting time (98 days). Based on (Primavera and Apud research, in 2004), 85% digested feed is used for growth for about 80%, 20% in the form of feces and the 15% dissolves in the water.

Optimization of Culture Production

Causal loop: Causal loop diagram is an illustration of causal relationship among variables interacting in the system. Causal loop diagram is arranged based on its causal relationship among variables from the production Whiteleg shrimp in intensive pond in Lemah Kembar village, Sumber asih, Probolinggo. Causal loop diagram is developed by adding causal relationship among variables which affect the culture production. For example, daily feed increase is in line with biomass weight increase but they are inversely proportional to the survival rate. The causal loop diagram then illustrates the interaction of production variables, feed supply and biomass is related by arrow and plus symbols, but arrow and minus symbols illustrate the survival rate.

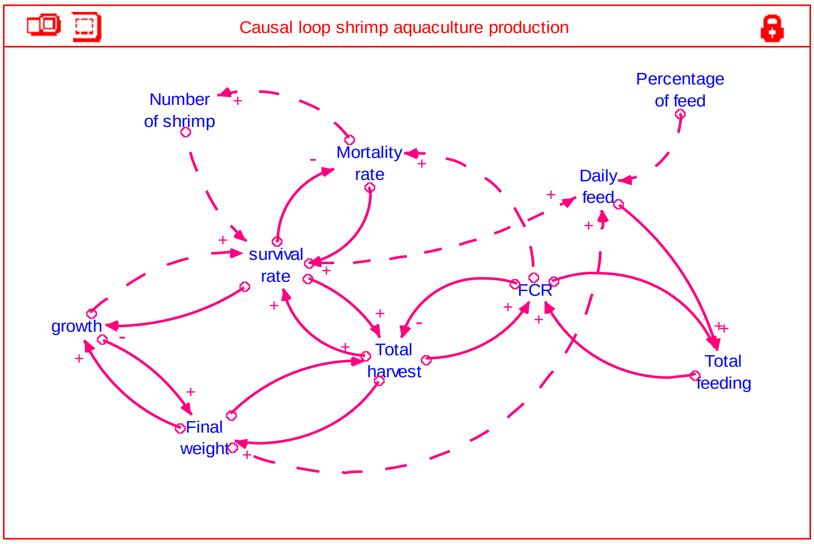

Figure 5 - Causal loop diagrams of shrimp vanname production

Conceptualization (*stock and flow*): Stock and flow maps are made based on causal loop diagram arranged. Stock and flow maps model of this research is divided into to sub models. This model development also involves mathematical formulation. This formulation shows the relation among the interacting variables, both concept arranged is based on the actual condition as shown in Figure 6 as follows:

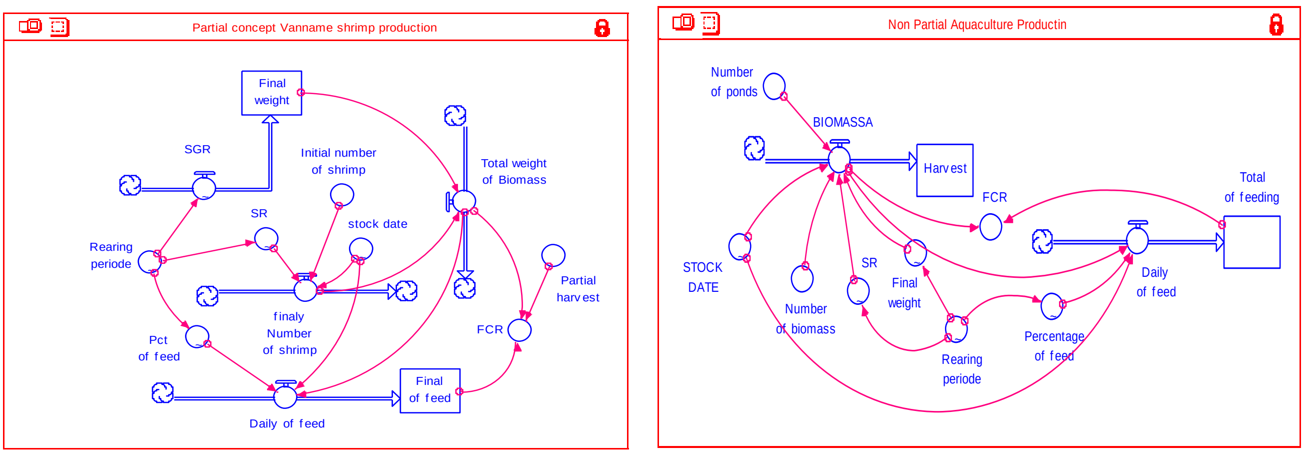

Figure 6. Conceptual models partial and non - partial

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Verification: Verification phase is a phase where simulation model is checked whether it works in logical way on the system object, whether it is appropriate with the conceptual model which is made. Checking process is conducted by check units and verification with STELLA software. The check units work to ensure the measurement consistency is appropriate with the formulation made. While verification is done to check formulation in the model and error which can be done by the made model.

Simulation Result:

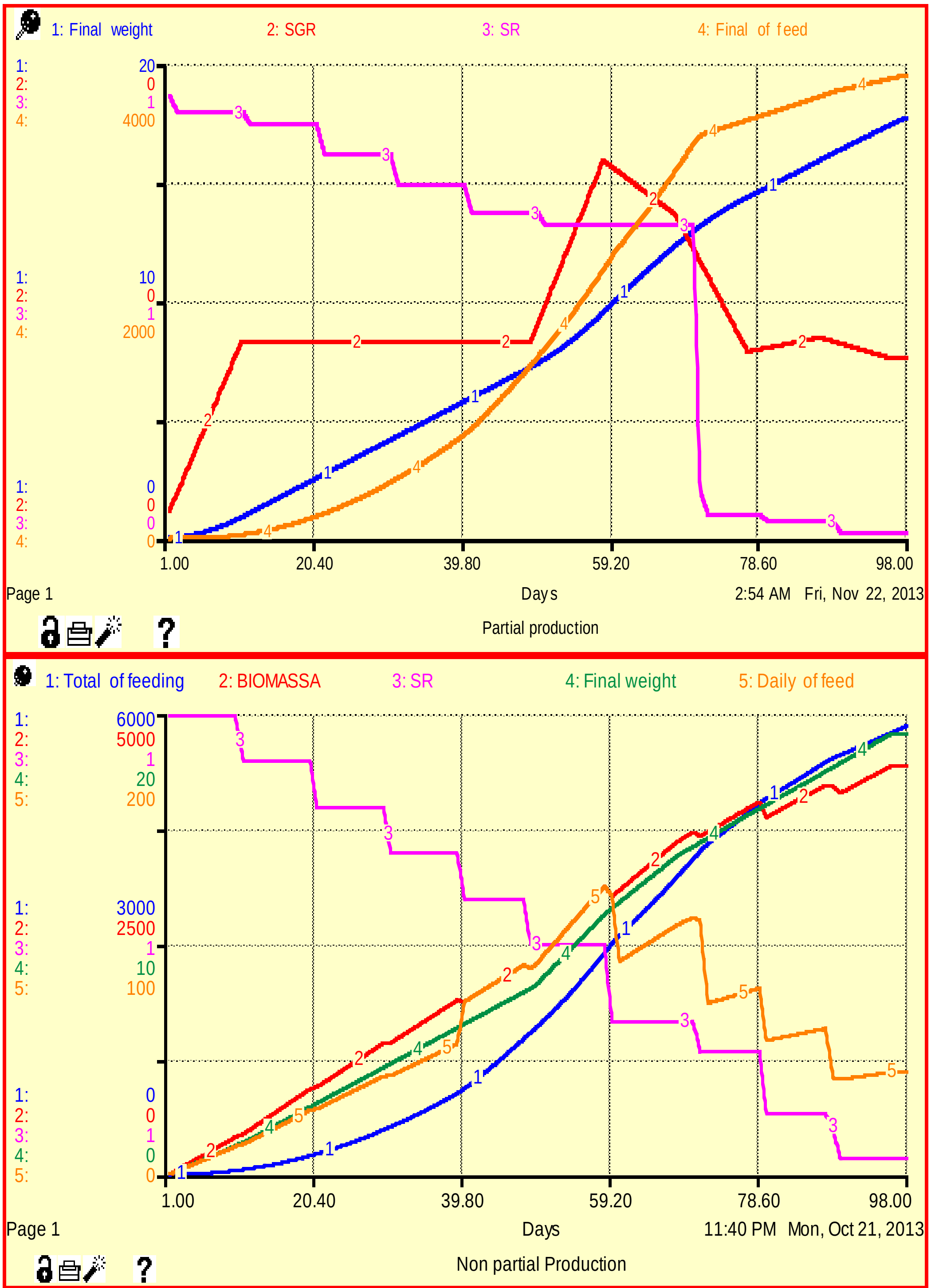

Figure 7. The simulation models partial and non-partial

Validation: Validation phase is a phase to ensure whether the made model can represent the actual observation object condition. Model validation process is conducted by discussing with the experts to ensure that the model which is made is correct and appropriate with the actual and existing system.

Model Discussion

Biomass shrimp production with dispersion of 326,000 shrimp/pond is 4182 kg with 68% SR, simulation result showed productivity about 3233 kg with 61% SR. In the existing pond, final biomass weight is 19.23 g for

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each individual shrimp while the simulation result is 17.82 g for each individual shrimp, with another words, total growth rate is 7% decreasing from the existing growth, this is in line with the total feed decrease which affect on the existing FCR improvement, which is about 1.34 in the existing pond and 1.24 in the simulation result. If non - partial culture production is done with the seed number, feed dosage and the culture period is same with the actual condition existing on the field, then harvest crop will be about 4,456 kg, feed supply is 5,862 kg, simulation final weight (Wt) is 19.23 g for each individual shrimp, final SR is 71%, FCR is 1.31 with average daily feed is 0.4% of biomass weight.

CONCLUSION

1. Intensive pond culture production result in this research showed $FCR_{initial}$ was 1.18 with 4,453 kg feed, biomass weight was 3,744 kg, in the period of 72 days and 78% SR with final weight was 14.7 gram for each individual shrimp (Size 68) harvested crop reached 1,714 kg. Then in the end of the culture showed FCR_{final} 2.1, with 1.118 kg feed and harvested crop was 2468,79 kg, 93% SR at the age of 98 days with Wt 19.23 gram. Overall production resulted FCR 1.34 with total harvested crop was 4182,79 kg with total feed 5621.5 kg, *stocking density* ±102 shrimps/m², the total survival rate (SR_{total}) was 75%, with final weight 19.23 grams for each individual shrimp (size 52) and specific growth rate of 0.22 ∂ 0.063 or achieved growth rate of 18.87 ε 0.503 gram/individual shrimp (size 54 – 52) then the feed efficiency in this culture production cycle was 68%.

2. Based on optimization model which is applied, there are two options, the first is by partially harvest 45% (PR 2) so the harvest crop reached 4165.4 kg, total feed 5148 kg, FCR 1.24 with dissolved oxygen 0.4 ppm in the early days and 0.7 ppm in the end of the production. Second option is using non-partial model, harvest crop is 4,456 kg, total feed 5,862 kg, FCR was 1.21. It showed that the optimization model can increase production and significantly decrease FCR.

Suggestions

1. It is necessary to do the growth sampling thoroughly in the culture which is done, so that high production efficiency can be achieved in the ecology and the economy, which is in linear will affect to the pond quality improvement.

2. Shrimp culture production evaluation is expected based on the model which is made in accordance with culture management in the existing condition to validate model which is used.

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