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RESEARCH PAPER

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Optimization model of paddlewheel as water quality engineering tool in intensive pond culture of vannamei shrimp (*litopenaeus vannamei*). in bbap situbondo, east java, Indonesia.

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Key words: Paddlewheel, water quality, vannamei shrimp.

Abstract

The aims of this reasearch was to determine the number of paddlewheel at shrimp intensive ponds. A dynamic model was used to obtain optimal value or amount in the application of paddlewheel. Stella 9.1.4 software programing was employed to find relationships among parameters. The result showed that the optimal number of paddlewheel was 1 paddlewheel with SAE (*Standart Aeration Efficiency)* was 1,31 kgO_2/kWh. The percentage of oxygen consumption on vannamei shrimp until final cultivation was 24% during the cultivation, the percentage of oxygen consumption on vannamei shrimp had increased. In this research, total oxygen demand was 567 ppm, shrimp production was 1054,88 kg, the amount of feed was 2278,1 kg with a pond area was 600 m^2, stocking density was 133 PL/m^2 during a cultivation period of 98 days.

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Introduction

Vannamei shrimp (*Litopenaeus vannamei*) is officially introduced as one of the leading commodited of aquaculture by the Ministry of Marine Aquaculture and Fisheries Republic of Indonesia in 2001, and Vannamei culture is very fast develop in Indonesia among the countries that have been developing such as China, Taiwan, and Thailand. (Annonymous, 2007). The problem in the intensive system is by increasing the density of Vannamei shrimp (*L. vannamei*), followed by increasing the number of oxygen consumption and how to overcome the lack of oxygen in the ponds at a high density of Vannamei shrimp (*L. vannamei*) in intensive pond and still needs to be investigated. Lack of oxygen concentration is recognized as a cause of stress, decreased appetite, slow growth, susceptible to disease, and mortality in shrimp or fish (Boyd, 2000). Paddlewheel can be used to add the concentration of dissolved oxygen in the pond and can prevent aquatic biota of death during the period of low oxygen (Boyd, 1982). The aim of this research was to determine the number of paddlewheel at shrimp intensive ponds and a dynamic model was used to obtain optimal value or amount in the application of paddlewheel.

Material and methods

Material used in this research was an intensive pond, Whiteleg shrimp sample, the feed supply. The equipments used are paddlewheel, thermometer, sampling net, daily feed log book and plastic bucket for biomass calculation.

These data were taken in intensive shrimp vannamei ponds at BBAP Situbondo, East Java. The research was carried out for 98 days and used 1 pond with the specification as shown in Table 1.

Water quality was measured with 4 parameters i.e.: dissolved oxygen, temperature, salinity, and pH. The purpose of the measurement was to determine the fluctuations during 24 hours and to calculated the optimizing number of paddlewheel in the ponds.

Statistical analysis

Quantitative analysis approach

Estimate of organic matter as a function of feed total (Table 1) reported by Primavera (1994) was used for the calculation of organic matter (kg). In the calculation, 100% of feed total input was divided into 4 parts, among others: the feed is dissolved in water, feces, growth, and moulting. 15% of the feed was dissolved in water, 20% of feces, 17% of growth, and 48% of moulting. So, organc matter was 35% (the feed was dissolved in water + feces) from the feed total input. Oxygen demand for degradation of organic matter was reported by Boyd (1989) i.e.: each kg of organic carbon would required 2.67 kg of oxygen for conversion to carbon dioxide and each kg of organic nitrogen would required 4.57 kg of oxygen for convesion to nitrate.

The vannamei shrimp (*L. vannamei*) respiration rate (mg O_2 shrimp^{-1} h^{-1}) as a function of temperature, salinity, and wet body weight (Table 1) (Vinatea *et al.* 2011). In the calculation, 1 m^3 of water per square meter of area was considered, and the respiratory rate was multiplied by the number of shrimp in each hypothetical stocking density and then divided by 1000 to find the oxygen consumption values (mg O_2 L^{-1} h^{-1}).

$$OD = OC + WR + SR$$

Discription:

OD : Oxygen demand (mgO_2L^{-1}h^{-1})

OC : Shrimp respiration (mgO_2L^{-1}h^{-1})

WR : Water respiration (mgO_2L^{-1}h^{-1})

SR : Sediment respiration (mgO_2L^{-1}h^{-1})

And than according to Lekang (2007) about total oxygen demand:

$$TOD = OD \times V \times 10^{-3}$$

Discription:

TOD : Total oxygen demand (kg O_2 h^{-1})

V : Volume (m3)

10^{-3} : Conversion factor (kg g^{-1})

$$OTR_T = OTR_{20} \times 1{,}024^{T-20}$$

Discription:

OTR_T : Oxygen transfer rate adjusted to the simulation temperatures (kg O_2 h^{-1})

OTR_{20} : Oxygen transfer rate at 20°C (kg O_2 h^{-1})

T : Temperature (°C)

Number of aerator = TOD / OTR_T

Dynamic system approach

Model development was done using dynamic system approach. Dynamic system modelling was based on conceptual representation of relation among different system components (Bullgao *et al.*, 2013). For this reason, STELLA™ software was used in this research. The conceptual model was made and than be translated into dynamic system modelling (Stella™) through stock and flow maps. Stages in the construction of models (Jianguo, 1991) (Figure 1).

Results

Water quality result was observed during 24 hours in order to determine the fluctuations Table 3.

Table 1. Specification of intensive ponds.

No	Variable	Unit	Value
1	Pond size	m^2	600
2	Stocking density	PL/m^2	133
3	Starting of aeration	hours	24
4	Time of cultivation	days	98
5	Water depth	m	120
6	O_2 transfer ability	kgO_2/h	2,62
7	SAE	kgO_2/h	1,31
8	Model number	NR-SC112	-
9	Gross weight	kg	100
10	Motor	1 set	1 HP, 3 phase
11	Reducer	1 set	Gear style 14:1
12	Floats	2 pcs	100% HDPE
13	Impeller	2 pcs	100% PP
14	Transmission shaft	2 pcs	Stainless steel
15	Frame	1 pcs	Stainless steel

Table 2. Individual respiratory rate (mg O_2 $Shrimp^{-1}$ h^{-1}) of *L. vannamei* as a function of temperature, salinity, and wet weight (Vinatea *et al.*, 2011).

Salinity (ppt)	temperature (C)	5 gr (mg/lt)	10 gr (mg/lt)	15 gr (mg/lt)	20 gr mg/lt
	20	0,8	1,91	3,2	4,6
37	25	1,22	1,84	2,35	2,79
	30	1,73	3,19	4,55	5,86
	20	0,81	1,88	3,08	4,37
25	25	1,23	2,5	3,78	5,08
	30	1,63	3,22	4,8	6,36
	20	1,01	2,22	3,52	4,88
13	25	1,25	2,53	3,83	5,13
	30	1,61	3,28	4,96	6,65
	20	0,86	1,66	2,42	3,18
1	25	1,19	2,55	3,98	5,45
	30	1,91	4,25	6,77	9,42

The highest oxygen concentration was observed at 13.00 (7,2 ppm) and subsequently decreased to the lowest concentration at 05.00 (1,5 ppm) than subsequently increased until 13.00 continuously during 24 hours. pH concentration showed no significant difference a range between 6,65 of 05.00 am to 7,05 of 13.00. Temperature value was no significantly different a range between 29,5°C at 05.00 am to 32°C at 15.00 and didn't show significant fluctuation. Salinity concentration showed no significantly different a range between 38 to 39 ppt.

The above graph showed that 13.00 was 118%, the value indicated the occurrence of super-saturation. After that, from 15.00 until 11.00 am oxygen consentration did not show the occurrence of super – saturation.

Figure 2 showed that to increase of the oxygen consumption from 1 to 25 days of cultivation an increase (138.4 until 196.80 mg O^2 L^{-1} h^{-1}), 25 to 50 days of cultivation an increase (196.80 until 244.04 mg O^2 L^{-1} h^{-1}), 50 to 74 days of cultivation an increase (244.04 until 294.12 mg O^2 L^{-1} h^{-1}), 74 to 98 days of cultivation an increase (294.12 until 345.80 mg O^2 L^{-1} h^{-1}).

Number of aerator demand was showed by a Model Dinamic System (Figure 3).

Table 3. Water quality during 24 hours *(@Excel microsoft)*.

Time	O_2 (ppm)	pH	Temperature (°C)	Salinity (ppt)
01.00	1,7	6,7	29,8	38
03.00	1,7	6,66	29,8	38
05.00	1,5	6,65	29,5	38
07.00	3	6,71	31,3	38
09.00	4,5	6,82	30,9	38
11.00	5,8	7	31	39
13.00	7,2	7,05	31,8	39
15.00	5,5	6,89	32	39
17.00	3,7	6,9	31,8	38
19.00	2,8	6,82	30,7	38
21.00	2,2	6,75	30,2	38
23.00	2	6,7	29,7	38

Table 4. The result of oxygen saturation persentation as an function temperature and salinity (± 30°C and 37 ppt) in vannamei shrimp (*L. vannamei*) pond.

No	Time	DO (mg/lt)	Saturated (mg/lt)	Saturation (%)	Transfer O_2 (mg/lt)
1	11.00	5	6,1	82,0	1
2	13.00	7,2	6,1	118,0	0,16
3	15.00	5,5	6,1	90,2	0,77
4	17.00	3,2	6,1	52,5	0,44
5	19.00	3	6,1	49,2	1,69
6	21.00	2	6,1	32,8	1,88
7	23.00	1,5	6,1	24,6	1,88
8	01.00	1,2	6,1	19,7	1,88
9	03.00	1	6,1	16,4	1,85
10	05.00	1,1	6,1	18,0	1,9
12	07.00	3	6,1	49,2	1,69
13	09.00	4,5	6,1	73,8	1,18

The above model showed that the number of aerator (number 2) and oxygen demand of the pond (number 1) was linear. The oxygen demand of the pond at day 1 to 25 was 142.82 to 214.00 ppm, at days 25 to 50 was 214.00 to 319.98 ppm, at days 50 to 74 was 319.98 to 460.50 ppm, and at days 74 to 98 was 460.50 to 567.00 ppm.

Table 5. The result of vannamei shrimp (*L. vannamei*) oxygen consumption rate (mg O^2 L^{-1} h^{-1}).

Days	Density (ekor)	Temprature (°C)	Salinity (ppt)	Weight 5 gr (mg O_2/L/hr)	Weight 10 gr (mg O_2/L/hr)	Weight 15 gr (mg O_2/L/hr)
1 - 20	80000	30	37	138,4	255,2	364
21 - 30	80000	30	37	138,4	255,2	364
31 - 40	80000	30	37	138,4	255,2	364
41 - 50	80000	30	37	138,4	255,2	364
51 - 60	76000	30	37	131,48	242,44	345,8
61 - 70	76000	30	37	131,48	242,44	345,8
71 - 80	76000	30	37	131,48	242,44	345,8
81 - 90	76000	30	37	131,48	242,44	345,8
91 - 98	76000	30	37	131,48	242,44	345,8

The number of paddle wheel needed at day 1 to 25 was 0.26 to 0.39 aerator, at days 25 to 50 was 0.39 to 0.58 aerator, at days 50 to 74 was 0.58 to 0.83 aerator, days 74 to 98 was 0.83 to 1 aerator

Discussion

The result of the fluctuation of water quality was different during 24 hours for intensive production of *L. vannamei* (Table 1). The highest level of oxygen in a pond appeared during the daytime when the phytoplankton was producing oxygen through photosynthesis (Conte and Cubbage, 2001). The purpose of aeration or oxygenation is either to remove gases such as nitrogen (N) and carbondioxide (CO_2) from the water, or to increased of gas concentration such as oxygen (O_2) in the water (Lekang, 2007).

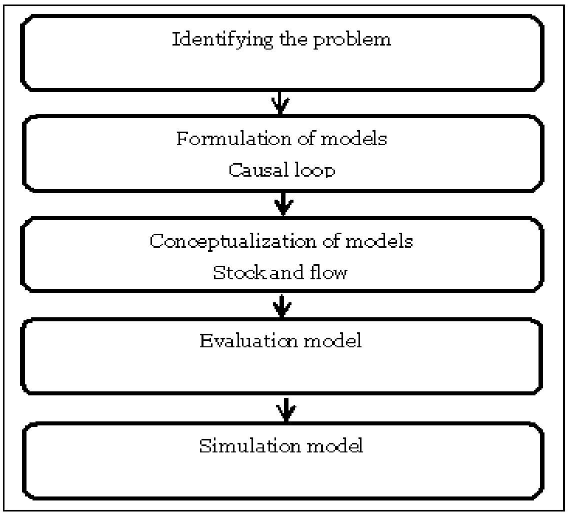

Fig. 1. System Modeling Operational Phases; (Source: Jianguo, 1991).

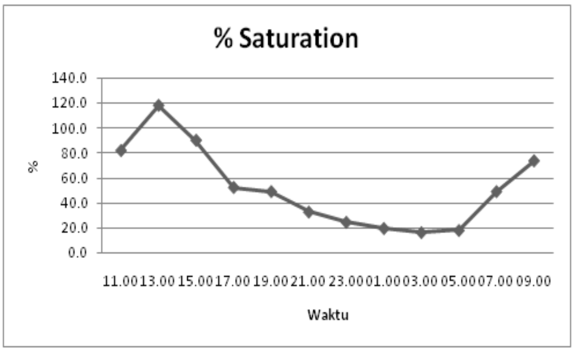

Fig. 2. Graphic of oxygen saturation.

Intensivication of aquaculture in general has caused higher oxygen demand in the culture unit and, consequently, in the number of aerator needed to fulfill satisfactorily the organism demands (Boyd, 1998). In this research, we found the appropriate number of aerator using dynamic system model. Analysis performed on the paddle wheel, based on the total oxygen demand on vannamei shrimp ponds was 567 ppm.

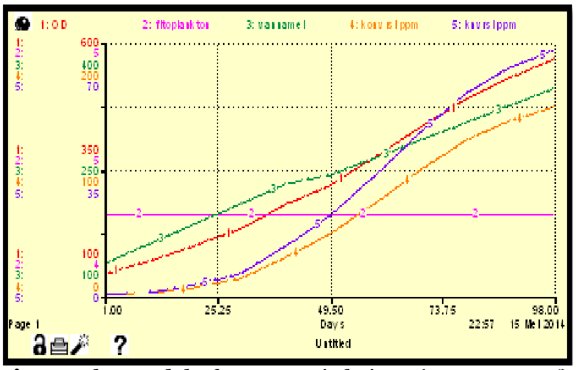

Fig. 3. The model of vannamei shrimp (*L. vannamei*) oxygen consumption rate (mg O^2 L^{-1} h^{-1}) ((1) Oxygen demand, (2) Phytoplankton, (3) vannamei shrimp (4) and (5) was oxygen consumption of organic matter).

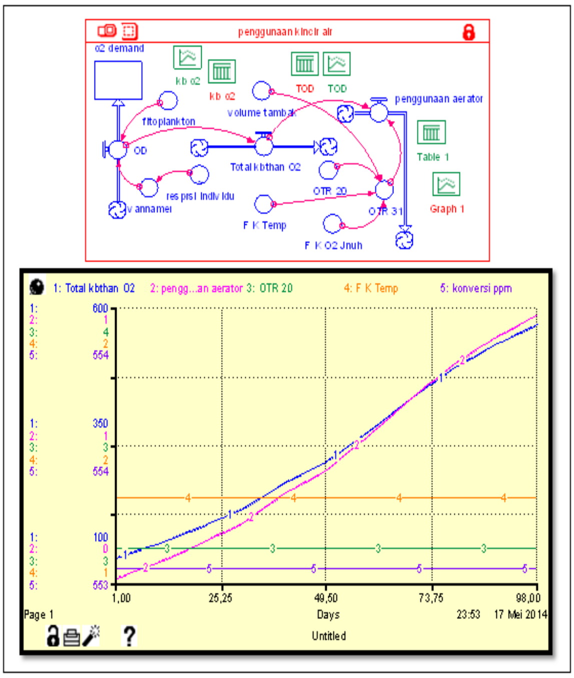

Fig. 4. The model of number of aerator.

OTR_{31} (Oxygen transfer rate) is the output of the paddle wheel in the pond and the temperature corrrection factor adapted to the situation at the study site and the result oxygen of the paddle wheel was 2212 kg oxygen or 553 ppm. The result will be associated with the total oxygen demand to determine the number of paddle wheel installed in vannamei shrimp ponds area of 600 m² and stocking density of 133 PL/m² and than using the dynamic model system for pressing the value of optimization to get the level of paddle whell efficiency number.

The result of model was linear between total oxygen demand and the number of paddle wheel. Increasing use of paddle wheel caused by increased oxygen demand in the pond for 98 days cultivation. Boyd (1998) stated that mentioned that in the aquaculture system, some researchers agree that the increased oxygen demand is directly proportional to the increasing number of cultivated species. Vinatea (2011) said that calculation of the number of aerator for extensive, semi-intensivve, intensif adapted to the size of the shrimp, stocking density, temperature and salinity.

Conclusion

The conclusion of the result showed that the amount of paddlewheel used was 1 paddlewheel in 600 m² pond area and stocking density of 133 vannamei PL/m².

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