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Water Environmental Carrying Capacity for Activities of Intensive Shrimp Farm in Banyuputih Sub-District, Situbondo Regency

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Abstract
This research was aimed to determine the width area of an intensive shrimp farm which can be supported by water environment of Banyuputih Sub-District, Situbondo Regency according to the water assimilation capacity towards the farm's organic waste. We used survey method and secondary data collection from other researches or result report of relevant institution. This study was using two approaches of environmental carrying capacities, i.e. (1) quantitative method on available water volume in coast (coastal water) and (2) quantitative method on available Dissolved Oxygen (DO) in waste receiving water body of coastal water. The result showed that the utilization of coastal area for intensive shrimp farm activities in this study area is not exceeding its carrying capacity of water yet. Based on the analysis, the water environmental carrying capacity for the farm's organic waste is 375.637 kg TSS. Organic waste (TSS) disposed from an intensive shrimp cultivation at the study area is 6.506 kg TSS.ha^{-1}.MT^{-1}. The width of intensive area which can be supported by Banyuputih Situbondo water environment is 58 ha. The width of available intensive pond area at study site is 113 ha, but only 39 ha is active/productive, the remaining 74 ha is inactive/unproductive area. If unproductive area will be re-operated/reactivated again, then we would recommend only 19 ha according to the water environment carrying capacity for the farm's organic waste (58 ha). Estimation result of water environment carrying capacity for this organic waste of shrimp farm can be used as reference to determine the development or management threshold of sustainable pond area at this study site.

Keywords: environment carrying capacity, organic waste, shrimp farm

INTRODUCTION

As the continental state with coast line about 81.000 km, Indonesia has great potential in developing business of pond cultivation. The width of potential area for developing pond cultivation in Indonesia is 913.000 ha with 1 million ton.year^{-1} of conservation potential [1].

Activity of shrimp pond cultivation conducted with intensive technology will produce organic waste, particularly from feed residue, feces, and dissolved cultivation material which disposed into water environment, and significantly affect the quality of coastal water. If the disposed waste to the coastal water exceeding the assimilation capacity or water environment carrying capacity, then it will affect the water ecological function [2].

Recent activities of shrimp pond cultivation at coastal area of Banyuputih Sub-District and future development will induce negative impacts on coastal environment and threatening the sustainability of shrimp pond cultivation, if the management is not environment-oriented. Therefore, to conserve shrimp farm and to decrease environment quality declining as effect from produced waste load, then the width area and technology of developed shrimp farm at coastal area must be based on water capacity in receiving organic waste.

Carrying capacity of pond environment has been discussed many times by some researchers. [3] predicted the value of coastal and marine cultivation environment carrying capacity at Xiamen by regression analysis method. Assessment method for environment carrying capacity was used relying on the report of actual production condition and *time-series*. Final result of this study showed the area width which can be supported for the cultivation activities. This approach is excellent for improving environment carrying capacity, because the variable values were based on actual condition. However, this method needs data on farm productivity development and area width of pond in time and places-series, which in some site were very difficult to obtain.

Widigdo and Pariwono[4] also developed the assessment method on environment carrying capacity of pond area. The carrying capacity

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assessment was based on water availability at water environment to receive waste from the pond cultivation. The method has been applied at north coast of West Java (Subang Regency, Jakarta Bay and Serang) for the shrimp farm. This environment carrying capacity method was also assessed [5,6,7]

Rustam [5] used the method to determine environment carrying capacity of coastal zone of Barru Regency of South Sulawesi for shrimp farm. In addition, [5] also used other approach based on dissolved oxygen with organic waste and water environment assimilation capacity (water potential to receive waste without causing pollution).

Sitorus [6] used estimation method of environment carrying capacity to develop the pond area based on biodegradation rate of pond waste at coastal water of Serang Tegency. [7] used the mixed method by *mass balance* method to estimate water carrying capacity for pond waste based on total concentration of *ammonia outflow* and *inflow* in coast of Tanah Bumbu Regency, South Kalimantan.

This research was purposed to determine the area width of intensive shrimp farm which can be supported by water carrying capacity of Banyuputih Sub-District, Situbondo Regency with water assimilation capacity for farm's organic waste.

RESEARCH METHOD

Study Site

This research was conducted from September 2013 until February 2014 at Banyuputih Sub-District, Situbondo Regency, East Java Province. Coastal area of Situbondo Regency, East Java has a great potential of pond cultivation. Recent pond area at Situbondo Regency is reaching 754.2 ha. It consisted of 550.1 ha as an intensive pond; 32.1 ha as semi- intensive pond and 172 ha as traditional pond [8].

Banyuputih Sub-District as selected area of this study is one of 12 Sub-Districts for developing the shrimp pond cultivation in site plan of Situbondo Regency Area 2008-2028. Currently, the width of pond area at Banyuputih Sub-District is 113 ha and totally managed with intensive technology [9].

Data Collection

Data collection in this study was categorized into two groups, i.e. primary data and secondary data. The primary data was obtained by observation and direct measurement in site with survey method, such as: coastal tide, slope of bottom water, distance of water intake, dissolved oxygen concentration of water, and activities of intensive shrimp farm.

Coastal tide observation conducted during September to October 2014 at coastal water using scaled board for 31 days (31 x 24 hours). The coastal tide observation was conducted to assess the difference of the highest and the lowest sea surface level and type of tide at coastal area of Banyuputih Sub-District. The measurement was conducted on the lowest point of sea water until the highest point of sea water.

Measurement of slope degree, water intake and DO was conducted at coast of Sumber Rejo Village, Sumber Waru Village and Pandean Village. Measurement for slope degree of bottom water conducted by using Teodollit (Wild T2) on three points of water locations with point interval 100 m to the sea.

Distance of water intake measured from the shoreline at highest tide up to 1 meter water depth of the lowest tide. Measurements were performed by mistar and theodolite at the shoreline. The concentration of dissolved oxygen in coastal waters measured by DO meter, for 24 hours with interval of three hours.

The data of water coastal tide, coastal slope degree, water intake distance and length of coast line (secondary data), were used to determine water volume that available at this water. While data of dissolved oxygen in water were used to determine the available dissolved oxygen in the water body (coastal water volume).

Monitoring on activities of shrimp cultivation was aimed to obtain data on amount of shrimp feed that was given during cultivation until harvesting. This amount of feed data was used for calculating the amount of organic waste in Total Suspended Solid (TSS) that produced from the shrimp farm activities at the study area.

Secondary data consisted of coastline length, area width of intensive shrimp farm and other supporting data were collected from the related agency, such as Department of Fisheries, Dept. of Regional Development Planning of Situbondo, and Statistical Center of Situbondo and the related research report with this study.

Carrying capacity based on available water volume

Observation for parameter y, h, x and θ were used to determine the available water volume at coastal (V_0), referred to formula of Widigdo and Pariwono [4].

$$Vo = 0{,}5\, h.y(2x - h/\tan\,\theta\,) \text{ ....(1)}$$

Description:

y = length of coastline (m)

h = range of tide (m)

x = distance from coastline to one meter water depth (m)

θ = coast slope degree (^{0})

If the frequency of tidal as f times per day, the the available water volume at coastal water is:

$$Vtot = Vo \times f \quad (2)$$

Determination for maximum width of pond area that still can be supported by water environment of this study area referring to Allison (1981) within Prasita [3]. Adequate waste receiving water body in public water environment for cultivation must have 60 – 100 time of disposed waste volume.

Carrying capacity based on available DO in water body and organic waste load

This method referred to the formula modification of [5], that describe the tidal cycle will provide or supply oxygen for coastal water. The dissolved oxygen is needed to decompose the organic waste of shrimp farm, thus it will determine coastal water ability to receive the organic waste load without exceeding the water carrying capacity.

First, we determined the amount of available dissolved oxygen in the water body, i.e. differences between the concentration of dissolved oxygen in the water body (O_{out}) with minimum concentration of disssolved oxygen needed by organism in cultivation (O_{in}). If the total of available water volume in coastal water (V_{tot} m^3) was known, then the total of available dissolved oxygen in the water during 24 hours (1.440 minute/day) is:

$$O_{tot} = V_{tot}\frac{m^3}{min} \times 1.440\,\frac{min}{day} \times (O_{out} - O_{in})\,\frac{g\,O_2}{m^3}$$
$$= A\ g\ O_2/day$$
$$= A\ g\ O_2/day\ x\ 10^{-3}$$
$$= A\ Kg\ O_2/day$$

Description:
- O_{tot} = total of available dissolved oxygen in coastal water ($Kg.day^{-1}$)
- V_{tot} = total volume of available water in coast (m^3)
- O_{0ut} = Dissolved Oxygen concentration in coastal water ($mg.l^{-1}$)
- O_{in} = minimum DO concentration needed by organism in cultivation ($mg.l^{-1}$)
- 1.440 = Total minute in a day

Second, we determined water carrying capacity with referring [5] that the disssolved oxygen needed for decomposing the *in* and *out* organic waste load at coastal water is 0.2 kg O_2/kg of organic waste. Thus, the amount of organic waste which can be retained by coastal water without exceeding the water carrying capacity formulated:

$$\frac{A\ Kg\ O_2}{0.2\ kgO_2/kg\ organic\ waste} = B\ kg\ organic\ waste$$

Furthermore, to determine the width of an intensive pond area that can be supported by the water, then we should calculated the amount of organic waste (TSS) of an intensive shrimp farm by referring to Widigdo and Soewardi's (2000) formula in Asbar [10]:

$$C_{an} = \frac{(\mathrm{L} \times \mathrm{P}) \times 1000}{\mathrm{V_{tb}}}$$

$$C_{n-1} = \frac{\left((Cb_{n-1}) \times V_{tb}\right) + (L \times P_{n-1}) \times 1000}{V_{tb}} mgl^{-1}$$

$$C_t \quad = \sum (Q\% \times Ca_{n-1}) mgl^{-1}$$

Description:
- C_{an} = pond waste concentration ($mg.l^{-1}$)
- C_t = concentration of total disposed waste to coastal water ($mg\ l^{-1}$)
- $Q\%$ = water substitution percentage (%)
- C_{an-1} = waste concentration disposed in previous day ($mg.l^{-1}$)
- V_{tb} = pond volume (m^3)
- P = total of feed given (kg)
- L = percentage of total feed as waste is 35% (Primavera and Apud, 1994)
- n = days of 1, 2, 3, … n (harvest day).

If it is known by one ha of pond producing C Kg of organic waste, then the maximum width of pond area which can be supported by water at study area is:

$$\frac{B\ Kg\ organic\ waste}{C\ kg\ organic\ waste/ha\ shrimp\ ponds} = D\ ha\ pond$$

RESULT AND DISCUSSION

Water Carrying Capacity Based on Available Water Volume

Dilution ability for coastal water of Banyuputih Sub-District, Situbondo Regency toward pond organic waste was calculated based on available water volume in the coast during one tidal cycle. [4], total volume of water at coast is influenced by range of tidal, length of coastline, slope of coast bottom, distance of water intake for pond and tidal frequency.

Banyuputih Sub-District has 22 km coastline [8]. Based on measurement, average degree of coast bottom slope is 0.77° from coastline (flood tide) to the site of water intake for pond is 724 m, range of tide is 1.78 m with frequency 2 times.day^{-1} (Table 1).

Table 1. Physical Characteristic of Banyuputih coastal

No.	Parameter	Value
1	Length of Coastline (m)	22,000.00
2	Slope of Coast bottom (°)	0.77
3	Distance of water intake (m)	724.00
4	Range of tidal (m)	1.78
5	Tidal frequency ($time.day^{-1}$)	2.00

Liquid waste from pond cultivation is periodically disposed into river, coastal water, and sea depends on the tidal flow. The pond waste will be diluted by surrounding water. Ability of coastal zone in receiving the pond waste named as environment carrying capacity of pond area. Determination for this carrying capacity of coastal water referred [4] formula of water volume = 0.5 hy (2x-(h.tanθ^{-1}), with requirement of water volume ≥ 100 volume of pond waste. In addition, we used assumption that maximum production of intensive shrimp cultivation is 5 ton.ha^{-1}.MT^{-1} (MT is unit of initial shrimp farming season).

Based on parameter value on Table 1, then the calculation of available water volume at coastal water is as follows:

$$Vo = 0.5\, h.y(2x - \frac{h}{\tan\theta})$$

$$Vo = 0.5\,(1.78).(22{,}000).(2(724) - (\frac{1.78}{0.013}))$$

$$Vo = 25{,}757{,}310\, m^3$$

Because the tidal frequency at study area is 2 time per day, then total volume of available water at the coast is 2 x 25,757,310 m^3 = 51,514,620 m^3.

Prasita [3] stated that to maintain the quality of public water environment to be adequate for fisheries cultivation, then the water as receiver of liquid waste from cultivation activities must have more than 60 – 100 times volume of liquid waste disposed to the public water. The safety condition to meet the carrying capacity criteria, total of maximum liquid waste from cultivation activities which entered into public water is 1% of water body volume of waste receiver. Referring to this assumption, then the maximum liquid waste volume of pond which can be supported by water environment at study site is 515,146.2 m^3 (1% from available coast water volume, i.e. 51,514,620 m^3). Briefly, the determination of water carrying capacity at intensive shrimp farm zone in study area has been presented on Table 2.

Table 2. The width of pond area based on carrying capacity of water volume on Banyuputih coast

No	Parameter	Value
1	Water volume (m^3)	51,514,620.0
2	Waste volume which can be supported by water environment (m^3)	515,146.2
3	Pond water volume (m^3)	5,151,462.0
4	Intensive Pond Area (ha)	515.2

If potential pond area at the study site will entirely developed into intensive pond with 10 ton.ha^{-1}.MT^{-1} average production (recent average production), then maximum land area that can be cultivated is 257.6 ha. Considering that pond area at Banyuputih Sub-District is 113 ha width [9], then recent pond activities in the study area is still below the maximum threshold of water environment carrying capacity. The land width of recent intensive pond that can still be developed more is 144.6 ha with production capacity of 10 ton. ha^{-1}.MT^{-1}.

Determination of carrying capacity with this approach is still having weakness, because carrying capacity of pond zone environment is not only determined by water availability. [11], environment carrying capacity is environment quality value produced by interaction from all elements of ecosystem unity. Therefore it is important to determine water environment carrying capacity based on the dissolved oxygen availability in water body and organic waste load.

Water Carrying Capacity Based on Available Dissolved Oxygen of Coast Water and Organic Waste Load of Shrimp Pond

Amount of dissolved oxygen that available for decomposing organic waste in water body is the differences between concentrations of dissolved oxygen in water (O_{out}) with minimum concentration of dissolved oxygen that needed for shrimp cultivation (O_{in}).

Average concentration of dissolved oxygen in coast water of Banyuputih (O_{out}) is 6.50 mg.l^{-1} (Tabel 3). Boyd (1990) and Wedemeyer (1996) in [5] concluded that minimum concentration of the dissolved oxygen that needed for shrimp cultivation (O_{in}) is 3 mg.l^{-1}. Thus, difference between O_{out} and O_{in} is 6.5 mg.l^{-1} – 3 mg.l^{-1} = 3.5 mg.l^{-1}.

Table 3. Dissolved Oxygen Concentration at Water of Banyuputih in 24 hours with interval of 3 hours

Observation Time	Dissolved Oxygen Concentration (mg.l^{-1})		
	Sumber Rejo	Sumber Waru	Wonorejo
09.00	6.80	6.71	6.25
12.00	9.35	6.05	9.58
15.00	7.38	7.22	7.35
18.00	6.82	6.56	6.65
21.00	5.65	5.90	5.56
24.00	5.38	5.56	5.19
03.00	6.11	5.91	6.07
06.00	5.59	6.34	6.11
Average	6.64	6.28	6.60

We found that total volume of available water during 24 hours is 51,514,620 m^3, then amount of total available dissolved oxygen in water body (coastal water) is 51,514,620 m^3/24 x 3.5 g O_2/m^3 = 75,125 kg O_2.

Dissolved Oxygen for decomposing 1 kg of organic waste is 0.2 kg O_2 [5]. Based on the assumption, then coastal water environment capacity in decomposing organic waste is 375,627 kg organic of waste. It mean that coastal water capacity of Banyuputih in accommodate organic waste of shrimp pond without exceeding environment carrying capacity is 375,627 kg.

Organic Waste Load of Intensive Shrimp Pond towards Coastal Water

Result of organic waste load calculated in TSS that was disposed into coastal water from activities of intensive shrimp farming with 3.500 m^2 width area was showed at Figure 1.

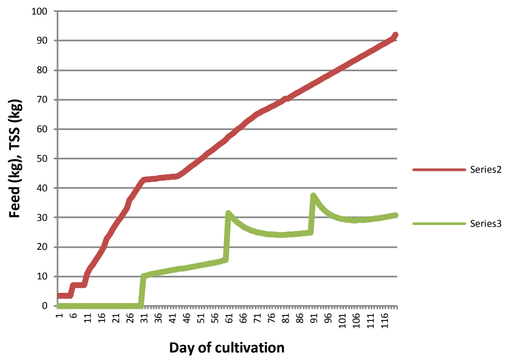

Figure 1. Feed and waste dosage resulted from 3.500 m^2 intensive shrimp pond during one cycle of cultivation (120 days)

On the first month of cultivation, there was no substitution of pond water, thus no organic waste disposed to coastal water. Substitution of pond water conducted by 5% of pond water volume at the second months (31st day), then 10% of pond water volume at the third months, and 15% of pond water volume at the forth month. The highest amount of TSS waste disposed into coastal water was found at the 91st day cultivation as much as 37.54 kg. Total of TSS waste disposed into coastal water during cultivation period (120 days) is 2,070.25 kg.

In final cultivation period (harvesting), shrimp pond was dried by flooded all water volume of pond (4.200 m^3) into coastal water. Based on calculation, amount of excluded TSS waste into coastal water is 206.56 kg. Thus, total suspended solid (TSS) of organic waste excluded by intensive shrimp pond into coastal water in one season of shrimp cultivation is 2,277.2 kg TSS per 3.500 m^2. If the width of pond were converted into 1 ha, then amount of produced organic waste (TSS) is 6,506 kg TSS.ha^{-1} (Table 4).

Table 4. Pond organic waste based on pond width

Pond Area	TSS (kg.MT^{-1})
3,500 m^2	2,277.2
1 ha	6,506

Related to the threshold of capacity or water environment carrying capacity based on the dissolved oxygen availability in decomposing organic waste which is 375,627 kg, then the maximum pond width that can be operated at Banyuputih Sub-District is 58 ha with production capacity 10.9 ton.ha^{-1}. MT^{-1} (Table 5). Recent width of intensive pond area at Banyuputih Sub-District is 113 ha. From the existing pond, only 39 ha is still active/productive, the remaining (74 ha) is inactive/unproductive pond area [9].

Table 5. Intensive pond area that adequate for applied in study site according to water carrying capacity for organic waste of pond

Waste Disposal of TSS (kg.ha^{-1})	Water Carrying Capacity for TSS Waste (kg)	Adequate Pond width to be Applied (ha)
6,506	375,627	58

Considering the capacity or water carrying capacity for pond organic waste, recent intensive shrimp farming activities at study site is 39 ha (Table 6). It has not exceeding the threshold of water capacity in accommodating the organic waste, which are 58 ha. If all remaining unproductive pond area (74 ha) is planned to re-operated, then the available dissolved oxygen in water is unable to decompose organic waste that produced from the pond. From recent productive pond (39 ha) can be only added 19 ha, according with water carrying capacity for organic waste of pond, which is 58 ha maximum.

Table 6. Intensive pond area of Banyuputih

No	Village	Area (ha)	Active/ Productive Area (ha)
1	Sumber Waru	75	19
2	Sumber Rejo	38	20
	Total	113	39

Source: DKP of Situbondo Regency (2013)

It implied that from recent remaining inactive/unproductive land of 74 ha, we recommend only 19 ha to be re-activated with production capacity 10.9 ton.ha^{-1}.MT^{-1}. If exceeded then it would be rising the degradation of water quality of coastal water at Banyuputih Sub-District and the pollution will threat the sustainability of intensive shrimp cultivation activities at this area.

CONCLUSSION

We concluded that recent 39 ha intensive shrimp pond at Banyuputih has not exceed the threshold of water environment carrying capacity yet. Based on available water volume at coastal water, maximum pond width that can be supported by water environment is 236.2 ha with 10.9 $ton.ha^{-1}.MT^{-1}$ production capacity.

Based on the available oxygen in water body to decompose organic waste load (TSS) of intensive shrimp pond at Banyuputih, only 58 ha is the maximum pond width that can be supported by the water environment. The maximum carrying capacity of coastal water at Banyuputih for pond organic waste is 375,627 kg TSS.

Recent active/productive intensive pond area at Banyuputih is 39 ha, while the remaining 74 ha is inactive/unproductive pond. We recommend only 19 ha to be re-activated for producing 10.9 $ton.ha^{-1}.MT^{-1}$ capacities according to the water carrying capacity to decompose organic waste in 58 ha intensive shrimp pond.

Management of shrimp farming in this study area must be conducted wisely. Because almost all todays shrimp ponds are using intensive technology which can lead to negative impact for the quality of coastal water environment, if the management is not considering the water carrying capacity for organic waste of the pond.

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