ILMU KELAUTAN: Indonesian Journal of Marine Sciences *June 2024 Vol 29(2):201-210* *e-ISSN 2406-7598*

Feasibility Study Area and Dissolved Oxygen *Carrying Capacity* of Silvofishery Pond on the Coastal Area

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Abstract

The aim of this research are to assess the feasibility of water and soil quality in silvofishery cultivation areas and to determine the environmental carrying capacity of the cultivation. The methods employed include Water Quality Index (WQI), Soil Quality Index (SQI), carrying capacity, and correlation analysis of parameters. The concentration of COD in the silvofishery pond water ranges from 705.34-749.50 mg.L^{-1}*, and the total nitrogen content in the soil ranges from 7-8 mg.L*$^{-1}$*. The COD parameter in water shows a strong correlation with dissolved oxygen. The soil type parameter silt is correlated with redox potential, while the clay soil type is correlated with sand soil. The variance in data for water and soil quality variables is considered significant as per cluster analysis. The WQI values range from 0.47-0.85, categorized as poor, good, and excellent. The SQI values range from 0.52-0.77, falling into the good and excellent categories. The carrying capacity of dissolved oxygen ranges from 0.7-1.99 kg.ha*$^{-1}$*, indicating that if the DO concentration is below this range, oxygen depletion may occur in the silvofishery pond. The research results indicate that the water and soil quality in the silvofishery pond is still sufficiently suitable for silvofishery activities. The carrying capacity of dissolved oxygen in the silvofishery pond is deemed adequate for operational silvofishery activities, ranging from 14.26-15.87 kg.ha*$^{-1}$*. This implies that the silvofishery cultivation system is capable of enhancing aquaculture productivity while minimizing environmental pollution in the surrounding aquatic areas resulting from the waste generated during aquaculture operations.*

Keywords: *aquaculture; mangrove; SQI; waste; WQI.*

Introduction

Silvofishery is an integrated aquaculture activity with the mangrove ecosystem (Rahman and Mahmud, 2018; Musa *et al*., 2020). Silvofishery is considered as an option for coastal area management based on an ecological approach (Lukman *et al*., 2021). This practice can be implemented in coastal regions as a means of managing the mangrove ecosystem. Various commodities utilized in silvofishery cultivation include *Oreochromis* sp, *Chanos chanos*, *Portunus pelagicus, Scylla* sp., and *Epinephelus* sp. (Musa *et al*., 2020; He *et al*., 2020; Ji *et al*., 2021). Mangrove commodities commonly cultivated include *Avicenia* sp., *Rhizopora* sp., and other species (Wulandari *et al*., 2022).

Silvofishery demonstrates a higher level of ecological utilization compared to aquaculture systems (Ariadi *et al*., 2019). This practice adds value to its aquaculture management (Perwitasari *et al*., 2020). Silvofishery can be calculated as a form of resource utilization value. The presence of resource utilization value (economic valuation) provides development options for future activities (Ariadi *et al*., 2019). The existence of mangrove ecosystems and fisheries cultivation will have a real impact in the fields of biodiversity, livelihoods and conservation for coastal areas (Come *et al*., 2023).

The important parameter in silvofishery activities is the water and soil quality parameters (Musa *et al*., 2020). The success of cultivation is heavily influenced by the quality of water and soil (Ariadi *et al*., 2023; Soeprapto *et al*., 2023). As ecological parameters, water and soil quality in cultivation ponds are essential for assessing land status (Soeprapto *et al*., 2023). Furthermore, the carrying capacity of cultivation is highly determined by the land's productivity level (He *et al*., 2020; Mardiana *et al*., 2023). In other words, the correlation between cultivation productivity and the carrying capacity along with the ecological parameters of the water is significant (Lukman *et al*., 2021; Dong *et al*.,

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https://ejournal.undip.ac.id/index.php/ijms
DOI: 10.14710/ik.ijms.29.2.201-210

Received : 16-02-2024
Accepted : 28-04-2024

2021). The objectives of this research are to assess the feasibility of water and soil quality in silvofishery cultivation areas, and to determine the environmental carrying capacity of the cultivation. This research is expected to provide empirical insights into the assessment of land feasibility and carrying capacity in silvofishery cultivation activities. It is hoped that the silvofishery research mapping can provide a model for environmentally friendly aquaculture concepts (Soeprobowati *et al*., 2024).

Materials and Methods

Research location

The research data was collected in the coastal waters of Pekalongan City (6°51’17,5’’ LS 109°42’42,8’’BT.) (Figure 1.). Data collection took place in four silvofishery ponds. The silvofishery ecosystem at the research site consists of mangroves (60%) and fish ponds (40%). The cultivated commodities include tilapia (*Oreochromis niloticus*), milkfish (*Chanos chanos*), and crab (*Scylla serrata*). The mangrove trees present at the silvofishery site belong to the *Avicennia* sp. species.

Sampling parameters

The sample data were obtained from 4 silvofishery cultivation ponds. In each pond, sampling was conducted during both the rainy and dry seasons to collect water and soil samples. Soil quality parameters observed included soil type and texture, measured using a hydrometer (Gao and Li, 2023). Additionally, soil pH, potential redox, organic carbon (OC), organic matter (OM), and cation exchange capacity (CEC) were measured using the formula by FAO (1980). Total nitrogen (N Total), C/N ratio, and nitrate (NO_3^-) parameters were measured by Jilkova *et al*, (2020).

Water quality parameters observed included pH, measured using a Eutech EC-pHTest30 pH tester, salinity measured with an ATAGO Master IP65 refractometer, and dissolved oxygen and water temperature measured with a YSI550i DO Meter. Carbon dioxide (CO_2), nitrate (NO_3^-), orthophosphate (PO_4^{3-}), ammonia (NH_3), Chemical Oxygen Demand (COD), Total Organic Matter (TOM), alkalinity, and nitrite (NO_2^-) parameters were measured using water quality assessment methods (APHA, 2005; Wafi *et al*., 2021). Data for soil and water quality were collected both *insitu* and *exsitu*. Parameters measured *insitu* include: pH water, soil texture, salinity, dissolved oxygen, and temperature. Parameters of Carbon dioxide (CO_2), nitrate (NO_3^-), orthophosphate (PO_4^{3-}), ammonia (NH_3), Chemical Oxygen Demand (COD), Total Organic Matter (TOM), alkalinity, nitrite (NO_2^-), soil pH, potential redox, organic carbon (OC), organic matter (OM), cation exchange capacity (CEC), Total nitrogen (N Total), C/N ratio, and soil nitrate (NO_3^-) parameters were measured *exsitu*.

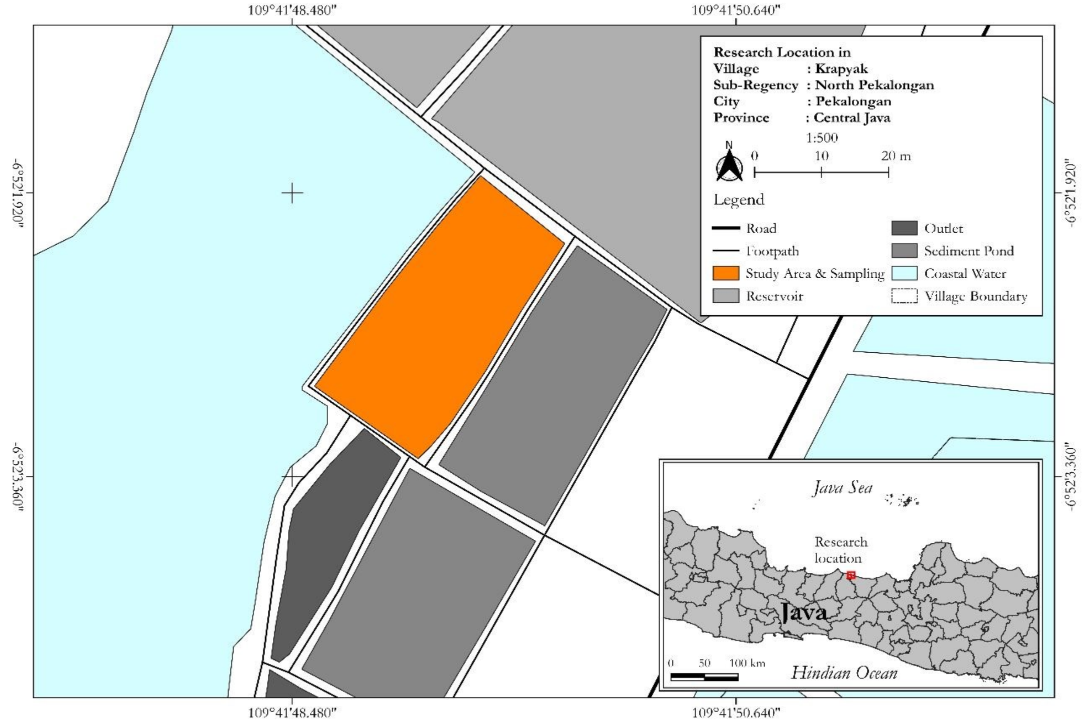

Figure 1. Study area of research

Data analysis

The analysis of water and soil quality data is descriptively analysis. The research findings are tested using non-parametric correlation tests to understand the correlation structure among variables. Subsequently, Principal Component Analysis (PCA) is applied to determine the correlation matrix weights for the entire dataset. Statistical data analysis in this study is facilitated using Microsoft Excel 2013 and SPSS software ver 19.2.

WQI and SQI analysis

To estimate the value of Water Quality Index (WQI) and Soil Quality Index (SQI) it is calculated based on the equation by Ma *et al.* (2023):

$$\text{WQI/SQI} = \sum_{i=1}^{n}(WkVFk)$$
$$\text{VFk} = \sum_{i=1}^{n}(AkiPij)$$

Note: *WQI/SQI* is water/soil quality index; W_k is the value factor in k; VF_k is principal component score; *Aki* is the value score; P_{ij} is coefficient standard; *"i"* is a variable and *"j"* is the maximum standard variable.

Furthermore, the scores on the WQI and SQI values are classified based on class using the Sturges formula used by Hoaglin *et al*, (1983) as follows:

$$\textit{Sturges formula}: n_c = 1+3.3\ \text{Log10}(N)$$
$$\textit{Class range}: h = A/n_c$$

Note: *nc* is the number of classes; *N* is the value of the observation result; *A* is the data range; and *h* is the class range. Furthermore, the calculation results from the formula are classified into ranks I to IV, where rank *"I"* is the excellent category.

Pond carrying capacity

The carrying capacity level and pond potential is estimated by comparing the DO value and the water volume average following equation by Mardiana *et al.*, (2023):

$$D = ([Vh-Vi]/t \times Vh$$

Note: *D* is the pond volume (m^3); *(V_h-V_i)* is the water exchange volume; V_h is the initial water volume (m^3); and *t* is the duration of the water exchange. After the pond water volume has been estimated, the next step is to determine of oxygen carrying capacity based on the inflow of water and the minimum DO concentration in the pond using formula by Mardiana *et al.* (2023):

$$\{Q_o m^3 \times (O_{in} - O_{out}t)\ \frac{gO2}{m3}\} + A = X\ kgO_2$$

Note: *A* is the average solubility of DO from other sources; Q_o is the pond volume (m^3); O_{in} is the solubility of DO ($mg.L^{-1}$); O_{out} is the DO minimum concentration for fish ($mg.L^{-1}$).

Result and Discussion

Water and soil quality parameters in silvofishery pond

The condition of water quality parameters in the silvofishery ponds tends to be good and stable (Table 1.). Notably, the profile of water quality in the silvofishery ponds indicates a relatively high concentration of COD (Chemical Oxygen Demand). The COD concentration in the ponds ranges from 705.34-749.50 $mg.L^{-1}$ (Table 1.). A similar trend is observed in the soil quality profile of the silvofishery ponds, where overall soil quality parameters tend to be dynamic stable (Table 2.). An abnormality is noted in the total nitrogen (N Total) parameter, with concentrations ranging between 7-8 $mg.L^{-1}$ (Table 2.). Overall, the water and soil quality conditions in the silvofishery ponds appear to be suitable for cultivation. The suitability of land and water in the silvofishery ecosystem is influenced by the scientific symbiosis between the aquaculture and silviculture ecosystems (Alder *et al.*, 2023).

The high concentration of COD suggests intense decomposition processes, likely stemming from organic waste from fish feed and feces (Junior *et al.*, 2021; Colette *et al.*, 2022). The low concentration of total nitrogen indicates that the level of nitrogen uptake by mangrove roots is very high (Alder *et al.*, 2023). The silt soil texture significantly influences nutrient solubility at the cultivation site. While nutrient-poor soil may not be fertile for agriculture, it does not significantly impact aquaculture activities (Liu *et al.*, 2023).

In terms of water quality parameters, a strong correlation is observed between COD and dissolved oxygen (DO) at the 0.05 significance level, as well as between nitrite (NO_2^-) and nitrate (NO_3^-) (Table 3.). The COD value is related to the level of oxygen demand used by microorganisms for the decomposition process (Nguyen *et al.*, 2022). Intensive decomposition of organic matter requires high oxygen consumption, affecting the solubility of nitrite (NO_2^-) and nitrate (NO_3^-) in the nitrification cycle (Medriano *et al.*, 2023). Other parameters such as salinity, dissolved oxygen, phosphate, COD, alkalinity show low correlation coefficients (Table 3.). The study reveals weak correlations between physical and chemical water parameters. Water quality in aquaculture ecosystems tends to fluctuate dynamically over time (Li *et al.*, 2021; Ariadi *et al.*, 2023).

Strong correlation is found in soil parameters, particularly between silt soil type and redox potential, and clay soil type with sand soil (Table 4.). Silt soil types tend to have a high cation exchange capacity (Huang *et al*., 2023), as indicated by the high oxidation values in silt soils (Wang *et al*., 2023). Clay soil types share similarities with sand soils due to particle size, influencing soil porosity and stability (Zhang *et al*., 2023). Coastal areas commonly feature clay and sand soils, and soil classification affects soil characteristics and productivity for aquaculture activities (Yuan *et al*., 2023). Other parameters such as C/N ratio, soil organic carbon (OC), and total nitrogen show strong correlations on a smaller scale. The presence of carbon elements in the soil is needed to balance the C:N Ratio levels and to stabilize the nutrient decomposition process by detritus (Stevenson *et al*., 2024).

Based on correlation results, nutrient parameters in water exhibit very strong correlations due to the high solubility of nutrients from feed, feces, leaf litter, and organic materials (McKercher *et al*., 2022). Silvofishery ponds, integrating mangrove ecosystems and multi-species aquaculture, experience elevated nutrient outputs (Harefa *et al*., 2022). In soil quality parameters, soil type shows strong correlations, influenced by the diverse composition of mangrove ecosystem soils, and affected by *run-off* and ongoing sedimentation processes (Junior *et al*., 2021; Harefa *et al*., 2022). Mangrove trees adapt to soil type characteristics (Musa *et al*., 2020).

The results of PCA Cluster analysis are described in Table 5. for water quality parameters and Table 6. for soil quality parameters. The data are derived from clustering data in 9 silvofishery ponds. The factor analysis results show eigenvalues >1, indicating the significance of the two water and soil data sets. The water quality parameter data (Table 5.) indicates that for VF1, parameters such as temperature, pH, CO_2, NO_3^-, PO_4^{3-}, NH_3, and TOM contribute significantly with loadings >0.80. VF1 accounts for 55.381% of the total variance. VF2 indicates that parameters like salinity, DO, COD, alkalinity, and NO_2^- contribute significantly with loadings >0.80. VF2 accounts for 31.187% of the total variance. The variance in water quality variables is strong and significant for cluster analysis. Soil parameters show a factor analysis with eigenvalues >1, signifying their significance. VF1 contributes 54.892% to the total variance, where parameters like pH, redox, OC, and OM have strong loadings (>0.80). VF2 indicates that parameters like total nitrogen, %sand, %silt, and %clay have strong loadings (>0.80) compared to other parameters. VF2 accounts for 27.495% of the total variance.

Table 1. Water quality parameters on silvofishery pond

Pond	Temperature (ºC)	pH	Salinity (g.L^{-1})	DO (mg.L^{-1})	CO_2 (mg.L^{-1})	NO_3^- (mg.L^{-1})	PO_4^{3-} (mg.L^{-1})	NH_3 (mg.L^{-1})	COD (mg.L^{-1})	TOM (mg.L^{-1})	Alkalinity (mg.L^{-1})	NO_2^- (mg.L^{-1})
1	31.5 ± 1.88	8.3 ± 0.61	7 ± 2.37	6.4 ± 0.14	0.006 ±0.11	0.322 ±0.45	0.117 ±0.15	0.021 ±0.19	726.25 ±25.12	71.50 ± 8.22	115 ± 9.49	0.212 ±0.68
2	30.8 ± 1.87	8.5 ± 0.69	8 ± 2.38	5.7 ± 0.19	0.008 ±0.13	0.374 ±0.40	0.188 ±0.17	0.037 ±0.18	705.34 ±24.25	83.25 ± 8.36	117 ± 9.50	0.237 ±0.64
3	31.1 ± 1.80	8.5 ± 0.62	7 ± 2.37	6.1 ± 0.19	0.008 ±0.15	0.341 ±0.47	0.137 ±0.19	0.042 ±0.19	733.22 ±25.25	75.50 ± 8.25	112 ± 9.35	0.225 ±0.62
4	29.8 ± 1.81	8.3 ± 0.66	7 ± 2.37	6.3 ± 0.18	0.002 ±0.09	0.366 ±0.43	0.153 ±0.16	0.047 ±0.19	749.50 ±25.12	78.50 ± 8.25	115 ± 9.45	0.219 ±0.67

Table 2. Soil quality parameters on silvofishery pond

Pond	pH	Redox (Eh)	OC (mg.L^{-1})	N Total	C/N	OM (mg.L^{-1})	CEC	NO_3^- (mg.L^{-1})	% sand	% silt	% clay
1	7.7 ± 0.11	13.58 ± 6.33	0.65 ± 0.19	0.10 ± 0.04	7 ± 4.36	0.85 ± 0.21	25.85 ± 14.12	4.22 ± 2.12	23 ± 18.43	43 ± 12.24	18 ± 7.41
2	7.8 ± 0.12	21.73 ± 6.89	0.75 ± 0.25	0.09 ± 0.08	7 ± 4.84	0.78 ± 0.21	24.25 ± 15.10	5.21 ± 2.22	27 ± 19.21	41 ± 12.27	21 ± 7.47
3	7.7 ± 0.12	23.05 ± 7.11	0.77 ± 0.20	0.06 ± 0.08	7 ± 4.72	0.88 ± 0.25	38.99 ± 14.45	5.40 ± 2.37	25 ± 18.25	48 ± 12.30	20 ± 7.56
4	7.7 ± 0.13	19.21 ± 6.74	0.69 ± 0.20	0.09 ± 0.07	8 ± 4.55	0.72 ± 0.21	42.10 ± 14.25	5.37 ± 2.25	28 ± 17.19	42 ± 12.25	20 ± 7.51

Table 3. Correlation coefficient between water quality variables (Spearman) as non-parametric

	Temperature	pH	Salinity	DO	CO$_2$	NO$_3$	PO$_4$	NH$_3$	COD	TOM	Alkalinity	NO$_2$
Temperature	1											
pH	.219	1										
Salinity	.553*	.391	1									
DO	.466*	.225	.872*	1								
CO$_2$	.109	.529	.246	.595	1							
NO$_3$	.333	.520*	.105	.377*	.555	1						
PO$_4$	.218	.302*	.656	.405*	.392	.445*	1					
NH$_3$	-.693	-.833	.704	.249	.593	.205	.439	1				
COD	.670	.205	.573	.101**	.629	.360	.228	.592	1			
TOM	-.458	-.105	-.437	-.333	-.659	.552	.793	.139	-.068	1		
Alkalinity	.818	.549*	.693	.452	.208*	.837	.280	.418	-.490	.463	1	
NO$_2$	-.118	.752*	.339	.538	.39	.688**	.027	.885	-.749	-.753	-.892	1

Table 4. Correlation coefficient between soil quality variables (Spearman) as non-parametric

	pH	Redox	OC	N Total	C/N	OM	CEC	NO$_3$	% sand	% silt	% clay
pH	1										
Redox	.449	1									
OC	-.218	.293*	1								
N Total	.420	.662	.971	1							
C/N	.752*	.793	.712	.048*	1						
OM	.602	.173	.902*	.078	.918	1					
CEC	.739	.187	.943	.406	.331	.084	1				
NO$_3$	.719	.018	.391	.107	.591	.106	.519	1			
% sand	.015	.159*	-.902	.201	-.118	.219*	.796	.331*	1		
% silt	.023	.377**	.175	.019	.379	.009*	.204	-.088	.935*	1	
% clay	.693	.517*	.567	.101	.779	.015*	.294	.619	.077**	.935*	1

Table 5. Loading of experimental water and soil quality variables on significant principal components

Water Parameters			Soil Parameters		
Variable^a	VF1^b	VF2^c	Variable^a	VF1^b	VF2^c
Temperature	0.794	0.231	pH	0.892	0.276
pH	0.837	0.169	Redox	0.849	0.021
Salinity	-0.238	0.891	OC	0.993	-0.115
DO	-0.103	0.899	N Total	0.177	0.948
CO$_2$	0.853	0.146	C/N	0.701	0.111
NO$_3$	0.912	0.133	OM	0.948	0.116
PO$_4$	0.883	0.103	CEC	0.519	0.089
NH$_3$	0.894	0.124	NO$_3$	0.427	0.124
COD	0.387	0.881	% sand	0.113	0.895
TOM	0.867	0.105	% silt	0.106	0.925
Alkalinity	0.238	0.826	% clay	0.128	0.884
NO$_2$	0.184	0.914	-	-	-
Eigenvalue	5.373	3.172	Eigenvalue	5.354	2.176
% variance	55.381	31.187	% variance	54.892	27.495
% cumulative variance	54.272	78.295	% cumulative variance	51.729	75.487

From the PCA analysis, it can be explained that chemical parameters dominantly influence the water and soil data sets. Additionally, there are physical parameters with low influence. In integrated aquaculture activities, the dynamics of chemical parameters are considered to be more intense and can have a direct influence on the environment (Stevenson *et al*., 2024). The chemical-physical parameters strongly influence the silvofishery ponds (Musa *et al*., 2020). Water quality in aquaculture ponds fluctuates dynamically over time (Ariadi *et al*., 2023). The dynamics of physicochemical parameters in silvofishery waters will have a correlative influence on fish growth rates, decomposition rates and chemical cycles in the waters (Ariadi *et al*., 2019).

WQI and SQI analysis

The estimations of Water Quality Index (WQI) and Soil Quality Index (SQI) in the silvofishery ponds are illustrated in Figure 2. Excellent WQI values are found in pond 4. Poor WQI values are observed in ponds 1 and 2, with pond 3 classified as having a good WQI. The range of WQI values in the silvofishery ponds is 0.47-0.85. Excellent SQI values are found in pond four, while the remaining silvofishery ponds are classified as having a good SQI. The range of SQI values in the silvofishery ponds is between 0.52-0.77. The classification of WQI and SQI status can be seen in Table 6. Variations in Water Quality Index (WQI) and Soil Quality Index (SQI) values in silvofishery ponds are due to differences in the aquaculture waste recycling process and the amount of aquaculture input provided (Nguyen *et al*., 2022).

The key to the balance of a aquaculture site is the presence of a stable environmental carrying capacity (Song *et al*., 2019). Soil quality, based on SQI Index classification, is relatively good and suitable for aquaculture activities. Good soil quality determines the level of land productivity in supporting aquaculture sites (Shafi *et al*., 2021; Hasibuan *et al*., 2023). The WQI Index tends to be relatively good for cultivation activities (Figure 2.). The unstable water status can be managed by using suitable fish species for aquaculture cultivation (Ariadi *et al*., 2019). Overall, this silvofishery site is considered good for fish farming.

The status of land and resources is a key factor that should be considered before engaging in cultivation activities (Song *et al*., 2019). Ideal land and water conditions are highly beneficial in supporting the operational cycle of aquaculture

Table 6. WQI/SQI modification distributed into four class indicating from condition of pond culture

The value of WQI	Water/soil condition	Interval classes	The value of SQI
>0.80	Excellent	I	>0.75
0.60 < WQI < 0.80	Good	II	0.50 < SQI < 0.75
0.30 < WQI < 0.60	Poor	II	0.25 < SQI < 0.50
0.05 < WQI < 0.30	Badly	IV	0.03 < SQI < 0.25

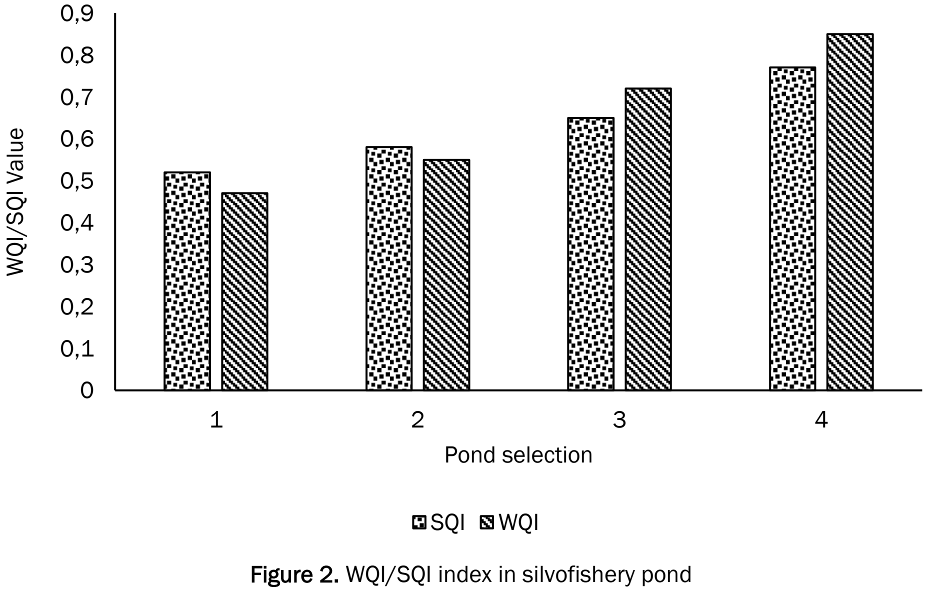

Figure 2. WQI/SQI index in silvofishery pond

Table 7. Data calculation of oxygen *carrying capacity* in each pond

Pond	Volume of Pond (m^3)	Volume of pond 60% (L)	DO in pond ($kg.pond^{-1}$)	TOM in pond ($kg.pond^{-1}$)	DO for TOM ($kg.pond^{-1}$)	DO for fish ($kg.pond^{-1}$)	DO for culture activity ($kg.pond^{-1}$)	CC
1	600	360	16.25	24.68	6.36	5.84	14.26	1.99
2	600	360	17.55	37.29	7.11	5.92	15.87	1.68
3	600	360	15.75	22.77	7.87	6.25	15.05	0.7
4	600	360	16.50	32.58	5.46	4.89	15.27	1.23

(Madusari *et al*., 2022). In these silvofishery ponds, there are feasibility values that are quite good to support the operational cycle of cultivation. The feasibility status of cultivation land is also related to the carrying capacity when the operational cycle of aquaculture is underway (Dong *et al*., 2021).

The silvofishery pond carrying capacity

Carrying capacity in the silvofishery ponds is calculated based on the availability of dissolved oxygen (DO) and the requirements for DO in the oxidation of organic matter, fish respiration, and the ecosystem activities in the silvofishery pond. Dissolved oxygen is important parameter that controls biochemical processes in aquaculture ecosystems (Wafi *et al*., 2021). The estimates are presented in Table 7. Overall, the DO carrying capacity in the silvofishery ponds is still highly sufficient for the DO consumption level in the ponds. The lowest DO production level is in pond 3 (15.75 $kg.pond^{-1}$), but its capacity can still cover the DO consumption level in the silvofishery ponds, which is 15.05 $kg.pond^{-1}$. The DO requirements for the oxidation of organic matter are 0.2 $kg.DO^{-1}$, and for fish respiration, it is 4 $mg.L^{-1}$. The range of oxygen production in these silvofishery ponds tends to be more stable (15.75-17.55 $kg.pond^{-1}$) compared to the findings of Musa *et al*. (2020), which ranged between 9.45-25.93 $kg.pond^{-1}$.

The high DO production in the silvofishery ponds is attributed to the high density of mangroves (Musa *et al*., 2020). In the research ponds, the cultivation area to mangrove ratio is 60:40. Mangrove roots produce oxygen that diffuses into the silvofishery pond ecosystem (Hossain *et al*., 2022; Musa *et al*., 2020). Mangroves also function as absorbers of organic matter resulting from fish farming activities (Kristensen *et al*., 2022). Nutrients from fish feces and uneaten feed can be converted into fertilizer for mangroves (Musa *et al*., 2020). Based on the research results, the lowest DO carrying capacity is 0.7 $kg.pond^{-1}$ (Table 7.). This means that if the DO conversion in the silvofishery pond is less than 0.7 $kg.pond^{-1}$, the pond's carrying capacity is considered unsuitable. The oxygen carrying capacity is limited factor by the maximum water that can cover the waste load for the decomposition process (Wafi *et al*., 2021). To enhance the DO carrying capacity, partial harvesting, effective water circulation management with paddle aerator, and the use of appropriate fish stocking densities can be implemented (da Silveira *et al*., 2022; Ariadi *et al*., 2023).

The carrying capacity of aquaculture ponds is dynamic due to the influence of biotic and abiotic factors (Dong *et al*., 2021). Information on carrying capacity is crucial for determining the level of input in fish farming production (Santanwat *et al*., 2023). Carrying capacity is also necessary to avoid excessive accumulation of waste in the surrounding environment of the pond (Mardiana *et al*., 2023). Silvofishery ponds with the utilization of mangrove ecosystems are well-suited for sustainable cultivation concepts with controlled carrying capacity (Ouyang and Guo, 2016). Silvofishery is very easy to develop and adaptive to be replicated in coastal waters (Urli *et al*., 2022). Silvofishery is also suitable for development in coastal areas as an effort to preserve mangrove ecosystems and promote integrated aquaculture patterns (Umilia and Asbar, 2016; Urli *et al*., 2022).

Conclusion

The findings of this study indicate that the feasibility of water and soil quality in the silvofishery pond is still technically suitable for silvofishery activities. The carrying capacity of the silvofishery pond, based on the DO carrying capacity and mangrove cover ratio, is still deemed highly sufficient for the operational aspects of silvofishery. In essence, the silvofishery cultivation system is considered capable of enhancing the overall productivity of aquaculture while minimizing the risk of environmental pollution in the vicinity of shrimp pond cultivation areas.

Acknowledgement

This publication is the implementation of research collaboration between the Faculty of Fisheries, Pekalongan University with the Faculty of Fisheries and Marine Sciences, Jenderal Soedirman

University, as stated in Memorandum of Agreement No. 3104/UN23.16/HK.06.00/2023 and research partnership between Pekalongan University with Kalasin University in 2023.

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