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Title	: **The Assessment of Water Compatibility of Adaptable Stick-Net Cage for Resilience Milkfish Cultivation in Tanjung Mas, Indonesia**
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In the reference above, I am the corresponding author; I am submitting this manuscript for publication in the **Jurnal Pendidikan IPA Indonesia (JPII)**. The manuscript is the original work of author and co-authors. All data, tables, figures, etc. used in the manuscript are prepared originally by us.

The manuscript concise of essential information about the compatibility of the Tanjung Mas seawater area for milkfish cultivation. This study has explained existing condition of the alternative aquaculture system using stick-net bamboo in Tanjung Mas. We also explain how physicochemical condition of marine ecosystem and industrial-household pollutant may affect milkfish cultivation. We assume that this research can be a good piece of puzzle in the **JPII** to complete more information about eco-friendly process in the sustainable milkfish culture .

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Thank you.
Sincerely

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The Assessment of Water **Compatibility of Adaptable Stick-Net Cage for Resilience Milkfish Cultivation in Tanjung Mas, Indonesia**

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Abstract

Milkfish cultivation becomes the main livelihood of farmers in coastal areas. However, the land for milkfish cultivation is shrinking due to land use for settlements, industries, and sea-level rise. A Stick-net cage is an aquaculture solution in limited space for an inland fishpond. It can be placed in seashore areas while maintaining the quality of the aquatic environment and nutrient circulation. This study aims to analyze water compatibility in the stick-net cage areas for supporting sustainable aquaculture activities. An exploratory observational study was conducted in Tanjung Mas Village, Semarang City, Central Java, Indonesia. Ten sampling areas were determined purposively by considering the point locations toward household wastewater and industrial outfalls. Based on these criteria, the ten stations used as sample areas were divided into industrial outfall areas (stations 1st – 5th) and areas close to the open sea (stations 6th – 10th). Physical parameters in the sampling areas, including temperature, water-current, turbidity, and clearness, met seawater standards for milkfish cultivation. Meanwhile, chemical indicators, such as NH_4 and P in waters were very high, which may cause by domestic and industrial waste contamination, and increased organic fermentation activity on the seabed. However, the existing stick-net cages have exceeded the capacity of the coastal water areas. In general, the physicochemical parameters in the Tanjung Mas waters area are suitable for milkfish cultivation. However, it is necessary to reduce the amount of pond density to give growth space for milkfish. In addition, wastewater management and treatment plants should be built up to reduce waters contamination.

Keywords: coastal management, sustainable livelihood, water compatibility

1. Introduction

Semarang City is a coastal city that produces milkfish in Central Java, with 328.65 tons in 2020. Milkfish is the main cultivated fish commodity in Semarang City and the livelihood for more than 1500 pond farmers with a total income of 6.32 trillion per year. (Central Java Statistics Agency [BPS], 2021). One area in Semarang City that relies on milkfish cultivation as its main source of income is the fish-farmers community in Tanjung Mas Village.

Inland pond for milkfish cultivation is at risk of being damaged by high waves and sea-level rise. Over the last ten years, abrasion has caused a shift in the coastline in Semarang City by more than 0.5 Km (Irsadi et al., 2019) and the loss of ponds in coastal areas (Andreas et al., 2018). In addition, the increase of industry, housing, and commercial spaces have decreased pond cultivation areas in Semarang City. As a result, milkfish farmers experience a decline in milkfish production, threatening business stability (Martuti et al., 2020) and lowering resilience against climate change (Bosma et al., 2017; Purwaningsih & Hermawan, 2021). Furthermore, milkfish ponds in Semarang City are currently threatened by climate change (Ahmed et al., 2019), land-use conflicts, and potential threats from anthropogenic factors, including industrial and household waste (Henriksson et al., 2019).

An adaptation activity in milkfish cultivation has been initiated by farmers in Tanjung Mas Village, Semarang City, who take initiation to build stick-net cages (Keramba Jaring Tancap [KJT]) in shallow water areas. KJT is arranged using bamboo sticks stuck to the seabed and installed with the net on the edges to the bottom. This cultivation technique claimed to maintain water quality, nutrient circulation, and physical conditions to support milkfish growth (Sambu, 2017). However, technology transformation from inland milkfish cultivation to KJT needs to be studied in-depth, especially the factors affecting pond water quality (Ganesh et al., 2020). Anthropogenic factors, such as chemicals pesticides, drugs (Chang et al., 2019), and feed (Srithongouthai & Tada, 2017) in milkfish cultivation, may affect physicochemical conditions of the aquatic ecosystem.

Inland aquaculture practice currently ignores the carrying capacity of the aquatic environment, causing a decline in the estuary ecosystem quality (Gusmawati et al., 2018; Hukom et al., 2020; Proisy et al., 2018). Hence, aquaculture management strategies using KJT must be conducted in line with the principle of sustainable development through balancing the social aspects, economic resources management, and environmental sustainability (Boyd et al., 2020). Therefore, this study aims to analyze the suitability of water conditions and biophysical aspects to support sustainable aquaculture activities in the Tanjung Mas coastal area. This study is expected to raise awareness among aquaculture actors regarding the suitability of the coastal area in their territory.

2. Method

This research was an explorational observation conducted in the KJT aquaculture area, which is administratively included in the Tanjung Mas Village area, Semarang City, Central Java, Indonesia. Data was taken in June – August or during the dry season to accurately photograph the pond waters' original condition.

2.1. Sampling site determination.

Sampling was carried out at 10 points spread from the end of the Mati River to the vicinity of the KJT location at the river's delta. The sample point was determined purposively by considering 1) the location of household wastewater discharge, the outfall of industries around the river, and the site of the KJT. Based on these criteria, the 10 sample area points were divided into 1) industrial waste and outfall areas (points 1-5) and areas close to the open sea (points 6-10) (Figure 1).

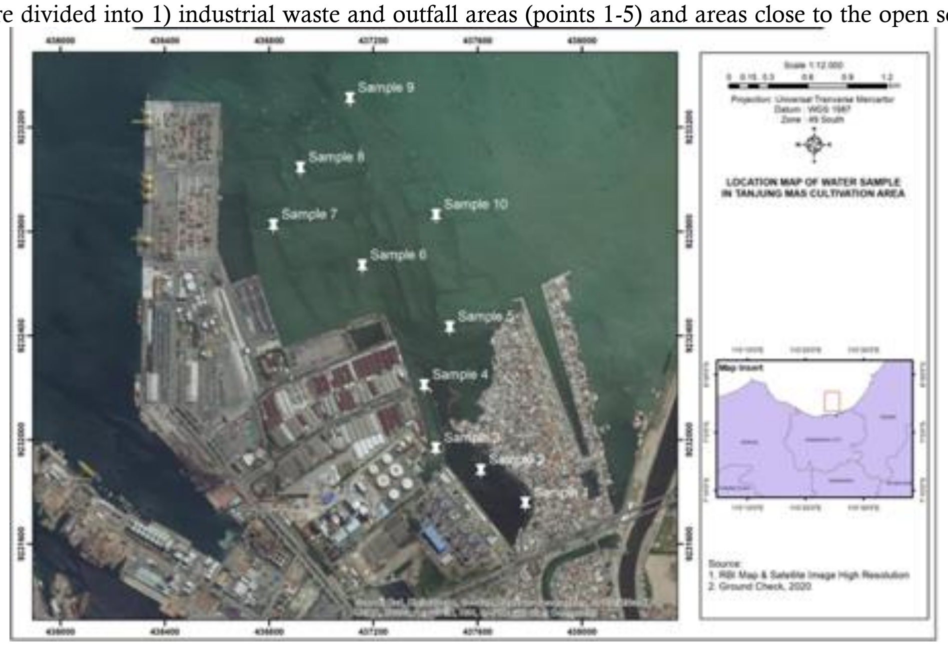


Figure 2. Map of the location for determining the water suitability analysis sample

Water samples were collected compositely from the pond area by taking 1 L of water each from five points or sides and the pond's center. The water was then combined and homogenized before being used for further analysis. The water samples are packaged in dark bottles to avoid chemical damage and physical changes due to light.

2.2. Water Suitability Analysis

Data on water conditions that support milkfish cultivation in this study are grouped into two parameters, namely physical and chemical (Table 1). The parameters were selected from the Government Regulation (PP) No. 22 of 2021 about seawater quality standards for cultivation (Table 1).

Table 1. Water suitability analysis (Site Capability)

Physicochemical parameters (n)	Scoring assumption*	Parameter values (S_n)	Rubric Score**	Weight (W)
Seawater depth (m)	Sea depths between 0 – 10 provide circulation of nutrients and plankton needed for fish growth	≤ 5	5	3
		5 – 10	3	
		≥ 10	1	
Light penetration (cm)	Into the water for milkfish cultivation ranges from 30 – 40 cm, while 0.7 – 1.4.	≤ 3	5	1
		3 – 5	3	
		≥ 5	1	

Physicochemical parameters (n)	Scoring assumption*	Parameter values (S_n)	Rubric Score**	Weight (W)
Turbidity (NTU)	Turbidity is related to the penetration of light needed by phytoplankton for photosynthesis. A reasonable waters threshold is < 5.	≤ 5	5	1
		> 5 - 20	3	
		> 20	1	
Water current (m/s)	Current plays a role in water circulation, which affects the amount of dissolved oxygen and nutrients in the water.	20 – 40	5	3
		10 – < 20 or > 40 – 70	3	
		< 10 or > 70	1	
Temperature (C)	The optimum temperature for milkfish growth is between 23 C – 35 C. Water temperature affects the growth and development of milkfish.	28 – 30	5	2
		26 – < 28 or	3	
		> 30 – 31		
		< 26 or > 31	1	
DO (mg/l)	DO levels suitable for marine life are in the range of > 5 mg/L or 4 – 8 ppm	≥ 5	5	3
		≥ 3 - < 5	3	
		< 3	1	
pH	A good pH value in milkfish cultivation is between 6.5 – 9.	7.5 – 8	5	2
		7 – < 7.5 or	3	
		> 8 – 8.5		
		< 7 or > 8.5	1	
Salinity (mg/L)	Good salinity for milkfish cultivation ranges from 0-35.	29 - 31	5	2
		27 - < 29 or	3	
		> 31 - 33		
		< 27 or > 33	1	
Nitrate (mg/L)	Phytoplankton can grow optimally at a nitrate content of 0.9 ± 3.5 mg/l, while at concentrations below 0.01 or above 4.5 mg/l it can be a limiting factor for phytoplankton growth (Oktora, 2000).	< 0.008	5	1
		> 0.008 - 0.4	3	
		> 0.4	1	
Nitrite (mg/L)	High nitrite causes a decrease in water pH and is toxic to marine biota	0	5	1
		< 0.1	3	
		≥ 0.1	1	
Phosphate Total (mg/L)	It is needed for the growth and metabolism of phytoplankton and marine organisms.	≤ 0.014	5	2
		0.015 - ≤ 0.8	3	
		> 0.8	1	
Ammonia (mg/L)	The lethal concentration (LC50) of ammonia is 1.10 to 22.8 ppm resulting in 5% mortality and 20% growth reduction for cultured fish	0 - 0.2	5	1
		> 0.2 - 0.5	3	
		> 0.5	1	
BOD (mg/L)	The level of pollution is low if the BOD value is 0 – 10 mg/L, while the level of pollution is moderate if it is 10 – 20 mg/l, > 20 mg/L.	≤ 10	5	1
		> 10 - 45	3	
		> 45	1	
Seabed materials	The media affect the survival of milkfish, thus affecting the success of the enlargement business.	Gravel	5	2
		Grit-silt (muddy)	3	
		Silt	1	

Note: * The parameter was adapted Government Regulation (PP) No. 22 of 2021 and modified from Kumar et al., (2017); Olatayo, (2014),

** Physicochemical parameters that are considered essential and dominant gives greater weight in affecting milkfish growth.

To obtain seawater compatibility value (SC) was measured from summaries of the weight (W) score that multiplied by the parameter score (S_n) for each parameter (n) (Formula 1). The seawater compatibility interval class (Table 2).

$$SC = \sum (S_n \times W)$$

Table 2. Water suitability classification criteria

Status Code	Scoring Criteria	Compatibility Status
S1	> 146.7	Excellent
S2	93.3 – 146.7	Proper
N	< 93.3	Improper

3. Result and Discussion

Previously, aquaculture in Tanjung Mas was carried out using inland ponds with embankments directly bordering the sea or other ponds. However, in the early 2000s, this activity began to be abandoned because damaged by abrasion and sea-level rise (Surya et al., 2019). Around 2008, several pond farmers developed aquaculture activities using the KJT system. Currently, the majority of the farmers conduct aquaculture business as a side job when the fishing season is disturbed by weather. However, because milkfish cultivation profit using the KJT system was higher than catching fish, the business became popular and income. KJT is made using bamboos construction that is plugged into a seabed forming a cage block. The nets used by the farmers have hole diameters ranging from 0.5 cm – 0.5 cm for nursery and 1 cm – 1 cm for enlargement (Figure 1).

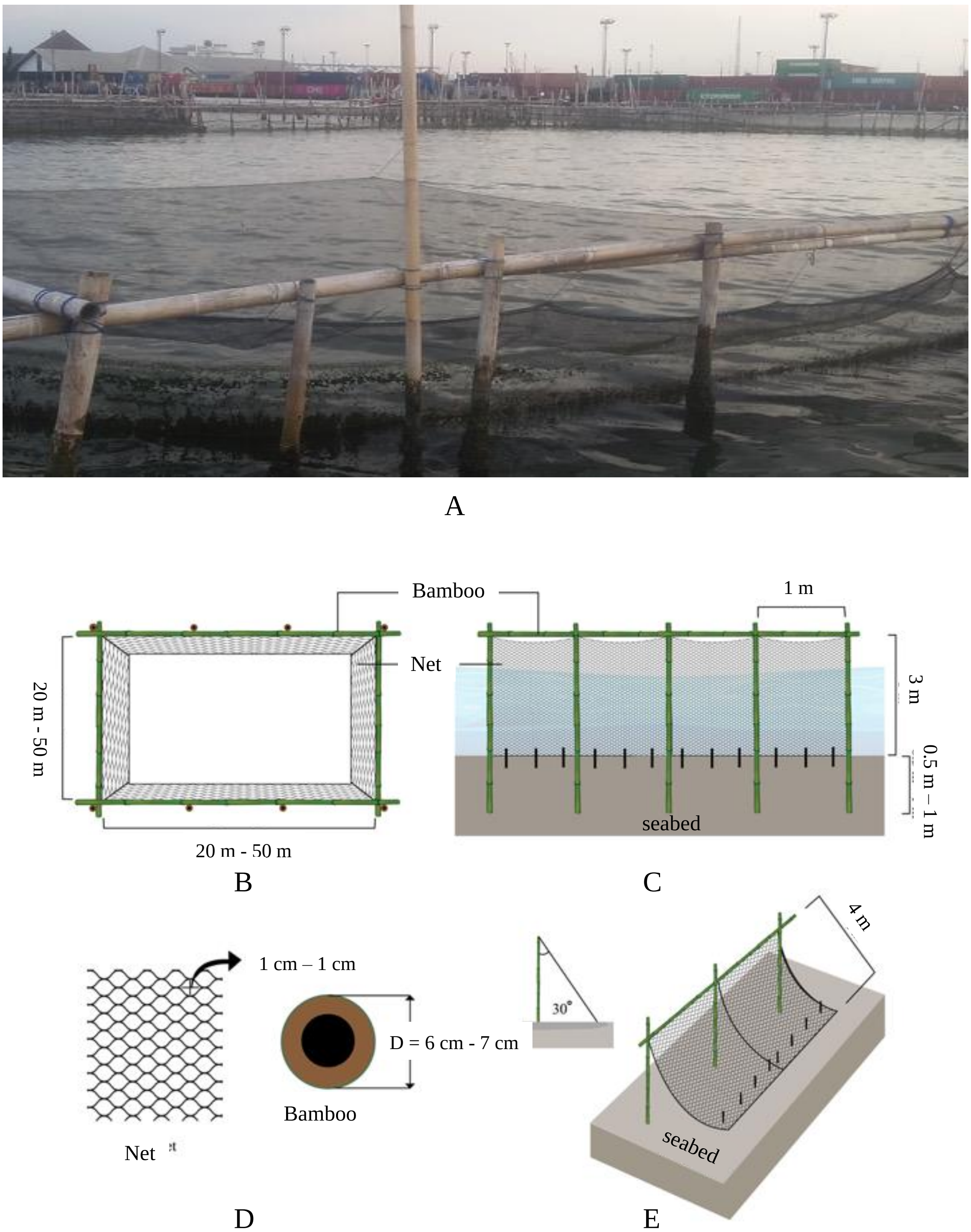


Figure 1. Detailed design of stick-net cage specification used for milkfish cultivation in Tanjung Mas. A) existing stick-net cage; B) upper view of the net-cage; B) construction design; C) materials specification; D) net position on the seabed.

KJT using three layers of nets surround a 1 ha of fishpond with a depth of 3 m. It takes about five rollers of net sizing 30 m x 5 m. The advantage of using KJT is the capability of the construction model that supports nutrient circulation in the seawater. It makes the availability of natural feed for milkfish and reduces additional fed for cultivation (Cornejo et al., 2020). On the other hand, pollutants from outside and ammonia from feed fermentation inside the cage are also very likely to circulate in and out of the pond, as illustrated in Figure 2 (Cha & Lee, 2018).

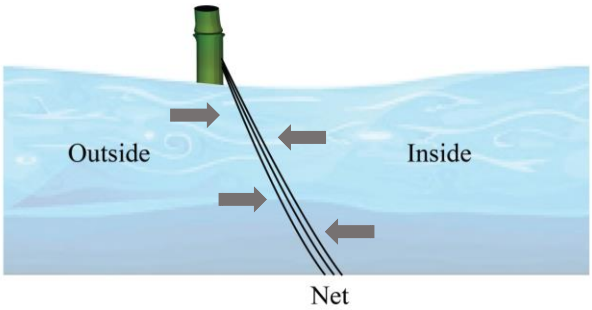


Figure 2. materials flow illustration through net-cage construction

KJT disadvantages are performed by uncontrolled physicochemical conditions inside the cage and are adequately dependent on natural factors. Consequently, the farmers cannot adjust waters condition to speed up milkfish growth. It is necessary to maintain the optimal physical and chemical conditions in the environment according to the age of the milkfish To get optimal growth (Failaman et al., 2021; Mandal et al., 2018).

Seawater aquaculture requires appropriate environmental conditions that support the growth and development of milkfish. In addition, KJT in Tanjung Mas is placed around industrial and household waste streams that contain toxic contaminants that may interfere with milkfish growth or are inappropriate for human consumption. On the other hand, milkfish cultivation may also impact the condition of the seawaters around the pond due to feed and milkfish manure that settles at the pond's seabed.

3.1. Water Suitability Analysis to Support KJT System Cultivation

The carrying capacity of the seawater environment is determining factor for milkfish cultivation. Physically, the Mati river's estuary (the only river in Tanjung Mas) supports milkfish cultivation. However, the differences in the milkfish pond's physical conditions, including water current, temperature, seabed substrate conditions, are observed as illustrated in Figure 3.

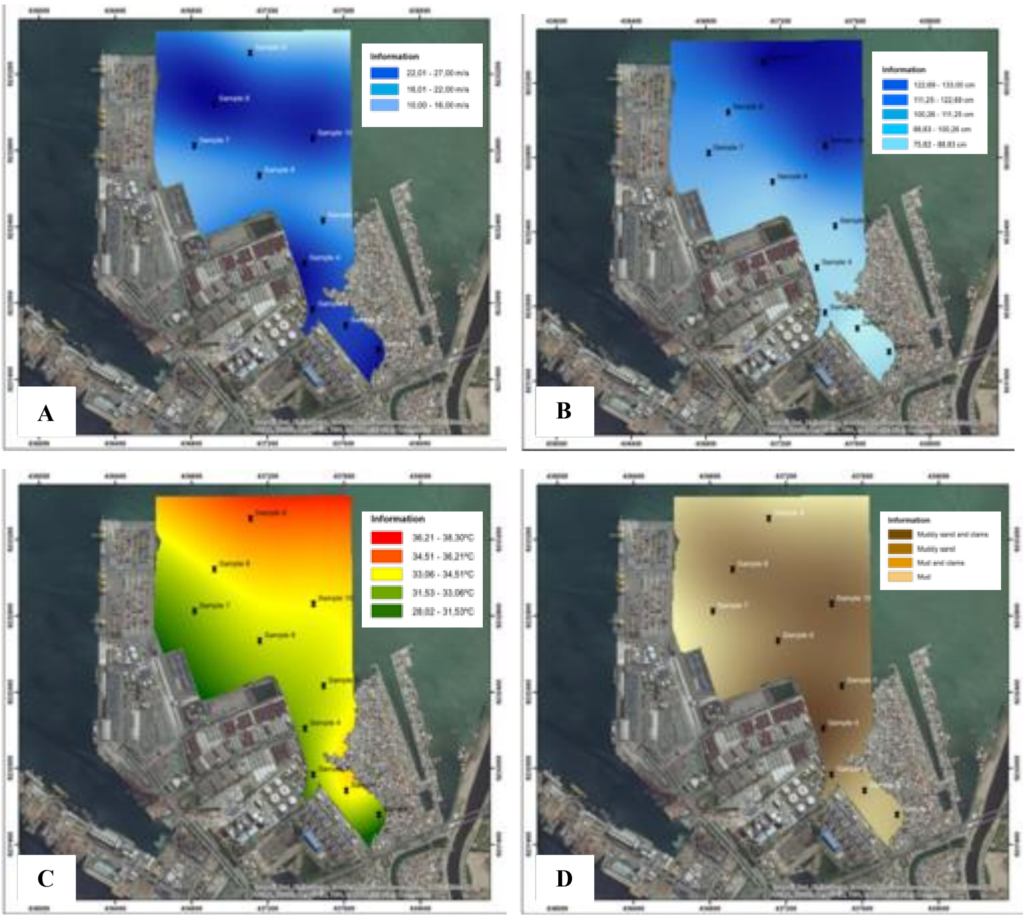


Figure 3 Physical condition of the research sites in Tanjung Mas. A) water current; B) light penetration; C) temperature; and D) seabed sediment in Tanjung Mas fishpond areas.

The seawater depth varies between 4 m – 6 m; however, it is still suitable for milkfish cultivation. Milkfish juveniles will generally live in shallow seawater for two to three weeks, then migrate to mangrove forests, river estuaries, or lakes. The adult will return to the sea to breed. Meanwhile, the substrate samples in Tanjung Mas seawaters range from silt to gravel contained shell fragments and sand. However, the seabed's substrate does not directly affect the milkfish growth because the KJT system is placed on the open seas with nets to a maximum depth of 3 m. In contrast to the inland ponds, which only have a depth from 1 m up to 1.5 m that makes milkfish are directly in contact with the bottom substrate of the seawaters.

Light penetration of water brightness (low debris) indicates good conditions to support milkfish cultivation, even though it is located in the industrial and household waste disposal system. The light penetration significantly correlates to the photosynthesis rate of phytoplankton in providing natural feed for milkfish growth. The abundance of phytoplankton is also supported by relatively low water current and calming waves that keep the water clear from seabed substrate. The seawater currents speed in Tanjung Mas was ranged around 10 m/s – 25 m/s and categorized as low water flow. The coastal area in Tanjung Mas is an estuary of Mati River that has a low discharge because the water sources only come from city drainage and water polder. Water current plays a vital role in nutrient circulation, carrying dissolved and suspended materials, feed distribution, total oxygen solubility, and salinity. Tanjung Mas have seawater with a salinity level of 30‰ – 34‰, which supports milkfish cultivation. Salinity conditions in Tanjung Mas are not much different from the average salinity value of Indonesian waters ranging from 32‰ – 34‰ (Hu et al., 2019). Fluctuations in salinity levels are caused by the high evaporation rate of the surface waters in the east monsoon and rainfall, especially in the west monsoon season. (Ratnawati et al., 2018), and the discharge of river water that enters the ocean (Hamzah et al., 2020). This is in line with this research that the first observation station has a lower salinity because it is located in the delta flow of the Mati River.

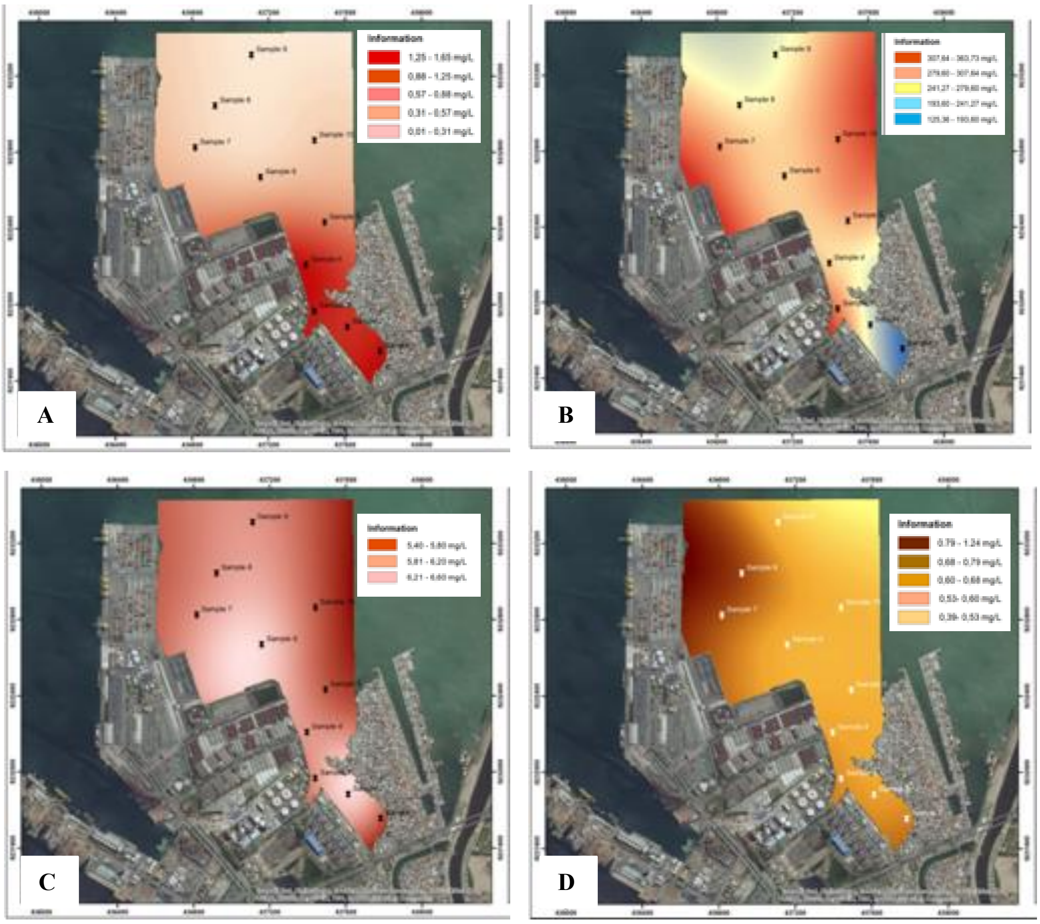
The water temperature of the KJT location in Tanjung Mas ranges between 31ºC – 37ºC. This temperature is not suitable for milkfish cultivation because the optimal temperature for milkfish growth goes from 27ºC – 30ºC (Astuti & Warsa, 2020). The high temperature in the KJT areas may be influenced by the long dry season that increases the water surface temperature due to the high intensity of sunlight. Temperatures that are too high or too low directly affect milkfish foraging behavior, reduce sensitivity and inhibit juvenile growth. (Failaman et al., 2021; Hanke et al., 2019). An increase in temperature raises the decomposition and fermentation of organic matter, producing ammonia that is toxic to fish. The temperature rise also causes stratification or coating of water, which affects the mixing of seabed material and disturbing nutrition distribution (Li et al., 2020). However, the temperature is also needed in oxygen mixing from the surface to the deep waters (Lobine et al., 2021). Seawater temperature also affects surface currents, the distribution of plankton, and the survival of marine life to control the condition of aquatic ecosystems.

An increase in water temperature affects the rate of metabolism and respiration of aquatic organisms and further increases oxygen consumption (Bonachea, 2021; Nie et al., 2017). An increase in water temperature of 10 C causes an increase in oxygen consumption by aquatic organisms about 2-3 times. However, an increase in temperature accompanied by a decrease in dissolved oxygen levels is often unable to meet the oxygen needs of aquatic organisms to carry out metabolism, thus affecting their growth (Audzijonyte et al., 2019; Das et al., 2018; Nelson, 2016; van Rijn et al., 2017). Physical conditions may affect the chemical requirements of pond waters. Based on the analysis of chemical parameters, it shows that in addition to natural physical factors, anthropogenic activities also cause chemical conditions between pond areas. The measurement results show varying values (Table 3) and uneven distribution for each physical and chemical parameter (Figure 3 & 4) at each observation station.

Table 3. Recapitulation of water suitability parameter data (Site Capability) at each observation station

Parameter	Station									
	1	2	3	4	5	6	7	8	9	10
Seawater depth (m)	4.00	4.00	4.00	4.00	4.00	4.00	5.00	5.00	6.00	4.00
Light Penetration (cm)	80,50	70.00	89.00	81.30	78,50	79,50	98,5	91,50	14,12	13,45
Turbidity (NTU)	3.15	3.26	2.58	3.51	3.26	2.96	2.97	2.68	2.38	1.66
Water current (m/s)	25.00	20.00	23.00	25.00	10.00	10.00	12.00	27.00	10.00	23.00
Temperature (C)	31.00	34.00	32.00	32.00	33.00	33.00	32.00	34.00	37.00	34.00
DO (mg/l)	6.40	5.44	6.00	5.84	6.32	5.68	6.16	6.00	5.92	6.24
pH	6.50	6.80	6.40	6.90	7.30	7.10	7.10	7.20	7.30	7.50
Salinity (‰)	30.00	31.00	32.00	32.00	32.00	32.00	33.00	34.00	34.00	33.00
Nitrate (mg/L)	0.68	0.57	0.62	0.55	0.45	0.46	0.90	0.94	0.40	0.68
Nitrite (mg/L)	0.03	0.04	0.06	0.04	0.02	0.02	0.01	0.01	0.01	0.01
Phosphate (mg/L)	0.99	0.41	0.26	0.27	0.11	0.20	0.07	0.08	0.06	0.08
Ammonia (mg/L)	1.57	1.40	1.54	1.57	0.92	0.36	0.29	0.16	0.07	0.30
BOD (mg/L)	124.70	249.40	364.50	306.90	326.10	306.90	345.30	287.80	268.60	364.50
Seabed materials	S	S	S-Cs	Gs-Cs	Gs	S-Cs	S	S-Cs	S	GS

Note: Cs = clam shell shards; Gs = Grit-silt (muddy); and S = Silt


A
B
C
D

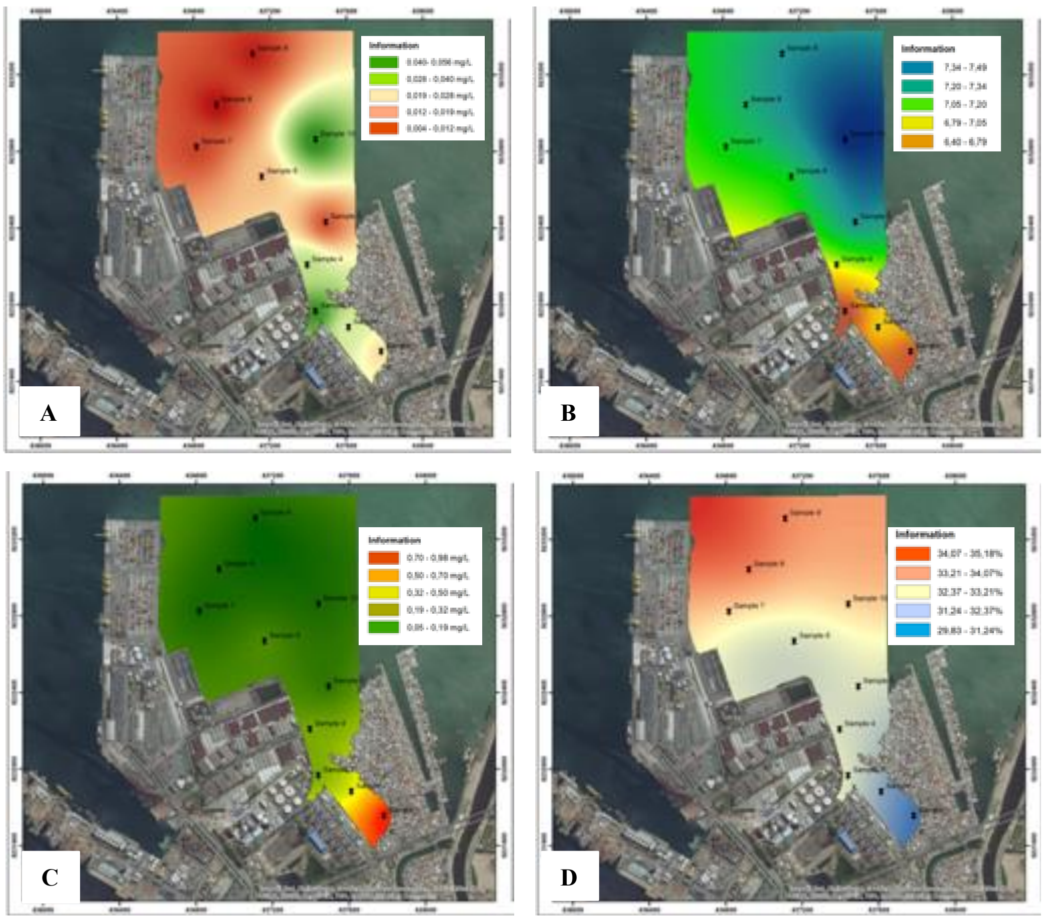

A
B
C
D

Figure 4. Chemical factors condition of the research sites in Tanjung Mas. A) ammonia distribution; B) BOD level; C) DO ; D) nitrate; E) nitrite; F) pH; G) phosphate; H) salinity Tanjung Mas fishpond areas.

The majority of chemical factors in the KJT aquatic environment are suitable for milkfish growth. Furthermore, dissolved oxygen (DO) levels meet seawater quality standards and support the development of cultured fish. Adequate dissolved oxygen levels may be produced from plankton photosynthesis and air diffusion (Horak et al., 2018). In addition, oxygen is a limiting factor for water quality because it plays an essential role in the fermentation of organic and inorganic materials at the seabed (Orsi, 2018).

The needed O_2 for decomposition and fermentation can be identified from biochemical oxygen demand (BOD) content. A higher concentration in the fishpond indicates the possibility of high organic matter in the waters. (Jorgensen & Marshall, 2016). The results of BOD measurements at ten observation stations shown a value of 124.7 mg/L – 364.5 mg/L, especially at stations 3 – 9. Based on the BOD criteria, it can be seen that the seawaters around Tanjung Mas are classified as high polluted by organic compounds. This is probably caused by the decomposition process of milkfish feed, which is sedimented at the seabed. In addition, the map (Figure 4B) shows high BOD concentrations are distributed mainly near the industrial's outfall areas. Even though the pH around the Tanjung Mas water area is in the neutral range of 6 – 7 and supports milkfish cultivation. In nature, the pH value ranges from 4 – 9, where the unbalancing of the pH affects aquaculture fish or the presence of seawater organisms.

The fermentation process of organic materials releases N into seawaters in the form of nitrate (NO_3), nitrite (NO_2), and ammonia (NH_4) (Oshiki et al., 2016; Spataru, 2021, 2017). The concentration of NO_3 in Tanjung Mas, was ranged from 0.3947 mg/L - 0.9386 mg/L, while nitrite was 0.0058 mg/L – 0.0338 mg/L, and ammonia was 0.073 mg/L – 1.568 mg/L. High concentrations of NO_3 and NO_2 in the seawaters can stimulate the growth and development of phytoplankton and become an indicator of fishpond fertility (Hardikar et al., 2019). NO_2 is also an indicator of decreasing N contamination because its formation comes from the oxidation of NH_4, which is toxic. Then, an availability of NO_2 comes from the oxidation of NH_4 to NO_2 carried out by Nitrosomonas bacteria, while the oxidation of NO_2 to NO_3 is carried out by Nitrobacter (Santoro et al., 2021). In nature, NO_2 is usually found in lower amounts than NO_3 because it is unstable and easy to react with oxygen.

The findings obtained in this study showed that the measured NH_4 levels were qu=ite high at seven observation stations (stations-1, 2, 3, 4, 5, 6, and 10). This is because the location is on the Mati River, which carries domestic waste from settlements. Organic materials from domestic waste increase the rate of decomposition and fermentation of organic materials to produce NH_4 as a by-product. The increase in NH_4 contamination is positively correlated with an increase in anthropogenic factors, primarily related to the residential, agricultural, livestock, and industrial sectors. (Bessa et al., 2021; Sproson et al., 2021). In addition, the problem faced in Tanjung Mas waters is the lack of suitable sanitation, causing pollution and the balance of the pond waters ecosystem.

Low NH_4 concentrations were measured at stations 7, 8, and 9 because they are located far from settlements and industrial outfall, have more than 5 m depth and are near the open sea. This condition improves water circulation due to ocean currents and a more homogeneous seawater diffusion process.

Domestic waste may be one of the main factors that increase phosphate concentrations in the KJT waters area. Various studies have shown that human activities, including household waste, have increased the concentration of contaminants in the oceans, such as nitrogen (Jickells et al., 2017), phosphate (Badawy et al., 2018; Thiombane et al., 2019), to heavy metals (Bessa et al., 2021; Chu et al., 2019), This is indicated by the distribution of phosphate levels at stations 1 to 5 which is higher than the other five observation stations. Phosphate is a nutrient that is a determining factor in the number of phytoplankton in the sea and is usually found in the form of organic compounds (Bristow et al., 2017).

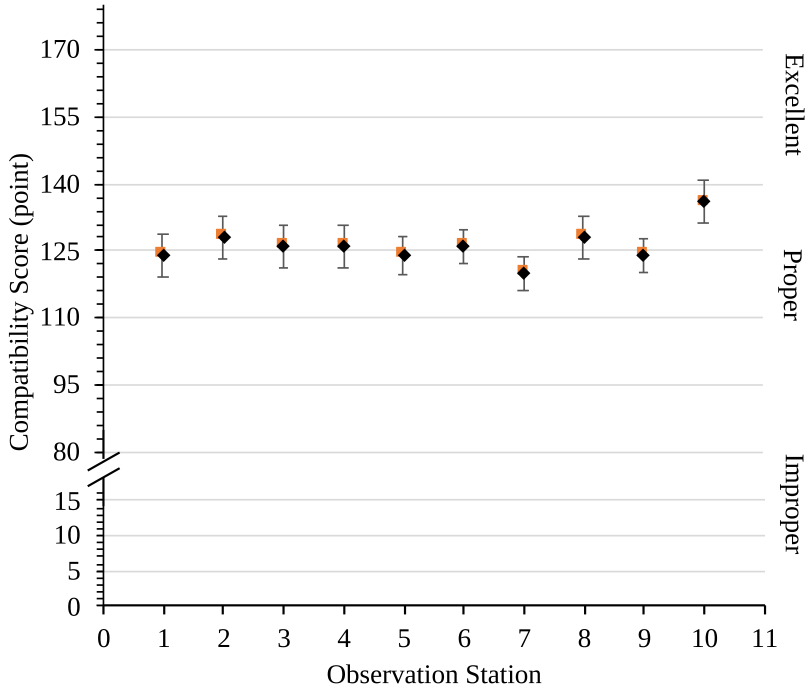


Table 4. Compatibility for milkfish cultivation in Tanjung Mas waters area based on the observation station.

The water compatibility value (Table 4) shows that all observation stations were categorized at the proper level (S2). It indicates that the Tanjung Mas water area is sufficient and potential to be developed as a KJT cultivation area. However, limiting factors require special attention to increasing milkfish productivity, such as N and P levels and BOD.

3.2. Analysis of KJT System Carrying Capacity Based on Water Capacity

The total area of potential waters in the Tanjung Mas for KJT is 119.51 Ha, but referring to the government regulation, it is only 20% that can be used for aquaculture. Then the optimum area for the KJT aquaculture system that can be developed is only about 23,902 Ha. However, based on the observation, the existence of KJT has overcapacity, which is occupied by 22 cages with more than 53.45 Ha of waters area. Furthermore, it can be seen that the utilization of the waters has exceeded the carrying capacity because the practical potential of the waters area for the KJT system is only 2.4 cage/ Ha for only 10 cage units. Therefore, it is necessary to reduce the number of KJT units by looking at the existing conditions.

High occupied waters area with dense cultured milkfish may overshoot the water's capacity and potentially triggering mass death of the marine organism. The condition of the waters directly adjacent to the sea provides an advantage for faster purification. However, the continuous input of domestic and industrial pollutants and low river discharge resulted in a low nature purification rate. This must be a common concern, considering that the waters in the KJT area are the output of several waste installations from the community (domestic) and industries.

4. Conclusion

In general, the physicochemical factors in Tanjung Mas water areas are proper and support milkfish cultivation. However, the existing condition shows that water utilization for milkfish aquaculture activities using KJT has exceeded the carrying capacity. It potentially disturbs milkfish growth and may lead to the unbalancing ecosystem and trigger the death of the marine organism. On the other hand, high pollution from industries and household waste has become a significant problem that may affect milkfish growth and become a health issue. High P and NH_4 were primarily detected in the observation station near the industrial outfall and Mati River estuary, containing domestic waste. It needs an improvement of waste management system from industrial and household by providing sewage purification utilities and scheduling waste disposal based on tidal conditions after purification treatment.

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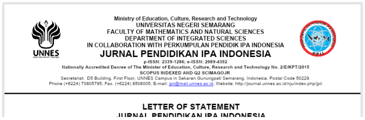

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LETTER OF STATEMENT

The Assessment of Water Compatibility of Adaptable Plug Net-Cage for Resilience Milkfish Cultivation in Tanjung Mas, Indonesia

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Abstrak

Budidaya bandeng telah menjadi mata pencaharian utama petani tambak di wilayah pesisir. Namun kondisi saat ini, lahan untuk budidaya ikan bandeng semakin menyusut akibat adanya pemanfaatan lahan untuk permukiman dan industri. Keramba jaring tancap (KJT) dianggap sebagai salah satu solusi dalam pengembangan budidaya bandeng di lahan terbatas, karena mampu/dapat digunakan sebagai sarana budidaya dengan tetap menjaga kualitas lingkungan perairan serta sirkulasi nutrisi. Oleh sebab itu, perlu adanya kajian daya dukung perairan dan kondisi eksisting tambak dalam mendukung keberhasilan budidaya bandeng sistem KJT. Penelitian ini bertujuan untuk menganalisis kesesuian kondisi perairan dan aspek biofisik untuk mendukung kegiatan budidaya perikanan yang berkelanjutan. Penelitian ini merupakan observasi eksporatif yang dilakukan di kawasan perairan Kelurahan Tanjung Mas, Kota Semarang, Jawa Tengah, Indonesia. Pengambilan sampel dilakukan di 10 titik yang ditentukan secara purposive dengan pertimbangan letak lokasi titik terhadap buangan air limbah rumah tangga dan outfall industry. Berdasarkan kriteria tersebut, 10 titik area sampel dibagi menjadi 1) area buangan limbah dan outfall sindustri (point 1-5) dan area dekat dengan laut terbuka (point 6-10). Hasil penelitian diperoleh hasil, parameter fisik meliputi suhu, arus, kekeruhan dan kecehahan hingga substrat dasar perairan berada dibawah ambang batas baku mutu air laut. Sedangkan secara kimiawi, kadar NH_4 dan P diperairan tambak sangat tinggi, kemungkinan karena cemaran limbah domestic dan industry serta tingginya aktivitas dekomposit oleh mikroorganisme. Namun kondisi eksisting KJT menunjukkan bahwa pemanfaatan perairan telah melebihi kapasitas daya tampung perairan. Secara umum kondisi perairan di lokasi KJT Budidaya ikan bandeng berdasarkan analisis kesesuaian perairan berada dalam kategori sesuai, meskipun perlu adanya pengurangan jumlah kepadatan tambak. Selain itu, perlu adanya pengelolaan limbah secara berkala dan pembangunan instalasi pengolahan air limbah.

Keyword: coastal management, sustainable livelihood, water compatibility

Latar Belakang

Kota Semarang merupakan kota pesisir penghasil bandeng di Jawa Tengah dengan total produksi mencapai 328,65 ton pada tahun 2020. Bandeng merupakan komoditas ikan budidaya utama di Kota Semarang dan menjadi mata pencaharian utama oleh lebih dari 1500 petani tambak dengan total omset mencapai 6.32 triliun per tahun (Badan Pusat Statistik Jawa Tengah

[BPS], 2021). Salah satu kawasan di Kota Semarang yang juga mengandalkan budidaya bandeng sebagai sumber penghasilan utama adalah masyarakat di Kelurahan Tanjung Mas.

Budidaya bandeng dalam tambak darat rentan mengalami kegagalan panen sebagai akibat abrasi oleh gelombang tinggi dan kenaikan muka air laut. Selama kurun waktu 10 tahun terakhir, abrasi telah menyebabkan pergeseran garis pantai di Kota Semarang hingga lebih dari 0.5 Km (Irsadi et al., 2019) dan hilangknya tambak di kawasan pesisir (Andreas et al., 2018). Selain itu, keberadaan industry dan peningkatan pembangunan perumahan atau kawasan komersil di pesisir Kota Semarang menyebabkan turunnya luas area budidaya tambak bandeng. Sebagai akibatnya, peternak bandeng mengalami penyusutan produksi yang mengancam kestabilan usaha (Martuti et al., 2020) dan ketahanan terhadap perubahan iklim (Bosma et al., 2017; Purwaningsih & Hermawan, 2021).

Bentuk adaptasi usaha budidaya bandeng telah mulai diinisiasi oleh petani bandeng di Kelurahan Tanjung Mas Semarang, melalui pembuatan keramba jaring tancap (KJT) di area perairan dangkal. KJT disusun menggunakan bamboo-bamboo yang ditancapkan pada dasar perairan dan dibatasi menggunakan waring pada bagian tepi dan dasar. Teknik budidaya tersebut diklaim menjaga kualitas air, sirkulasi nutrisi, dan kestabilan kondisi fisik sehingga dapat mendukung pertumbuhan bandeng (Sambu, 2017). Meskipun demikian pemindahan budidaya bandeng dari metode tambak menjadi KJT perlu dikaji secara mendalam, terutama terkait faktor-faktor yang mempengaruhi kondisi kualitas perairan (Ganesh et al., 2020). Faktor-faktor seperti penggunaan bahan kimia, obat-obatan (Chang et al., 2019), dan pakan (Srithongouthai & Tada, 2017) dalam budidaya bandeng kemungkinan berpengaruh terhadap kondisi fisikokimia lingkungan. Lebih lanjut, ketahanan tambak bandeng saat ini terancam oleh perubahan iklim (Ahmed et al., 2019), konflik pemanfaatan ruang, limbah, dan potensi ancaman dari faktor antropogenik (Henriksson et al., 2019)

Seringkali, pengembangan budidaya perikanan tidak memperhatikan daya dukung lingkungan, sehingga menyebabkan terjadinya penurunan kualitas ekosistem estuarin (Gusmawati et al., 2018; Hukom et al., 2020; Proisy et al., 2018). Padahal, strategi pengelolaan budidaya perikanan dengan KJT harus dilakukan dengan memperhatikan prinsip pembangunan berkelanjutan. Prinsip berkelanjutan harus diarahkan melalui pola pemanfaatan sumberdaya perairan dengan menyeimbangkan aspek sosial, pemanfaatan sumber daya ekonomi, dan kelestarian lingkungan (Boyd et al., 2020). Oleh sebab itu, penelitian ini bertujuan untuk menganalisis kesesuian kondisi perairan dan aspek biofisik untuk mendukung kegiatan budidaya perikanan yang berkelanjutan di perairan Tanjung Mas. Diharapkan melalui kegiatan ini dapat meningkatkan edukasi dan kesadaran terhadap para pelaku budidaya terkait kondisi kesesuaian perairan di wilayahnya.

Method

Penelitian ini merupakan observasi eksporatif yang dilakukan di kawasan budidaya perikanan KJT yang secara administratif masuk dalam wilayah Kelurahan Tanjung Mas, Kota Semarang, Jawa Tengah, Indonesia. Data diambil pada bulan Juni – Agustus atau selama musim kemarau dengan tujuan memotret kondisi asli kawasan perairan tambak secara akurat.

Penentuan titik sampel.

Pengambilan sampel dilakukan pada 10 titik yang tersebar mulai dari ujung Sungai Mati hingga sekitar lokasi KJT yang ada di muara sungai. Titik sampel ditentukan secara purposive dengan pertimbangan 1) lokasi buangan air limbah rumah tangga, outfall industry-industri yang berada di sekitar sungai, serta lokasi KJT. Berdasarkan kriteria tersebut, 10 titik area sampel dibagi menjadi 1) area buangan limbah dan outfall sindustri (point 1-5) dan area dekat dengan laut terbuka (point 6-10) (Figure 1).

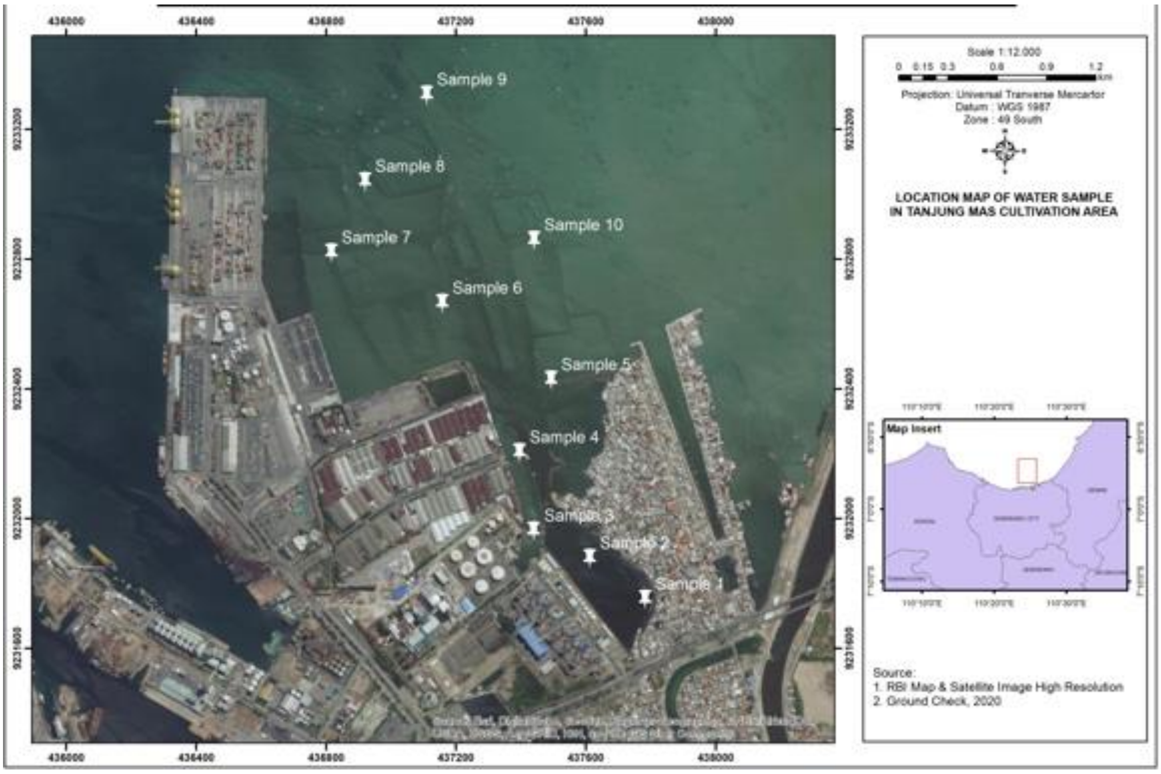


Figure 1. Peta lokasi penentuan sampel analisis kesesuaian perairan

Sampel air dikumpulkan secara komposit dari area tambak dengan mengambil masing-masing 1 L air dari lima titik atau sisi dan tengah tambak. Air kemudian digabung dan dihomogenisasi sebelum digunakan untuk analisis lebih lanjut. Sampel air kemudian dikemas dalam botol gelap untuk menghindari kerusakan kandungan kimia dan perubahan fisik akibat cahaya.

Analisis Kesesuaian Perairan

Data kondisi perairan yang menunjang budidaya bandeng dalam penelitian ini dikelompokkan menjadi dua parameter, yaitu fisik dan kimia (Tabel 1). Pemilihan parameter tersebut berdasarkan pada Peraturan Pemerintah (PP) Nomer 22 Tahun 2021 tentang baku mutu air laut yang disesuaikan dengan kebutuhan terkait budidaya bandeng. Jenis-jenis parameter, dan rubrik penilaian esmeralf (Tabel 1).

Tabel 1. Analisis kesesuaian perairan (*Site Capability*)

Parameter	Asumsi Penilaian	Kisaran nilai	Skor	Bobot
Kedalaman perairan (m)	Kedalaman laut antara 0 – 10 menyediakan sirkulasi nutrisi dan plamkton ynag dibutuhkan untuk pertumbuhan ikan	≤ 5	**5**	3
		5 – 10	3	
		≥ 10	1	
Kedalaman penetrasi cahaya (m)	kedalam air untuk budidaya ikan bandeng berkisar antara 30 – 40 cm (WWF, 2014), sedangkan 0.7 – 1.4 m menurut (Cocon 2018)	≤ 3	**5**	1
		3 – 5	3	
		≥ 5	1	
Kekeruhan/ turbiditas (NTU)	Kekeruhan terkait penetrasi cahaya yang dibutuhkan oleh fitoplankton untuk berfotosintesis. Ambang batas perairan yang baik yaitu < 5.	≤ 5	**5**	1
		> 5 - 20	3	
		> 20	1	
		20 – 40	**5**	3

Parameter	Asumsi Penilaian	Kisaran nilai	Skor	Bobot
Kecepatan Arus (m/s)	Arus berperan dalam sirkulasi air yang mempengaruhi jumlah kelarutan oksigen dan nutrisi dalam air.	10 – < 20 atau > 40 – 70	3	
		< 10 atau > 70	1	
Suhu (C)	suhu optimum untuk pertumbuhan ikan bandeng antara 23 ºC – 35 ºC. Suhu perairan mempengaruhi pertumbuhan dan perkembangan bandeng.	28 – 30	**5**	2
		26 – < 28 atau > 30 – 31	3	
		< 26 atau > 31	1	
DO (mg/l)	Kadar DO perairan yang cocok untuk kehidupan biota laut adalah berkisar antara > 5 mg/L atau 4 – 8 ppm	≥ 5	**5**	3
		≥ 3 - < 5	3	
		< 3	1	
pH	Nilai pH yang baik dalam budidaya ikan bandeng yaitu antara 6,5 – 9, sedangkan menurut WWF berkisar antara 6 - 8.	7.5 – 8	**5**	2
		7 – < 7.5 atau > 8 – 8.5	3	
		< 7 atau > 8.5	1	
Salinitas (ppm)	Salinitas yang baik untuk budidaya bandeng berkisar antara 0-35 ‰.	29 - 31	**5**	2
		27 - < 29 atau > 31 - 33	3	
		< 27 atau > 33	1	
Nitrat (mg/l)	Fitoplankton dapat tumbuh optimal pada kandungan nitrat sebesar 0,9 ± 3,5 mg/l, sedangkan pada konsentrasi dibawah 0,01 atau diatas 4,5 mg/l dapat merupakan faktor pembatas pertumbuhan fitopankton (Oktora, 2000).	< 0.008	**5**	1
		> 0.008 - 0.4	3	
		> 0.4	1	
Nitrit (mg/l)	Nitrit yang tinggi menyebabkan penurunan pH air dan bersifat toksik bagi biota laut	0	**5**	1
		< 0.1	3	
		≥ 0.1	1	
Phosphat Total (mg/l)	Dibutuhkan untuk proses pertumbuhan dan metabolisme fitoplankton dan organisme laut	≤ 0.014	**5**	2
		0.015 - ≤ 0.8	3	
		> 0.8	1	
Amonia (mg/l)	Kadar letal concentration (LC50) ammonia adalah 1,10 hingga 22,8 ppm menghasilkan mortalitas 5% dan 20% penurunan pertumbuhan untuk ikan budidaya	0 - 0.2	**5**	1
		> 0.2 - 0.5	3	
		> 0.5	1	
BOD (mg/l)	tingkat pencemaran rendah jika nilai BOD 0 – 10 mg/L, sedangkan tingkat pencemaran sedang jika 10 – 20 mg/l, > 20 mg/L.	≤ 10	**5**	1
		> 10 - 45	3	
		> 45	1	
Substrat Dasar	Media berpengaruh terhadap kesintasan hidup ikan bandeng, sehingga mempengaruhi keberhasilan usaha pembesaran.	Pasir	**5**	3
		Pasir Berlumpur	3	
		Lumpur	1	

Note: adapted and modified from (Kumar et al., 2017; Olatayo, 2014)

Parameter perairan yang dianggap penting dan dominan menjadi dasar pertimbangan pemberian bobot yang lebih besar. Untuk memperoleh nilai kelayakan atau kesesuaian setiap parameter, maka nilai bobot dikalikan dengan skor untuk masing-masing parameter pada setiap stasiun yang diperoleh dari hasil pengukuran lapangan. Interval kelas kesesuaian perairan diperoleh berdasarkan metode Equal Interval, yaitu selang tiap-tiap kelas diperoleh dari jumlah perkalian nilai maksimum tiap bobot dan skor dikurangi jumlah perkalian nilai minimunya dibagi menjadi tiga kelas (Tabel 2)

Tabel 2. Kriteria klasifikasi kesesuaian perairan

Kode	Kriteria	Klasifikasi
S1	> 146.7	Sangat sesuai
S2	93.3 – 146.7	Sesuai
N	< 93.3	Tidak Sesuai

Result and Discussion

Pada mulanya, budidaya perikanan di Tanjung Mas dilakukan menggunakan tambak-tambak dengan tanggul tanah yang mengitari kolam dan menjadi pembatas dengan laut. Namun pada awal tahun 2000an, aktivitas tersebut mulai ditinggalkan karena tambak mengalami abrasi dan rusak akibat peningkatan muka air laut (Surya et al., 2019). Sekitar tahun 2008 beberapa warga mulai melakukan kegiatan budidaya perikanan dengan sistem KJT.

Konstruksi KJT diinisiasi sebagai respon terhadap semakin berkurangnya lahan tambak permanen di darat akibat pembangunan dan abrasi. Mayoritas pemilik tambak budidaya bandeng merupakan nelayan yang menggunakan KJT sebagai usaha sampingan ketika musim tangkap ikan terganggu cuaca. Namun, keuntungan yang dihasilkan dari budidaya bandeng dengan sistem KJT lebih tinggi dibanding menangkap ikan. Hal tersebut menyebabkan pembudidaya ikan bandeng lebih fokus dengan usaha budidaya tersebut dibanding menangkap ikan di laut lepas. KJT dibuat menggunakan kontruksi berbahan bambu yang ditancapkan ke dasar perairan membentuk petak karamba. Waring yang digunakan oleh pembudidaya bandeng memiliki diameter lubang berkisar antara 0.5 cm – 0.5 cm untuk tambak pembibitan dan 1 cm – 1 cm untuk tambak pembesaran. Untuk mencegah kerusakan akibat ombak laut, sebagai pembatas diikatkan ke bambu dan bagian bawah waring diikatkan pemberat atau ditancapkan menggunakan pasak bamboo (Figure 1).

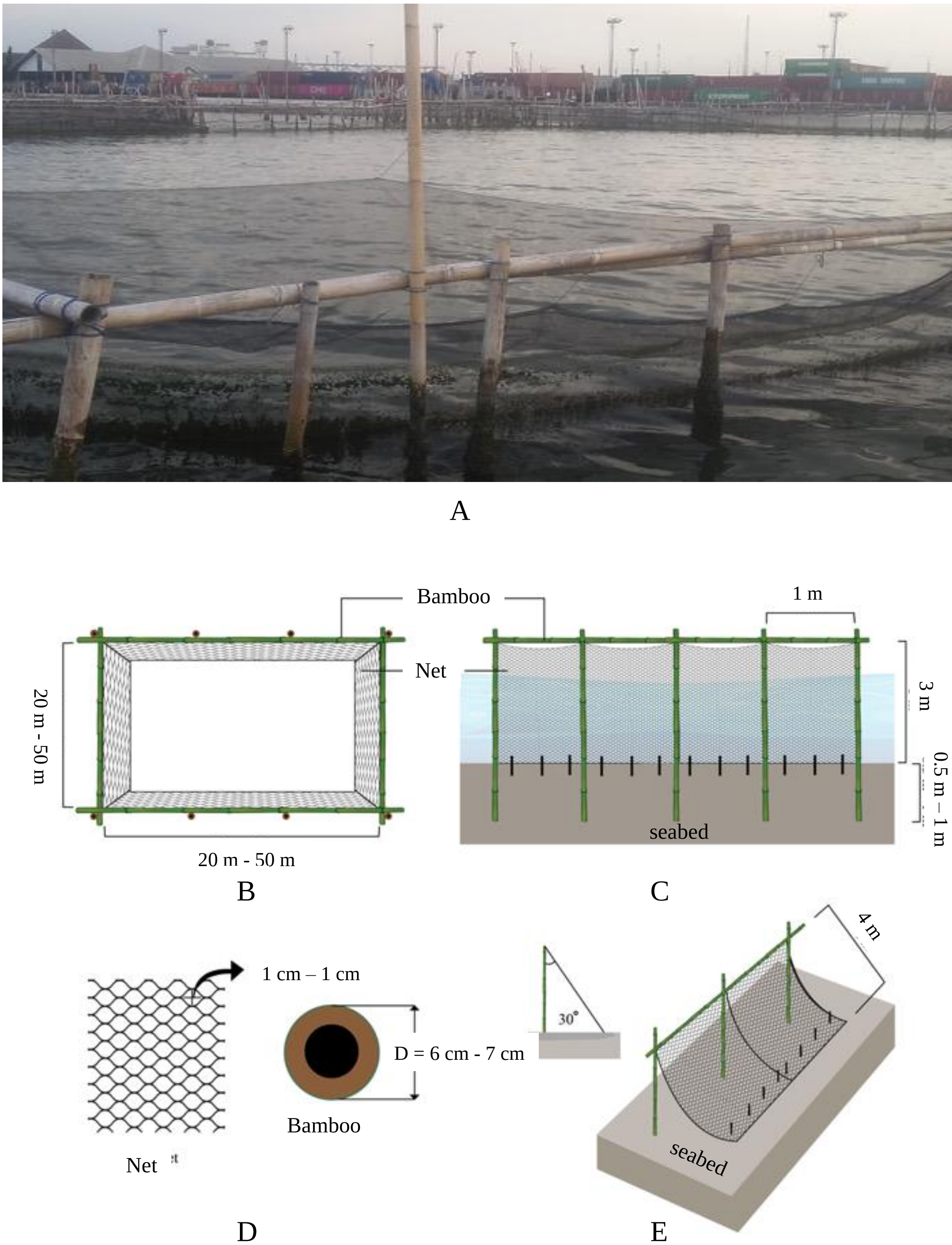


Figure 1. Detail design of Plug Net-Cage specification used for milkfish cultivation in Tanjung Mas. A) upper view of the net-cage; B) plug net-cage construction design; C) materials specification; D) net position on the seabed.

KJT yang digunakan petani untuk budidaya ikan dan udang dibuat dengan teknik yang masih sederhana dengan beberapa bahan seperti: waring (jaring), bambu, jangkar dan tali. Untuk menghasilkan tiga lapis waring yang mengitari 1 Ha tambak dengan kedalaman 3 m, dibutuhkan sekitar 5 rol waring berukuran 30 m x 5 m. Kelebihan penggunan design keramba tersebut adalah dukungan model konstruksi yang memungkinkan terjadinya sirkulasi air laut yang kaya nutrisi. Hal tersebut berdampak pada ketersediaan pakan alami dan mengurangi pemberian pellet (Cornejo et al., 2020). Disisi lain, pencemar dari luar maupun ammonia dari dalam karamba sebagai akibat fermentasi pakan juga sangat mungkin untuk bersirkulasi keluar masuk tambak seperti ilustrasi pada Figure 2 (Cha & Lee, 2018).

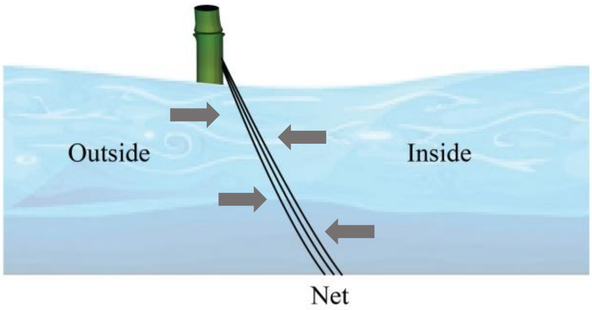


Figure 2. materials flow illustration through net-cage construction

Kualitas air tidak dapat dikontrol dengan baik dan tergantung pada faktor alam, tanpa dapat disesuaikan untuk mendukung kebutuhan hidup ikan bandeng. Padahal untuk mendapatkan pertumbuhan yang optimal, diperlukan penyesuaian kondisi fisik dan kimia yang optimal di lingkungan sesuai umur bandeng (Failaman et al., 2021; Mandal et al., 2018).

Usaha budidaya perairan lepas membutuhkan kondisi lingkungan yang dapat mendukung pertumbuhan dan perkembangan ikan bandeng. Ditambah tempat usaha KJT di Tanjung Mas, berada disekitar industry dan permukiman padat yang menghasilkan kontaminan yang kemungkinan mengganggu pertumbuhan bandeng. Disisi lain, budidaya bandeng kemungkinan juga berdampak terhadap konsisi perairan di sekitar tambak, akibat pakan dan kotoran bandeng yang mengendap di dasar tambak.

Analisis Kesesuaian Perairan untuk Mendukung Budidaya Sistem KJT

Daya dukung lingkungan fisik menjadi salah satu faktor penentu keberhasilan budidaya bandeng. Secara fisik, perairan di muara sungai Mati, Tanjung mas memiliki parameter lingkungan fisik yang mendukung budidaya bandeng. Meskipun demikian, perbedaan kondisi fisik yang meliputi kecepatan gelombang, suhu, kedalaman hingga kondisi substrat secara jelas teramati sebagaimana tergambar pada Figure 3.

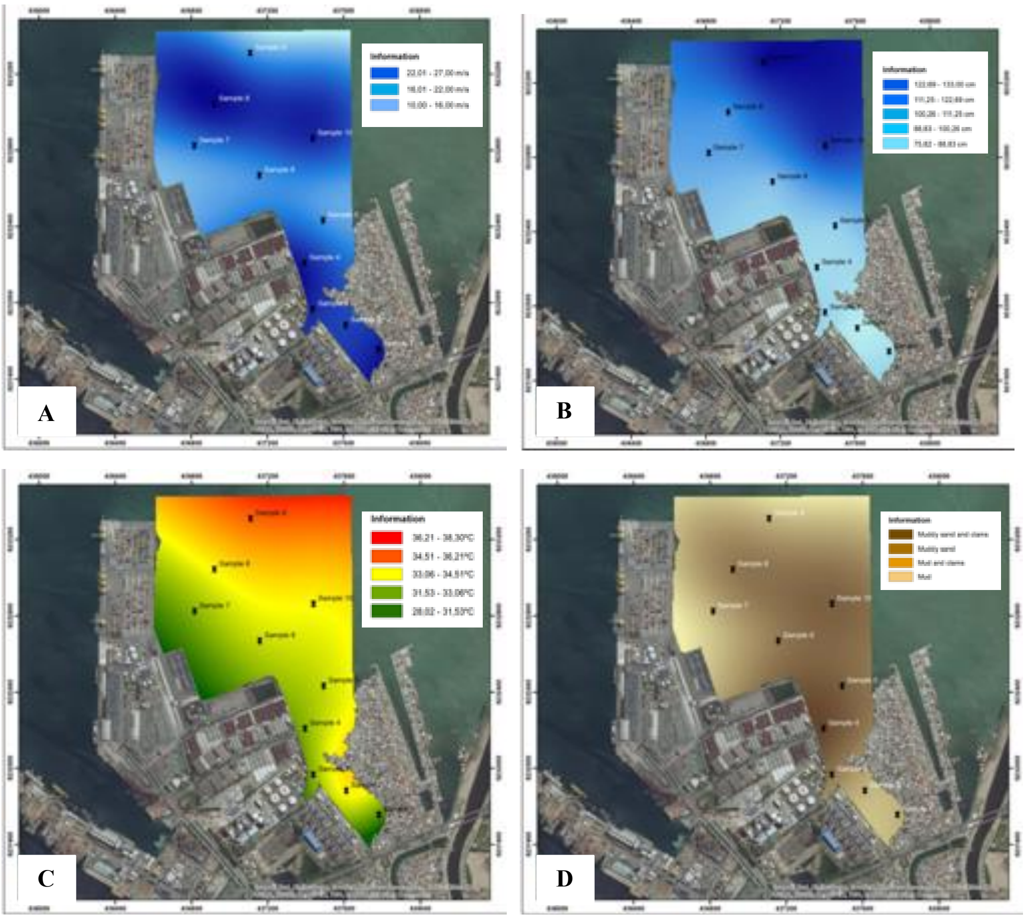


Figure 3 Physical condition of the research sites in Tanjung Mas. A) water current; B) light penetration; C) temperature; and D) seabed sediment in Tanjung Mas fishpond areas.

Kedalaman perairan yang bervariasi antara 4 m – 6 m, masih sesuai untuk budidaya ikan bandeng. Jouvenil bandeng pada umumnya akan hidup pada perairan laut dangkal selama 2 hingga 3 minggu, kemudian bermigrasi ke hutan mangrove, muara sungai, hingga danau. Banden dewasa akan kembali ke laut dengan kedalaman 10 m – 30 m untuk berkembang biak. Sementara itu, sampel substrat dasar di perairan Tanjung Mas berjenis lumpur hingga campuran pecahan cangkang kerang dan berpasir. Substrat dasar perairan tidak berpengaruh secara langsung pada pertumbuhan bandeng karena budidaya dilakukan pada laut lepas dengan jaring hingga kedalaman maksimal 3 m. Berbeda dengan tambak di daratan yang hanya memiliki kedalaman 1 m – 1,5 m dimana ikan bandeng secara langsung kontak dengan substrat dasar perairan.

Faktor fisik, seperti tingkat kecerahan air menunjukkan kondisi yang baik dalam mendukung budidaya bandeng, meskipun berada di muara sungai, dekat permukiman, dan buangan limbah industri. Tingkat kecerahan air laut sangat menentukan laju fotosintesis fitoplankton sehingga menyediakan pakan alaminya untuk pertumbuhan. Kelimpahan sumber pakan alami tersebut juga didukung oleh kondisi perairan yang relatif tenang dan tidak bergelombang sehingga tidak mengaduk substrat dasar perairan. Kecepatan arus perairan sekitar KJT berkisar antara 10 – 25 m/s. Hal tersebut karena lokasi KJT berada di muara Sungai Mati, yang memiliki debit rendah karena sumber air berasal dari saluran air pemukiman local, sehingga kecepatan arus hanya dari gelombang laut. Arus sangat berperan dalam sirkulasi air, membawa bahan terlarut dan tersuspensi, distribusi pakan, jumlah kelarutan oksigen, dan salinitas. Perairan Tanjung Mas memiliki tingkat salinitas sebesar 30‰ – 34‰ yang mendukung budidaya bandeng. Kondisi SSS di Tanjung Mas tidak berbeda jauh dengan nilai rata-rata salinitas perairan Indonesia berkisar antara 32‰ – 34‰ (Hu et al., 2019). Fluktuasi kadar SSS disebabkan oleh laju evaporasi permukaan perairan yang tinggi pada monsoon timur dan curah hujan terutama pada musim monsoon barat (Ratnawati et al., 2018), serta debit air sungai yang masuk ke lautan (Hamzah et al., 2020). Hal tersebut sejalan dengan peneliitan ini bahwa stasiun pengamatan pertama memiliki salinitas yang lebih rendah karena berada di aliran delta Sungai Mati.

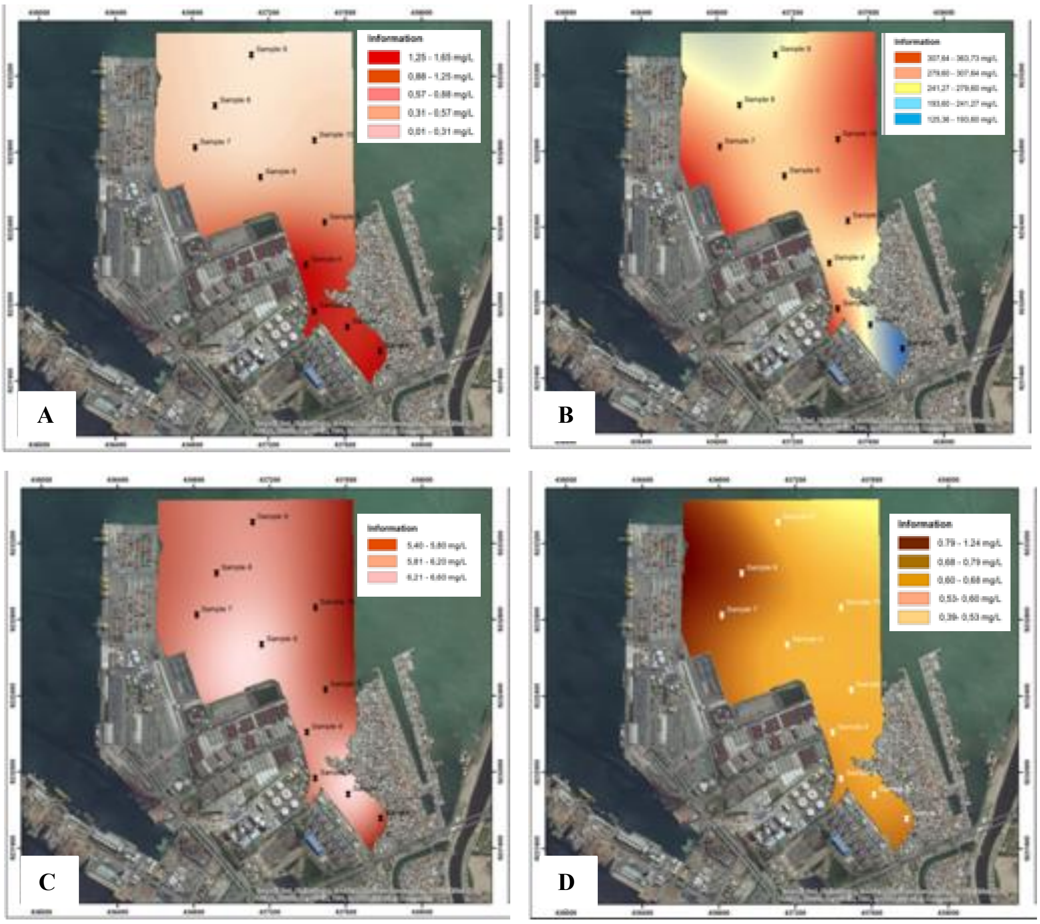
Suhu perairan lokasi KJT di Tanjung Mas berkisar antar 31ºC – 37 ºC, suhu tersebut **kurang sesuai** untuk budidaya ikan bandeng, karena suhu optimal pertumbuhan bandeng berkisar antara 27 ºC – 30 ºC (Astuti & Warsa, 2020). Tingginya suhu di perairan KJT, dikarenakan pengaruh musim kemarau yang panjang, juga perairan pada lahan terbuka sehingga menyebabkan sinar matahari masuk ke periaran tanpa ada penghalang. Suhu yang terlalu tinggi maupun rendah secara langasung mempengaruhi perilaku bandeng dalam mencari makan, menurunkan sensitivitas dan menghambat pertumbuhan jouvenil (Failaman et al., 2021; Hanke et al., 2019). Peningkatan suhu menyebabkan peningkatan dekomposisi dan fermentasi bahan organik sehingga meningkatkan produksi ammonia yang bersifat toksis bagi ikan (upwelling). Kenaikan suhu juga menyebabkan stratifikasi atau pelapisan air yang berpengaruh terhadap pengadukan dasar air (Li et al., 2020) dan diperlukan dalam rangka penyebaran oksigen dari permukaan ke dasar laut (Lobine et al., 2021). Suhu air laut juga mempengaruhi arus permukaan, persebaran plankton dan kesintasan biota laut hingga mengendalikan kondisi ekosistem perairan.

Adanya peningkatan suhu perairan, berpengaruh terhadap peningkatan kecepatan metabolisme dan respirasi organisme air, dan selanjutnya mengakibatkan peningkatan konsumsi oksigen (Bonachea, 2021; Nie et al., 2017). Peningkatan suhu perairan sebesar 10 ºC menyebabkan terjadinya peningkatan konsumsi oksigen oleh organisme akuatik sekitar 2-3 kali lipat. Namun peningkatan suhu disertai dengan penurunan kadar oksigen terlarut seringkali tidak mampu memenuhi kebutuhan oksigen bagi organisme akuatik untuk melakukan metabolisme, sehingga mempengaruhi pertumbuhannya (Audzijonyte et al., 2019; Das et al., 2018; Nelson, 2016; van Rijn et al., 2017). Kondisi fisik kemungkinan berpengaruh terhadap kondisi kimia perairan tambak. Berdasarkan hasil analisis parameter kimia, menunjukkan bahwa selain faktor fisik alami, aktivitas antropogenik juga menyebabkan kondisi kimiawi antar area tambak. Adapun hasil pengukuran menunjukkan nilai yang bervariasi (Tabel 3) dan distribusi yang tidak merata untuk masing-masing parameter fisik dan kimia (Figure 3 & 4) pada masing-masing stasiun pengamatan.

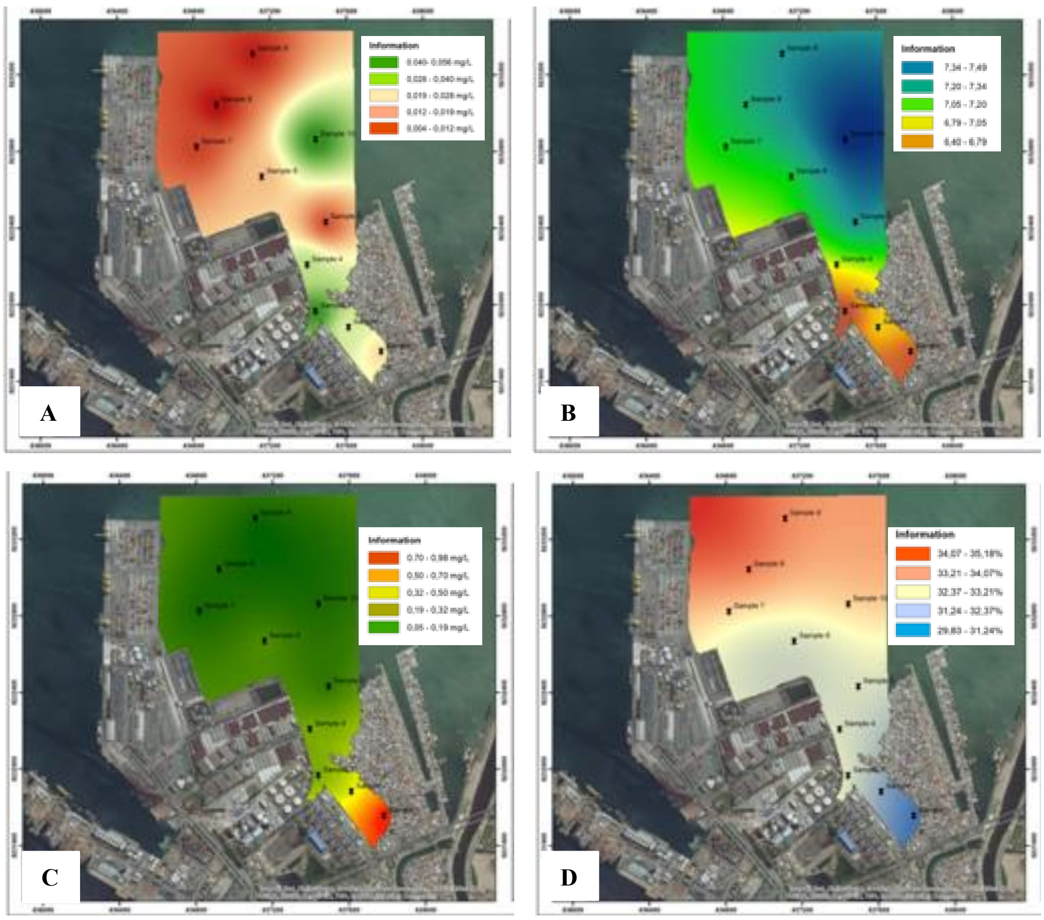
Tabel 3. Rekapitulasi data parameter kesesuaian perairan (*Site Capabllity*) pada masing-masing stasiun pengamatan

Parameter	Stasiun Pengamatan									
	1	2	3	4	5	6	7	8	9	10
Kedalaman (m)	4	4	4	4	4	4	5	5	6	4
Kecerahan (cm)	80,50	70.00	89.00	81.30	78,50	79,50	98,5	91,50	14,12	13,45
Kekeruhan (NTU)	3.15	3.26	2.58	3.51	3.26	2.96	2.97	2.68	2.38	1.66
Arus (m/s)	25.00	20.00	23.00	25.00	10.00	10.00	12.00	27.00	10.00	23.00
Suhu (C)	31.00	34.00	32.00	32.00	33.00	33.00	32.00	34.00	37.00	34.00
DO (mg/l)	6.40	5.44	6.00	5.84	6.32	5.68	6.16	6.00	5.92	6.24
pH	6.50	6.80	6.40	6.90	7.30	7.10	7.10	7.20	7.30	7.50
Salinitas (‰)	30.00	31.00	32.00	32.00	32.00	32.00	33.00	34.00	34.00	33.00
Nitrat (mg/L)	0.68	0.57	0.62	0.55	0.45	0.46	0.90	0.94	0.40	0.68
Nitrit (mg/L)	0.03	0.04	0.06	0.04	0.02	0.02	0.01	0.01	0.01	0.01
Fosfat (mg/L)	0.99	0.41	0.26	0.27	0.11	0.20	0.07	0.08	0.06	0.08
Amonia (mg/L)	1.57	1.40	1.54	1.57	0.92	0.36	0.29	0.16	0.07	0.30
BOD (mg/L)	124.70	249.40	364.50	306.90	326.10	306.90	345.30	287.80	268.60	364.50
Substrat Dasar	L	L	LK	LPK	LP	LK	L	LK	L	LP

Keterangan: L = Lumpur; LK = Lumpur Pecahan Kerang; LP = Lumpur berpasir; LPK = Lumpur Pasir Pecahan Kerang



Information
1,25 - 1,65 mg/L
0,88 - 1,25 mg/L
0,57 - 0,88 mg/L
0,31 - 0,57 mg/L
0,01 - 0,31 mg/L
A
Information
307,64 - 363,73 mg/L
279,60 - 307,64 mg/L
241,27 - 279,60 mg/L
193,60 - 241,27 mg/L
125,36 - 193,60 mg/L
B
Information
5,40 - 5,80 mg/L
5,81 - 6,20 mg/L
6,21 - 6,60 mg/L
C
Information
0,79 - 1,24 mg/L
0,68 - 0,79 mg/L
0,60 - 0,68 mg/L
0,53- 0,60 mg/L
0,39- 0,53 mg/L
D



Information
0,040- 0,056 mg/L
0,028 - 0,040 mg/L
0,019 - 0,028 mg/L
0,012 - 0,019 mg/L
0,004 - 0,012 mg/L
A
Information
7,34 - 7,49
7,20 - 7,34
7,05 - 7,20
6,79 - 7,05
6,40 - 6,79
B
Information
0,70 - 0,88 mg/L
0,50 - 0,70 mg/L
0,32 - 0,50 mg/L
0,19 - 0,32 mg/L
0,05 - 0,19 mg/L
C
Information
34,07 - 35,18%
33,21 - 34,07%
32,37 - 33,21%
31,24 - 32,37%
29,83 - 31,24%
D

Figure 4. Chemical factors condition of the research sites in Tanjung Mas. A) ammonia distribution; B) BOD level; C) DO ; D) nitrat; E) nitrit; F) pH; G) phosphate; H) salinity Tanjung Mas fishpond areas

Berdasarkan analisis perairan di Tanjung mas, menunjukkan hasil bahwa mayoritas faktor kimia lingkungan perairan sesuai untuk pertumbuhan bandeng. Lebih lanjut, kadar oksigen terlarut (DO) memenuhi standar baku mutu air laut dan mendukung pertumbuhan ikan budidaya. Kecukupan kadar oksigen terlarut kemungkinan dihasilkan oleh proses fotosintesa plankton dan diffusi dari udara (Horak et al., 2018). Disamping itu, oksigen menjadi faktor pembatas kualitas perairan karena berperan penting dalam fermentasi bahan-bahan organic dan anorganik di dasar perairan (Orsi, 2018).

Kebutuhan O_2 dalam proses dekomposit dan fermentasi oleh mikroorganisme diketahui melalui kandungan *biochemical oxygen demand* (BOD), dimana semakin tinggi kosentrasi BOD di tambak, menunjukan kemungkinan tingginya bahan organic di perairan (Jorgensen & Marshall, 2016). Hasil pengukuran BOD di sepuluh setasiun pengamatan perairan sekitar KJT menunjukkan nilai sebesar 124.7 mg/l – 364.5 mg/l terutama di stasiun 3 – 9. Berdasarkan kriteria BOD tersebut, dapat diketahui perairan sekitar Tanjung Mas tergolong dalam tingkat pencemaran tinggi. Hal tersebut kemungkinan disebabkan oleh proses dekomsisi pakan bandeng yang tersedimentasi di dasar perairan. Selain itu, peta rona (Figure 4B) menunjukkan bahwa sebaran konsentrasi BOD yang tinggi berada di area buangan/ outfall industry sekitar KJT.

Tingginya BOD, limbah industry dan rumah tangga kemungkinan berpengaruh terhadap fluktuasi kondisi pH perairan KJT. Meskipun demikian, derajat keasaman perairan sekitar KJT Tanjung Mas masih berada pada kisaran netral yaitu 6 – 7 dan memenuhi kriteria yang baik untuk budidaya ikan bandeng. Di alam nilai pH berkisar antara 4 – 9, dimana besaran dari nilai pH tersebut akan mempengaruhi kehidupan ikan budidaya. Variasi nilai pH perairan sangat mempengaruhi keberadaan biota yang hidup pada suatu perairan.

Proses fermentasi senyawa organic di perairan juga melepaskan N ke perairan dalam bentuk nitrat (NO_3), nitrit (NO_2), dan ammonia (NH_4) (Oshiki et al., 2016; Spataru, 2021, 2017). Konsentrasi nitrat pada perairan Tanjung Mas sekitar KJT, berkisar antara 0.3947 - 0.9386 mg/L, sedangkan nitrit sebesar 0.0058 – 0.0338 mg/L, dan ammonia sebesar 0.073 – 1.568 mg/L. Konsentrasi NO_3 dan NO_2 yang tinggi di perairan dapat menstimulasi pertumbuhan dan perkembangan fitoplankton dan menjadi indikator tingkat kesuburan tambak (Hardikar et al., 2019). NO_2 juga merupakan indikator penurunan cemaran N, karena proses pembentukannya berasal dari oksidasi NH_4 yang bersifat toksik. Ketersediaan NO_2 berasal dari proses oksidasi NH_4 menjadi NO_2 dilakukan oleh bakteri nitrosomonas, sedangkan oksidasi NO_2 menjadi NO_3 dilakukan oleh Nitrobacter (Santoro et al., 2021). Dalam perairan alami, NO_2 biasanya ditemukan dalam jumlah yang lebih sedikit dibanding NO_3, karena bersifatnya yang tidak stabil akibat keberadaan oksigen.

Temuan yang diperoleh dalam penelitian ini menunjukkan bahwa kadar NH_4 terukur cukup tinggi di tujuh setasiun pengamatan (stasiun-1, 2, 3, 4, 5, 6, dan 10). Hal tersebut karena lokasi tersebut berada di jalur aliran Sungai Mati yang membawa limbah domestic dari pemukiman. Bahan-bahan organic dari limbah domestic meningkatkan lau dekomposisi dan fermentasi sehingga menghasilkan NH_4 sebagai produk sampingan. Peningkatan cemaran NH_4 berkorelasi positif dengan peningkatan faktor antropogenik terutama terkait aktivitas sector pemukiman, pertanian, perternakan, maupun industry (Bessa et al., 2021; Sproson et al., 2021).

Selain itu, permasalahan yang dihadapi di perairan Tanjung Mas adalah kurangnya sanitasi lingkungan yang baik sehingga menyebabkan pencemaran dan keseimbangan ekosistem perairan tambak.

Konsentrasi NH_4 yang rendah terukur di setasiun 7, 8 dan 9 karena berada di lokasi yang jauh dari permukiman, memiliki kedalam lebih dari 5 m dan berada di dekat laut terbuka. Kondisi tersebut memungkinkan terjadinya sirkulasi air karena adanya arus laut dan proses difusi air laut yang lebih homogen.

Limbah domestic kemungkinan menjadi salah satu penyebab utama peningkatan konsentrasi fosfat di perairan tambak. Berbagai penelitian telah menunjukkan bahwa aktivitas manusia termasuk limbah domestic telah meningkatkan konsentrasi kontaminan di lautan seperti nitrogen (Jickells et al., 2017), Phosphat (Badawy et al., 2018; Thiombane et al., 2019), hingga logam berat (Bessa et al., 2021; Chu et al., 2019), Hal tersebut ditunjukkan oleh distribusi kadar fosfat di stasiun 1 hingga 5 yang lebih tinggi dibanding lima stasiun pengamatan lainnya. Fosfat merupakan nutrient yang menjadi faktor determinan jumlah fitoplankton di laut dan biasanya ditemukan dalam bentuk senyawa organic (Bristow et al., 2017).

Tabel 4. Rekapitulasi skor kesesuaian perairan

No	Parameter	Stasiun Pengamatan									
		1	2	3	4	5	6	7	8	9	10
1	Kedalaman (m)	3	3	3	3	3	3	3	3	9	3
2	Kecerahan (Cm)	1	1	1	1	1	1	1	1	1	1
3	Kekeruhan (NTU)	5	5	5	5	5	5	5	5	5	5
4	Arus (m/s)	15	15	15	15	9	9	9	15	9	15
5	Suhu (C)	6	6	2	2	2	2	2	2	2	2
6	DO (mg/L)	15	15	15	15	15	15	15	15	15	15
7	pH	2	2	2	2	6	6	6	6	6	10
8	Salinitas (ppm)	10	10	6	6	6	6	6	2	2	6
9	Nitrat (mg/L)	1	1	1	1	1	1	1	1	3	1
10	Nitrit (mg/L)	3	3	3	3	3	3	3	3	3	3
11	Fosfat (mg/L)	2	6	6	6	6	6	6	6	6	6
12	Amonia (mg/L)	1	1	1	1	1	3	3	3	3	3
13	BOD (mg/L)	1	1	1	1	1	1	1	1	1	1
14	Substrat Dasar	3	3	9	9	9	9	3	9	3	9
15	Jalur Transportasi	15	15	15	15	15	15	15	15	15	15
16	Aspek legalitas	2	2	2	2	2	2	2	2	2	2
17	Resiko Pencemaran	9	9	9	9	9	9	9	9	9	9
18	Keberadaan pelabuhan/ Dermaga	15	15	15	15	15	15	15	15	15	15
19	Keberadaan Terumbu Karang/Kondisi Ekosistem	15	15	15	15	15	15	15	15	15	15
	Total Skor	**124**	**128**	**126**	**126**	**124**	**126**	**120**	**128**	**124**	**136**

Berdasarkan nilai kesesuaian perairan (Tabel 4), menunjukkan bahwa seluruh stasiun pengamatan memiliki tingkat kelayakan/ kesesuaian perairan pada kategori sesuai (S2), yakni kawasan ini cukup dan berpotensi untuk dikembangkan sebagai kawasan budidaya KJT. Meskipun demikian, terdapat faktor pembatas yang memerlukan perhatian khusus untuk meningkatkan produktivitas bandeng seperti kadar N dan P serta BOD.

Analisis Daya Dukung Sistem KJT Berdasarkan Kapasitas Perairan

Berdasarkan hasil observasi lapangan, menunjukkan bahwa luas total perairan yang potensial di kawasan sistem budidaya KJT Kelurahan Tanjung Mas adalah sebesar 119,51 ha. Selanjutnya jika mengacu pada rekomendasi pemanfaatan lahan untuk budidaya yaitu sebesar 20%, maka luas lahan budidaya optimum yang dapat dikembangkan adalah seluas 23.902 ha. Namun, berdasarkan kondisi yang ada di lapangan menunjukkan bahwa keberadaan KJT yaitu sebanyak 22 unit atau sebesar 53.45 ha atau melebihi kapasitas yang seharusnya. Sehingga ~~Maka~~ dari nilai tersebut dapat dilihat bahwa pemanfaatan perairan telah melebihi daya dukung. Potensi efektif luas lahan yang direkomendasikan untuk pengembangan KJT rata-rata unit KJT 2.4 ha/pembudidaya untuk 10 unit saja. Oleh karena itu, dengan melihat kondisi eksisting diperlukan pengurangan jumlah unit KJT di perairan Kelurahan Tanjung Mas.

Kepadatan keramba dan tingginya jumlah bandeng budidaya yang telah melebihi daya tampung perairan berpotensi menyebabkan terjadinya kematian masal biota laut, bila melebihi kondisi faktor pembatas baku mutu perairan. Kondisi perairan yang langsung berbatasan dengan laut memberi keuntungan untuk melakukan purifikasi (memulihkan diri) lebih cepat. Namun beban pencemar domestic dan industry yang masuk secara kontinyu dan debit sungai yang rendah mengakibatkan fungsi purifikasi tidak berjalan secara optimal. Hal ini yang harus menjadi perhatian bersama, mengingat perairan di kawasan KJT merupaan output dari beberapa instalasi limbah baik dari masyarakat (domestik) maupun industry.

Conclusion

Secara umum kondisi perairan di lokasi KJT Budidaya ikan bandeng berdasarkan analisis kesesuaian perairan berada dalam kategori sesuai. Namun kondisi eksisting KJT menunjukkan bahwa pemanfaatan perairan untuk kegiatan budidaya bandeng sistem KJT telah melebihi kapasitas daya tamping perairan dan menyebabkan potensi gangguan pertumbuhan hingga kemungkinan kematian bandeng Peningkatan pengelolaan limbah pada pabrik-pabrik yang memiliki output pipa limbah ke arah perairan KJT, jadwal pembuangan limbah dilakukan dengan memperhatikan kondisi pasang surut, seperti membuang air limbah ketika pasang agar air mampu melakukan purifikasi. Pembuangan limbah ketika air laut surut dapat mengakibatkan substrat dasar tambak naik dan mengakibatkan penurunan DO, selanjutnya keterbatasan waktu untuk purifikasi perairan tambak mengakibatkan kematian pada organisme di dalam badan air.

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The Assessment of Water Compatibility of Adaptable Stick-Net Cage for Resilience Milkfish Cultivation in Tanjung Mas, Indonesia

Abstract

Milkfish cultivation becomes the main livelihood of farmers in coastal areas. However, the land for milkfish cultivation is shrinking due to land use for settlements, industries, and sea-level rise. A Stick-net cage is an aquaculture solution in limited space for an inland fishpond. It can be placed in seashore areas while maintaining the quality of the aquatic environment and nutrient circulation. This study aims to analyze water compatibility in the stick-net cage areas for supporting sustainable aquaculture activities. An exploratory observational study was conducted in Tanjung Mas Village, Semarang, Central Java, Indonesia. Ten sampling areas were determined purposively by considering the point locations toward household wastewater and industrial outfalls. Based on these criteria, the ten stations used as sample areas were divided into industrial outfall areas (1^{st} – 5^{th} station) and areas close to the open sea (6^{th} – 10^{th} station). Physical parameters in the sampling areas, including temperature, water-current, turbidity, and clearness, met seawater standards for milkfish cultivation. Chemical indicators, such as NH_4 and P in water, were very high, which may cause by domestic and industrial waste contamination, and increased organic fermentation activity on the seabed. However, the existing stick-net cages have exceeded the capacity of the coastal water areas. In general, the physicochemical parameters in the Tanjung Mas waters area are suitable for milkfish cultivation. However, it is necessary to reduce the amount of pond density to give growth space for milkfish. In addition, wastewater management and treatment plants should be built up to reduce waters contamination.

Keywords: coastal management, sustainable livelihood, water compatibility

1. Introduction

Semarang is a coastal city that produces milkfish in Central Java, with 328.65 tons in 2020. Milkfish is the main cultivated fish commodity in Semarang and the livelihood for more than 1500 pond farmers with a total income of 6.32 trillion per year (Central Java Statistics Agency [BPS], 2021). One area in Semarang that relies on milkfish cultivation as its primary source of income is the fish-farmers community in Tanjung Mas.

Inland pond for milkfish cultivation is at risk of being damaged by high waves and sea-level rise. Over the last ten years, abrasion has caused a shift in the coastline in Semarang by more than 0.5 km (Irsadi et al., 2019) and the loss of ponds in coastal areas (Andreas et al., 2018). In addition, the increase of industry, housing, and commercial spaces have decreased pond cultivation areas in Semarang. As a result, milkfish farmers experience a decline in milkfish production, threatening business stability (Martuti et al., 2020) and lowering resilience against climate change (Bosma et al., 2017; Purwaningsih & Hermawan, 2021). Furthermore, milkfish ponds in Semarang are currently threatened by climate change (Ahmed et al., 2019), land-use conflicts, and potential threats from anthropogenic factors, including industrial and household waste (Henriksson et al., 2019).

An adaptation activity in milkfish cultivation has been initiated by farmers in Tanjung Mas, Semarang, who take initiation to build stick-net cages (*Keramba Jaring Tancap* [KJT]) in shallow water areas. KJT is arranged using bamboo sticks stuck to the seabed and installed with the net on the edges to the bottom. This cultivation technique claimed to maintain water quality, nutrient circulation, and physical conditions to support milkfish growth (Sambu, 2017). However, technology transformation from inland milkfish cultivation to KJT needs to be studied in-depth, especially the factors affecting pond water quality (Ganesh et al., 2020). Anthropogenic factors, such as chemical pesticides, drugs (Chang et al., 2019), and feed (Srithongouthai & Tada, 2017) in milkfish cultivation, may affect physicochemical conditions of the aquatic ecosystem.

Inland aquaculture practice currently ignores the carrying capacity of the aquatic environment, causing a decline in the estuary ecosystem quality (Gusmawati et al., 2018; Hukom et al., 2020; Proisy et al., 2018). Hence, aquaculture management strategies using KJT must be conducted in line with the principle of sustainable development through balancing the social aspects, economic resources management, and environmental sustainability (Boyd et al., 2020). Therefore, this study aims to analyze the suitability of water conditions and biophysical aspects to support sustainable aquaculture activities in the Tanjung Mas coastal area. This study is expected to raise awareness among aquaculture actors regarding the suitability of the coastal area in their territory.

Dikomentari [U1]: Delete the numbering.

Dikomentari [U2]: INTRODUCTION should:
- contain urgency (importance) to research
- contain a carrying capacity in the form of supporting data and facts
- contain a preliminary study as a basis for the importance of the research conducted
- contain a GAP ANALYSIS Departing from the preliminary study, analysis of published articles formulated in the Gap analysis

GAP ANALYSIS refers to articles published in various internationally reputable journals to emphasize the novelty of research.
- clear limitation of research objectives

2. Method

This research was an explorational observation conducted in the KJT aquaculture area, administratively included in the Tanjung Mas, Semarang, Central Java, Indonesia. Data was taken in June – August or during the dry season to photograph the pond waters' original condition accurately.

Dikomentari [U3]: METHODS should
• contain detailed research stages
• Each stage is explained and analyzed by what method
• Data analysis must be with clear references
• The research instruments used were elaborated to the data analysis technique
• It is hoped that there will be a modification in the stages of research from sources referred by the researcher

2.1. Sampling site determination.

Sampling was carried out at 10 points spread from the end of the Mati River to the vicinity of the KJT location at the river's delta. The sample point was determined purposively by considering 1) the location of household wastewater discharge, the outfall of industries around the river, and the site of the KJT. Based on these criteria, the 10 sample area points were divided into 1) industrial waste and outfall areas (points 1-5) and areas close to the open sea (points 6-10) (Figure 1).

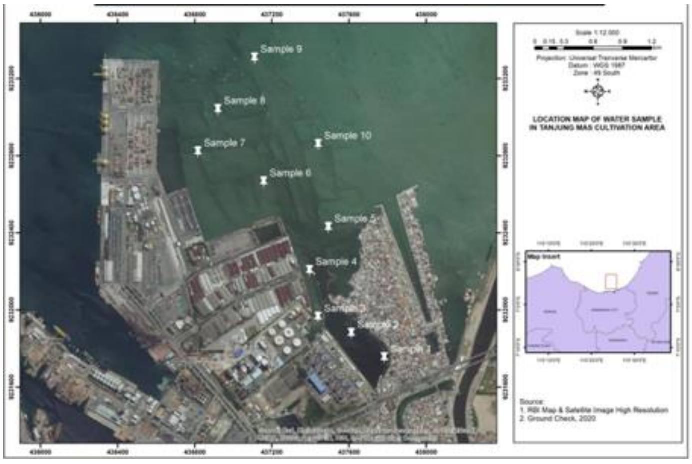


Figure 2. Map of the location for determining the water suitability analysis sample

Water samples were collected compositely from the pond area by taking 1 L of water each from five points or sides and the pond center. The water was then combined and homogenized before being used for further analysis. The water samples are stored in dark bottles to avoid chemical damage and physical changes due to light.

2.2. Water Suitability Analysis

Data on water conditions that support milkfish cultivation in this study are grouped into two parameters, physical and chemical (Table 1). The parameters were selected from the Government Regulation (PP) No. 22 of 2021 about seawater quality standards for cultivation (Table 1).

Table 1. Water suitability analysis (Site Capability)

Physicochemical parameters (n)	Scoring assumption*	Parameter values (S_n)	Rubric Score**	Weight (W)
Seawater depth (m)	Sea depths between 0 – 10 provide circulation of nutrients and plankton needed for fish growth	≤ 5	5	3
		5 – 10	3	
		≥ 10	1	
Light penetration (cm)	Into the water for milkfish cultivation ranges from 30 – 40 cm, while 0.7 – 1.4.	≤ 3	5	1
		3 – 5	3	
		≥ 5	1	
Turbidity (NTU)	Turbidity is related to the penetration of light needed by phytoplankton for photosynthesis. A reasonable waters threshold is < 5.	≤ 5	5	1
		> 5 - 20	3	
		> 20	1	

Physicochemical parameters (n)	Scoring assumption*	Parameter values (S_n)	Rubric Score**	Weight (W)
Water current (m/s)	Current plays a role in water circulation, which affects the amount of dissolved oxygen and nutrients in the water.	20 – 40	5	3
		10 – < 20 or > 40 – 70	3	
		< 10 or > 70	1	
Temperature (C)	The optimum temperature for milkfish growth is between 23 C – 35 C. Water temperature affects the growth and development of milkfish.	28 – 30	5	2
		26 – < 28 or > 30 – 31	3	
		< 26 or > 31	1	
DO (mg/l)	DO levels suitable for marine life are in the range of > 5 mg/L or 4 – 8 ppm	≥ 5	5	3
		≥ 3 - < 5	3	
		< 3	1	
pH	A good pH value in milkfish cultivation is between 6.5 – 9.	7.5 – 8	5	2
		7 – < 7.5 or > 8 – 8.5	3	
		< 7 or > 8.5	1	
Salinity (mg/L)	Good salinity for milkfish cultivation ranges from 0-35.	29 - 31	5	2
		27 - < 29 or > 31 - 33	3	
		< 27 or > 33	1	
Nitrate (mg/L)	Phytoplankton can grow optimally at a nitrate content of 0.9 ± 3.5 mg/l, while at concentrations below 0.01 or above 4.5 mg/l, it can be a limiting factor for phytoplankton growth (Oktora, 2000).	< 0.008	5	1
		> 0.008 - 0.4	3	
		> 0.4	1	
Nitrite (mg/L)	High nitrite causes a decrease in water pH and is toxic to marine biota	0	5	1
		< 0.1	3	
		≥ 0.1	1	
Phosphate Total (mg/L)	It is needed for the growth and metabolism of phytoplankton and marine organisms.	≤ 0.014	5	2
		0.015 - ≤ 0.8	3	
		> 0.8	1	
Ammonia (mg/L)	The lethal concentration (LC50) of ammonia is 1.10 to 22.8 ppm resulting in 5% mortality and 20% growth reduction for cultured fish	0 - 0.2	5	1
		> 0.2 - 0.5	3	
		> 0.5	1	
BOD (mg/L)	The level of pollution is low if the BOD value is 0 – 10 mg/L, while the level of pollution is moderate if it is 10 – 20 mg/l, > 20 mg/L.	≤ 10	5	1
		> 10 - 45	3	
		> 45	1	
Seabed materials	The media affect the survival of milkfish, thus affecting the success of the enlargement business.	Gravel	5	2
		Grit-silt (muddy)	3	
		Silt	1	

Note: * The parameter was adapted Government Regulation (PP) No. 22 of 2021 and modified from Kumar et al. (2017); Olatayo (2014),

** Physicochemical parameters that are considered essential and dominant give greater weight in affecting milkfish growth.

To obtain seawater compatibility value (SC), it was measured from summaries of the weight (W) score that multiplied by the parameter score (S_n) for each parameter (n) (Formula 1). The seawater compatibility interval class (Table 2).

$$SC = \sum (S_n \times W)$$

Table 2. Water suitability classification criteria

Status Code	Scoring Criteria	Compatibility Status
S1	> 146.7	Excellent
S2	93.3 – 146.7	Proper
N	< 93.3	Improper

3. Result and Discussion

Previously, aquaculture in Tanjung Mas was carried out using inland ponds with embankments directly bordering the sea or other ponds. However, in the early 2000s, this activity began to be abandoned because damaged by abrasion and sea-level rise (Surya et al., 2019). Around 2008, several pond farmers developed aquaculture activities using the KJT system. Currently, the majority of the farmers conduct aquaculture business as a side job when the fishing season is disturbed by weather. However, because milkfish cultivation profit using the KJT system was higher than catching fish, the business became popular and income. KJT is made using bamboos construction that is plugged into a seabed forming a cage block. The nets used by the farmers have hole diameters ranging from 0.5 cm – 0.5 cm for nursery and 1 cm – 1 cm for enlargement (Figure 1).

Dikomentari [U4]: RESULTS AND DISCUSSION
- •Tables or graphs (one selected) must represent different results
- • The results of data analysis must be strong in answering the analysis gap
- •Display of results other than those narrated in table-graph-image-modeling
- •The research novelty has not been clear enough
- • It is recommended not to repeat the references in the introduction, using previous research findings.
- • References used should be taken from reputable journals.

It is necessary to explain the specifications of the findings in this study that show

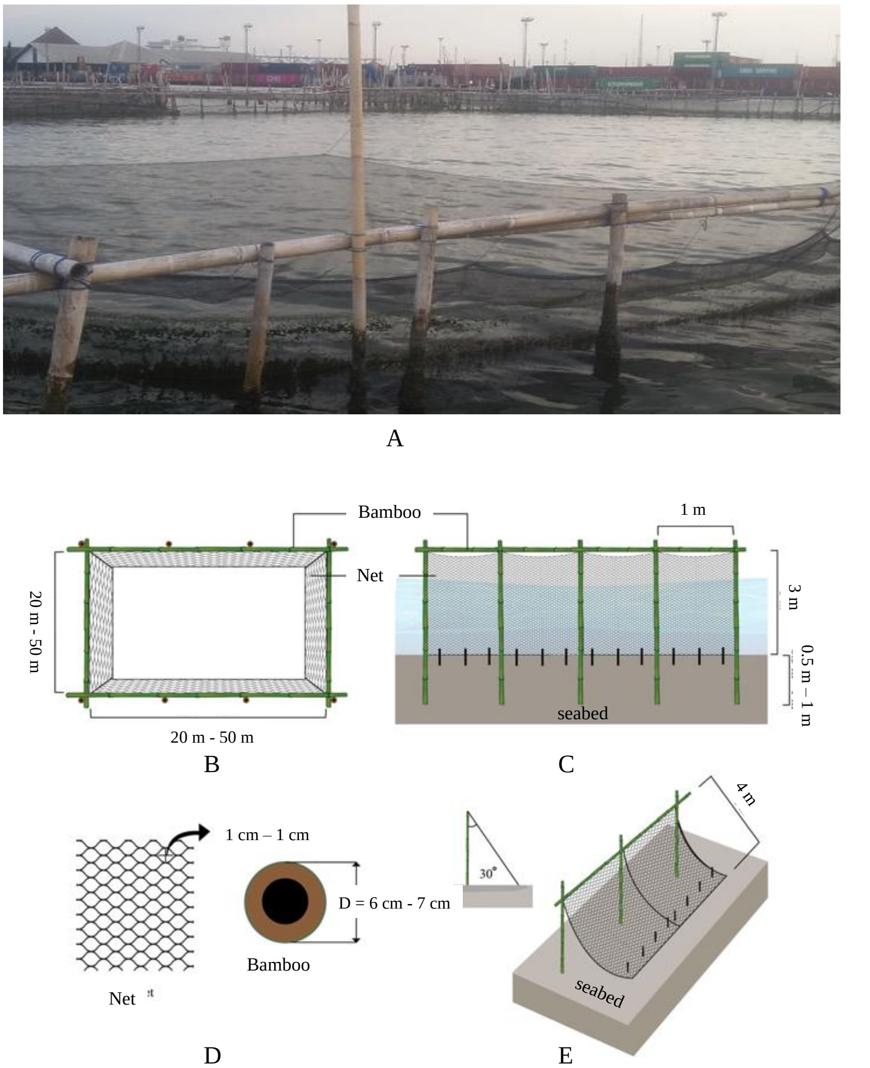


Figure 1. Detailed design of stick-net cage specification used for milkfish cultivation in Tanjung Mas: A) existing stick-net cage; B) upper view of the net-cage; B) construction design; C) materials specification; D) net position on the seabed.

KJT using three layers of nets surround a 1 ha of fishpond with a depth of 3 m. It takes about five rollers of net sizing 30 m x 5 m. The advantage of using KJT is the capability of the construction model that supports nutrient circulation in the seawater. It makes the availability of natural feed for milkfish and reduces additional fed for cultivation (Cornejo et al., 2020). Pollutants from outside and ammonia from feed fermentation inside the cage circulate in the pond, as illustrated in Figure 2 (Cha & Lee, 2018).

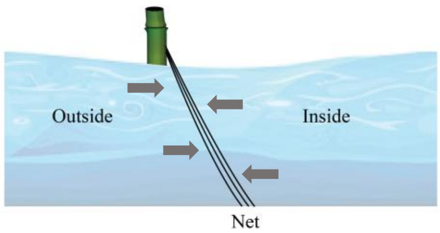


Figure 2. Materials flow illustration through net-cage construction

KJT disadvantages are performed by uncontrolled physicochemical conditions inside the cage and are adequately dependent on natural factors. Consequently, the farmers cannot adjust waters condition to speed up milkfish growth. It is necessary to maintain the optimal physical and chemical conditions in the environment according to the age of the milkfish to get optimal growth (Failaman et al., 2021; Mandal et al., 2018).

Seawater aquaculture requires appropriate environmental conditions that support the growth and development of milkfish. In addition, KJT in Tanjung Mas is placed around industrial and household waste streams that contain toxic contaminants that may interfere with milkfish growth or are inappropriate for human consumption. On the other hand, milkfish cultivation may also impact the condition of the seawaters around the pond due to feed and milkfish manure that settles at the pond's seabed.

3.1. Water Suitability Analysis to Support KJT System Cultivation

The carrying capacity of the seawater environment is determining factor for milkfish cultivation. Physically, the Mati River's estuary (the only river in Tanjung Mas) supports milkfish cultivation. However, the differences in the milkfish pond's physical conditions, including water current, temperature, seabed substrate conditions, are observed as illustrated in Figure 3.

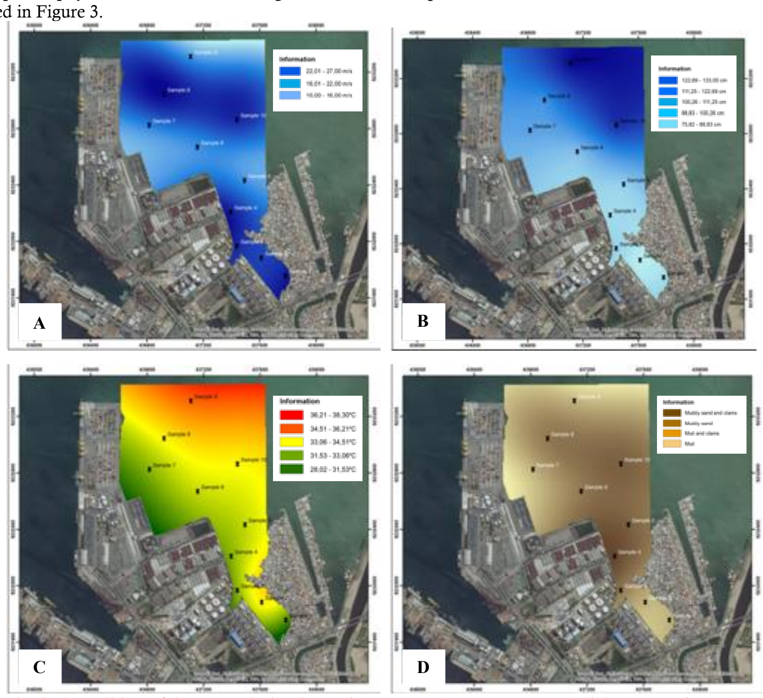


Figure 3 Physical condition of the research sites in Tanjung Mas: A) water current; B) light penetration; C) temperature and D) seabed sediment in Tanjung Mas fishpond areas.

The seawater depth varies between 4 m – 6 m; however, it is still suitable for milkfish cultivation. Milkfish juveniles will generally live in shallow seawater for two to three weeks, then migrate to mangrove forests, river estuaries, or lakes. The adult will return to the sea to breed. Meanwhile, the substrate samples in Tanjung Mas seawaters range from silt to gravel containing shell fragments and sand. However, the seabed's substrate does not directly affect the milkfish growth because the KJT system is placed on the open seas with nets to a maximum depth of 3 m. In contrast to the inland ponds, which only have a depth from 1 m up to 1.5 m that makes milkfish are directly in contact with the bottom substrate of the seawaters.

Light penetration of water brightness (low debris) indicates good conditions to support milkfish cultivation, even though it is located in the industrial and household waste disposal system. The light penetration significantly correlates to the photosynthesis rate of phytoplankton in providing natural feed for milkfish growth. The abundance of phytoplankton is also supported by relatively low water current and calming waves that keep the water clear from seabed substrate. The seawater currents speed in Tanjung Mas was ranged around 10 m/s – 25 m/s and categorized as low water flow. The coastal area in Tanjung Mas is an estuary of Mati River that has a low discharge because the water sources only come from city drainage and water polder. Water current plays a vital role in nutrient circulation, carrying dissolved and suspended materials, feed distribution, total oxygen solubility, and salinity. Tanjung Mas have seawater with a salinity level of 30‰ – 34‰, which supports milkfish cultivation. Salinity conditions in Tanjung Mas are not much different from the average salinity value of Indonesian waters ranging from 32‰ – 34‰ (Hu et al., 2019). Fluctuations in salinity levels are caused by the high evaporation rate of the surface waters in the east monsoon and rainfall, especially in the west monsoon season (Ratnawati et al., 2018) and the discharge of river water that enters the ocean (Hamzah et al., 2020). Their statement is in line with this research that the first observation station has a lower salinity because it is located in the delta flow of the Mati River.

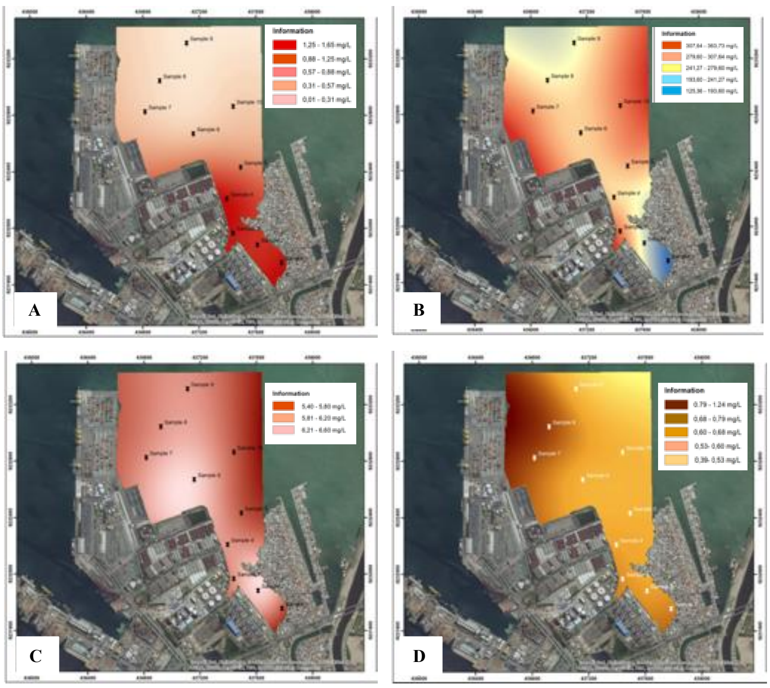
The water temperature of the KJT location in Tanjung Mas ranges between 31ºC – 37ºC. This temperature is not suitable for milkfish cultivation because the optimal temperature for milkfish growth goes from 27ºC – 30ºC (Astuti & Warsa, 2020). The high temperature in the KJT areas may be influenced by the long dry season that increases the water surface temperature due to the high intensity of sunlight. Temperatures that are too high or too low directly affect milkfish foraging behavior, reduce sensitivity and inhibit juvenile growth (Failaman et al., 2021; Hanke et al., 2019). An increase in temperature raises the decomposition and fermentation of organic matter, producing ammonia that is toxic to fish. The temperature rise also causes stratification or coating of water, which affects the mixing of seabed material and disturbs nutrition distribution (Li et al., 2020). However, the temperature is also needed in oxygen mixing from the surface to the deep waters (Lobine et al., 2021). Seawater temperature also affects surface currents, the distribution of plankton, and the survival of marine life to control the condition of aquatic ecosystems.

An increase in water temperature affects the metabolism and respiration of aquatic organisms and further increases oxygen consumption (Bonachea, 2021; Nie et al., 2017). An increase in water temperature of 10 C causes an increase in oxygen consumption by aquatic organisms about 2-3 times. However, an increase in temperature accompanied by a decrease in dissolved oxygen levels is often unable to meet the oxygen needs of aquatic organisms to carry out metabolism, thus affecting their growth (Audzijonyte et al., 2019; Das et al., 2018; Nelson, 2016; van Rijn et al., 2017). Physical conditions may affect the chemical requirements of pond waters. The analysis of chemical parameters shows that in addition to natural physical factors, anthropogenic activities also cause chemical conditions between pond areas. The measurement results show varying values (Table 3) and uneven distribution for each physical and chemical parameter (Figure 3 & 4) at each observation station.

Table 3. Recapitulation of water suitability parameter data (Site Capability) at each observation station

Parameter	Station									
	1	2	3	4	5	6	7	8	9	10
Seawater depth (m)	4.00	4.00	4.00	4.00	4.00	4.00	5.00	5.00	6.00	4.00
Light Penetration (cm)	80,50	70.00	89.00	81.30	78,50	79,50	98,5	91,50	14,12	13,45
Turbidity (NTU)	3.15	3.26	2.58	3.51	3.26	2.96	2.97	2.68	2.38	1.66
Water current (m/s)	25.00	20.00	23.00	25.00	10.00	10.00	12.00	27.00	10.00	23.00
Temperature (C)	31.00	34.00	32.00	32.00	33.00	33.00	32.00	34.00	37.00	34.00
DO (mg/l)	6.40	5.44	6.00	5.84	6.32	5.68	6.16	6.00	5.92	6.24
pH	6.50	6.80	6.40	6.90	7.30	7.10	7.10	7.20	7.30	7.50
Salinity (‰)	30.00	31.00	32.00	32.00	32.00	32.00	33.00	34.00	34.00	33.00
Nitrate (mg/L)	0.68	0.57	0.62	0.55	0.45	0.46	0.90	0.94	0.40	0.68
Nitrite (mg/L)	0.03	0.04	0.06	0.04	0.02	0.02	0.01	0.01	0.01	0.01
Phosphate (mg/L)	0.99	0.41	0.26	0.27	0.11	0.20	0.07	0.08	0.06	0.08
Ammonia (mg/L)	1.57	1.40	1.54	1.57	0.92	0.36	0.29	0.16	0.07	0.30
BOD (mg/L)	124.70	249.40	364.50	306.90	326.10	306.90	345.30	287.80	268.60	364.50
Seabed materials	S	S	S-Cs	Gs-Cs	Gs	S-Cs	S	S-Cs	S	GS

Note: Cs = clam shell shards; Gs = Grit-silt (muddy); and S = Silt


Information
1,25 - 1,65 mg/L
0,88 - 1,25 mg/L
0,57 - 0,88 mg/L
0,31 - 0,57 mg/L
0,01 - 0,31 mg/L
A
Information
B
Information
5,40 - 5,80 mg/L
5,81 - 6,20 mg/L
6,21 - 6,60 mg/L
C
Information
0,79 - 1,24 mg/L
0,68 - 0,79 mg/L
0,60 - 0,68 mg/L
0,53- 0,60 mg/L
0,39- 0,53 mg/L
D

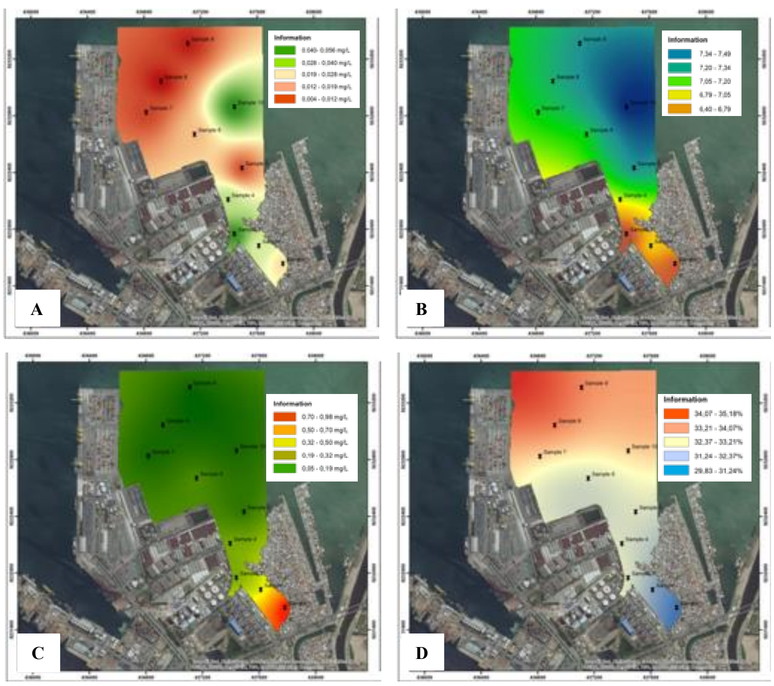

Information
0,040- 0,056 mg/L
0,028 - 0,040 mg/L
0,019 - 0,028 mg/L
0,012 - 0,019 mg/L
0,004 - 0,012 mg/L
A
Information
7,34 - 7,49
7,20 - 7,34
7,05 - 7,20
6,79 - 7,05
6,40 - 6,79
B
Information
0,70 - 0,98 mg/L
0,50 - 0,70 mg/L
0,32 - 0,50 mg/L
0,19 - 0,32 mg/L
0,05 - 0,19 mg/L
C
Information
34,07 - 35,18%
33,21 - 34,07%
32,37 - 33,21%
31,24 - 32,37%
29,83 - 31,24%
D

Figure 4. Chemical factors condition of the research sites in Tanjung Mas: A) ammonia distribution; B) BOD level; C) DO ; D) nitrate; E) nitrite; F) pH; G) phosphate; H) salinity Tanjung Mas fishpond areas.

The majority of chemical factors in the KJT aquatic environment are suitable for milkfish growth. Furthermore, dissolved oxygen (DO) levels meet seawater quality standards and support the development of cultured fish. Adequate dissolved oxygen levels may be produced from plankton photosynthesis and air diffusion (Horak et al., 2018). In addition, oxygen is a limiting factor for water quality because it plays an essential role in the fermentation of organic and inorganic materials at the seabed (Orsi, 2018).

The needed O_2 for decomposition and fermentation can be identified from biochemical oxygen demand (BOD) content. A higher concentration in the fishpond indicates the possibility of high organic matter in the waters (Jorgensen & Marshall, 2016). The results of BOD measurements at ten observation stations showed a value of 124.7 mg/L – 364.5 mg/L, especially at stations 3 – 9. Based on the BOD criteria, it can be seen that the seawaters around Tanjung Mas are classified as high polluted by organic compounds. It is probably caused by the decomposition process of milkfish feed, which is sedimented at the seabed. In addition, the map (Figure 4B) shows that high BOD concentrations are distributed mainly near the industrial's outfall areas even though the pH around the Tanjung Mas water area is in the neutral range of 6 – 7 and supports milkfish cultivation. In nature, the pH value ranges from 4 – 9, where the unbalancing of the pH affects aquaculture fish or the presence of seawater organisms.

The fermentation process of organic materials releases N into seawaters in the form of nitrate (NO_3), nitrite (NO_2), and ammonia (NH_4) (Oshiki et al., 2016; Spataru, 2021, 2017). The concentration of NO_3 in Tanjung Mas, was ranged from 0.3947 mg/L - 0.9386 mg/L, while nitrite was 0.0058 mg/L – 0.0338 mg/L, and ammonia was 0.073 mg/L – 1.568 mg/L. High concentrations of NO_3 and NO_2 in the seawaters can stimulate the growth and development of phytoplankton and become an indicator of fishpond fertility (Hardikar et al., 2019). NO_2 is also an indicator of decreasing N contamination because its formation comes from the oxidation of NH_4, which is toxic. Then, an availability of NO_2 comes from the oxidation of NH_4 to NO_2 carried out by Nitrosomonas bacteria, while the oxidation of NO_2 to NO_3 is carried out by Nitrobacter (Santoro et al., 2021). NO_2 is usually found in lower amounts than NO_3 because it is unstable and easily reacts with oxygen.

The findings obtained in this study showed that the measured NH_4 levels were quite high at seven observation stations (stations-1, 2, 3, 4, 5, 6, and 10). The location is on the Mati River, which carries domestic waste from settlements. Organic materials from domestic waste increase the rate of decomposition and fermentation of organic materials to produce NH_4 as a by-product. The increase in NH_4 contamination is positively correlated with anthropogenic factors, primarily related to the residential, agricultural, livestock, and industrial sectors (Bessa et al., 2021; Sproson et al., 2021). In addition, the problem faced in Tanjung Mas waters is the lack of suitable sanitation, causing pollution and the balance of the pond waters ecosystem.

Low NH_4 concentrations were measured at stations 7, 8, and 9 because they are located far from settlements and industrial outfall, have more than 5 m depth and are near the open sea. This condition improves water circulation due to ocean currents and a more homogeneous seawater diffusion process.

Domestic waste may be one of the main factors that increase phosphate concentrations in the KJT waters area. Various studies have shown that human activities, including household waste, have increased the concentration of contaminants in the oceans, such as nitrogen (Jickells et al., 2017), phosphate (Badawy et al., 2018; Thiombane et al., 2019), to heavy metals (Bessa et al., 2021; Chu et al., 2019). It is indicated by the distribution of phosphate levels at stations 1 to 5, which is higher than the other five observation stations. Phosphate is a nutrient that is a determining factor in phytoplankton in the sea and is usually found in the form of organic compounds (Bristow et al., 2017).

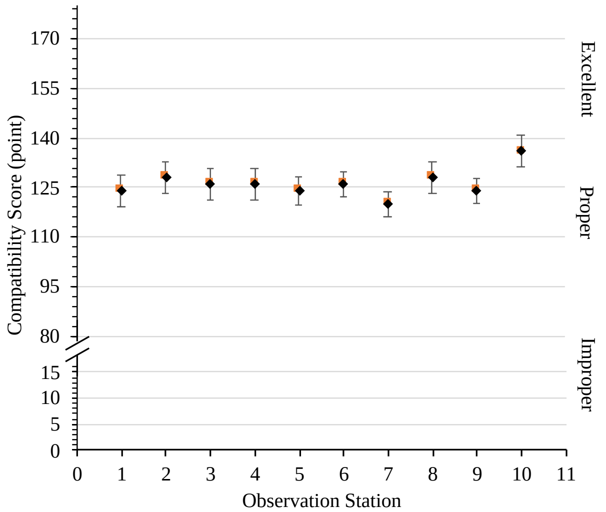


Table 4. Compatibility for milkfish cultivation in Tanjung Mas waters area based on the observation station.

The water compatibility value (Table 4) shows that all observation stations were categorized at the proper level (S2). It indicates that the Tanjung Mas water area is sufficient and can be developed as a KJT cultivation area. However, limiting factors require special attention to increasing milkfish productivity, such as N and P levels and BOD.

3.2. Analysis of KJT System Carrying Capacity Based on Water Capacity

The total area of potential waters in the Tanjung Mas for KJT is 119.51 Ha, but referring to the government regulation, it is only 20% that can be used for aquaculture. Then the optimum area for the KJT aquaculture system that can be developed is only about 23,902 Ha. However, based on the observation, the existence of KJT has overcapacity. Twenty-two cages occupy it with more than 53.45 Ha of waters area. Furthermore, it can be seen that the utilization of the waters has exceeded the carrying capacity because the practical potential of the waters area for the KJT system is only 2.4 cage/ Ha for only ten cage units. Therefore, it is necessary to reduce the number of KJT units by looking at the existing conditions.

High occupied waters area with dense cultured milkfish may overshoot the water's capacity and potentially trigger mass death of the marine organism. The condition of the waters directly adjacent to the sea provides an advantage for faster purification. However, the continuous input of domestic and industrial pollutants and low river discharge resulted in a low nature purification rate. It must be a common concern, considering that the waters in the KJT area are the output of several waste installations from the community (domestic) and industries.

4. Conclusion

In general, the physicochemical factors in Tanjung Mas water areas are proper and support milkfish cultivation. However, the existing condition shows that water utilization for milkfish aquaculture activities using KJT has exceeded the carrying capacity. It potentially disturbs milkfish growth and may lead to the unbalancing ecosystem and trigger the death of the marine organism. On the other hand, high pollution from industries and household waste has become a significant problem affecting milkfish growth and becoming a health issue. High P and NH_4 were primarily detected in the observation station near the industrial outfall and Mati River estuary, containing domestic waste. It needs an improvement of waste management system from industrial and household by providing sewage purification utilities and scheduling waste disposal based on tidal conditions after purification treatment.

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The Assessment of Water Compatibility of Adaptable Stick-Net Cage for Resilience Milkfish Cultivation in Tanjung Mas, Indonesia

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Abstract

Milkfish cultivation becomes the main livelihood of farmers in coastal areas. However, the land for milkfish cultivation is shrinking due to land use for settlements, industries, and sea-level rise. A Stick-net cage is an aquaculture solution in limited space for an inland fishpond. It can be placed in seashore areas while maintaining the quality of the aquatic environment and nutrient circulation. This study aims to analyze water compatibility in the stick-net cage areas for supporting sustainable aquaculture activities. An exploratory observational study was conducted in Tanjung Mas Village, Semarang, Central Java, Indonesia. Ten sampling areas were determined purposively by considering the point locations toward household wastewater and industrial outfalls. Based on these criteria, the ten stations used as sample areas were divided into industrial outfall areas (1st – 5th station) and areas close to the open sea (6th – 10th station). Physical parameters in the sampling areas, including temperature, water-current, turbidity, and clearness, met seawater standards for milkfish cultivation. Chemical indicators, such as NH_4 and P in water, were very high, which may cause by domestic and industrial waste contamination, and increased organic fermentation activity on the seabed. However, the existing stick-net cages have exceeded the capacity of the coastal water areas. In general, the physicochemical parameters in the Tanjung Mas waters area are suitable for milkfish cultivation. However, it is necessary to reduce the amount of pond density to give growth space for milkfish. In addition, wastewater management and treatment plants should be built up to reduce waters contamination.

Keywords: coastal management, sustainable livelihood, water compatibility

INTRODUCTION

Semarang is a coastal city that produces milkfish in Central Java, with 328.65 tons in 2020. Milkfish is the main cultivated fish commodity in Semarang and the livelihood for more than 1500 pond farmers with a total income of 6.32 trillion per year (Central Java Statistics Agency [BPS], 2021). One area in Semarang that relies on milkfish cultivation as its primary income source is the fish-farmers community in Tanjung Mas.

Inland pond for milkfish cultivation is at risk of being damaged by high waves and sea-level rise as the effect of climate change (Ahmed et al., 2019). Over the last ten years, abrasion has caused a shift in the coastline in Semarang by more than 0.5 km (Irsadi et al., 2019) and the loss of ponds in coastal areas (Andreas et al., 2018). In addition, the increase of industry, housing, and commercial spaces have decreased pond cultivation areas in Semarang. As a result, milkfish farmers experience a decline in milkfish production, threatening business stability (Martuti et al., 2020) and lowering resilience against climate change (Bosma et al., 2017; Purwaningsih & Hermawan, 2021). land-use conflicts, and potential threats from anthropogenic factors, including industrial and household waste (Henriksson et al., 2019). A case study in the Tanjung Mas waters area, shows that the high risk milkfish cultivation due to climate change and land-use conflict has prompted milkfish farmers to change to using cages planted in coastal waters.

An adaptation activity in milkfish cultivation has been initiated by farmers in Tanjung Mas, Semarang, who take initiation to build stick-net cages (*Keramba Jaring Tancap* [KJT]) in shallow water areas. KJT is arranged using bamboo sticks stuck to the seabed and installed with the net on the edges to the bottom. This cultivation technique claimed to maintain water quality, nutrient circulation, and physical conditions to support milkfish growth (Sambu, 2017). However, Tanjung Mas waters bodies is a deltas area that becomes an outlet for domestic and industrial waste. It is possible that the waste pollution interferes milkfish growth during cultivation. Furthermore, technology transformation from inland milkfish cultivation to KJT needs to be studied in-depth, especially the factors affecting pond water quality (Ganesh et al., 2020). In addition, chemical and organic contamination may increase in estuarine ecosystem that affect fish growth as a result of replaced cultivation activity. In recent studies, the anthropogenic factors, such as chemical pesticides, drugs (Chang et al., 2019), and feed (Srithongouthai & Tada, 2017) in milkfish cultivation affects physicochemical conditions of the aquatic ecosystem.

Inland aquaculture practice currently ignores the carrying capacity of the aquatic environment, causing a decline in the estuary ecosystem quality (Gusmawati et al., 2018; Hukom et al., 2020; Proisy et al., 2018). Hence, aquaculture management strategies using KJT must be conducted in line with the principle of sustainable development through balancing the social aspects, economic resources management, and environmental sustainability (Boyd et al., 2020). Therefore, this study aims to analyze the suitability of water conditions and biophysical aspects to support sustainable aquaculture activities in the Tanjung Mas coastal area. This study is expected to raise awareness among aquaculture actors regarding the suitability of the coastal area in their territory.

METHOD

This research was an explorational observation conducted in the KJT aquaculture area, administratively included in the Tanjung Mas, Semarang, Central Java, Indonesia. Data was taken in June – August or during the dry season to photograph the pond waters' original condition accurately.

Sampling site determination.

Sampling was carried out at 10 points spread from the end of the Mati River to the vicinity of the KJT location at the river's delta. The sample point was determined purposively by considering 1) the location of household wastewater discharge, the outfall of industries around the river, and the site of the KJT. Based on these criteria, the 10 sample area points were divided into 1) industrial waste and outfall areas (points 1-5) and areas close to the open sea (points 6-10) (Figure 1).

Dikomentari [U1]: Delete the numbering.

Dikomentari [U2]: INTRODUCTION should:
- contain urgency (importance) to research
- contain a carrying capacity in the form of supporting data and facts
- contain a preliminary study as a basis for the importance of the research conducted
- contain a GAP ANALYSIS Departing from the preliminary study, analysis of published articles formulated in the Gap analysis

GAP ANALYSIS refers to articles published in various internationally reputable journals to emphasize the novelty of research.
- clear limitation of research objectives

Dikomentari [au3]: 1.The facts and the problems found in Semarang coastal area was explained in paragraph 2. Then the final statement of final preliminary basis information was elaborated in the end of the paragraph.
2.The gaps was explained in the 3rd paragraph
3.clear limitation of research objectives was completed in the last paragraph

Dikomentari [U4]: METHODS should
- contain detailed research stages
- Each stage is explained and analyzed by what method
- Data analysis must be with clear references
- The research instruments used were elaborated to the data analysis technique
- It is hoped that there will be a modification in the stages of research from sources referred by the researcher

Dikomentari [au5]: All of the method used in this research was explained specifically and respectively

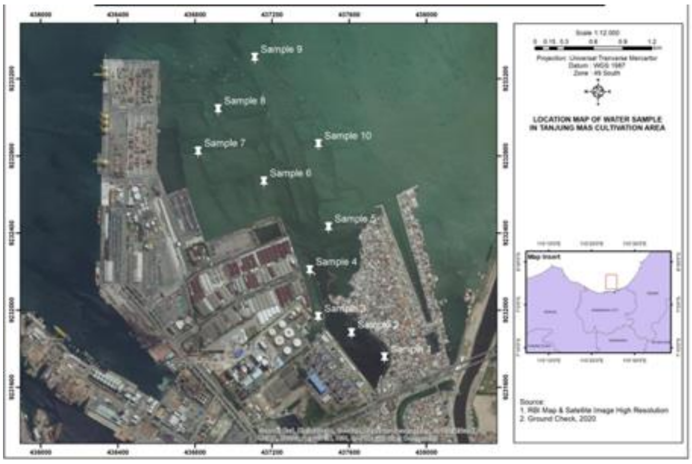


Figure 2. Map of the location for determining the water suitability analysis sample

Water samples were collected compositely from the pond area by taking 1 L of water each from five points or sides and the pond center. The water was then combined and homogenized before being used for further analysis. The water samples are stored in dark bottles to avoid chemical damage and physical changes due to light.

Water Suitability Analysis

Data on water conditions that support milkfish cultivation in this study are grouped into two parameters, physical and chemical (Table 1). The parameters were selected from the Government Regulation (PP) No. 22 of 2021 about seawater quality standards for cultivation (Table 1).

Table 1. Water suitability analysis (Site Capability)

Physicochemical parameters (n)	Scoring assumption*	Parameter values (S_n)	Rubric Score**	Weight (W)
Seawater depth (m)	Sea depths between 0 – 10 provide circulation of nutrients and plankton needed for fish growth	≤ 5	5	3
		5 – 10	3	
		≥ 10	1	
Light penetration (cm)	Into the water for milkfish cultivation ranges from 30 – 40 cm, while 0.7 – 1.4.	≤ 3	5	1
		3 – 5	3	
		≥ 5	1	
Turbidity (NTU)	Turbidity is related to the penetration of light needed by phytoplankton for photosynthesis. A reasonable waters threshold is < 5.	≤ 5	5	1
		> 5 - 20	3	
		> 20	1	
Water current (m/s)	Current plays a role in water circulation, which affects the amount of dissolved oxygen and nutrients in the water.	20 – 40	5	3
		10 – < 20 or > 40 – 70	3	
		< 10 or > 70	1	
Temperature (C)	The optimum temperature for milkfish growth is between 23 C – 35 C. Water temperature affects the growth and development of milkfish.	28 – 30	5	2
		26 – < 28 or	3	
		> 30 – 31		

Physicochemical parameters (n)	Scoring assumption*	Parameter values (S_n)	Rubric Score**	Weight (W)
		< 26 or > 31	1	
DO (mg/l)	DO levels suitable for marine life are in the range of > 5 mg/L or 4 – 8 ppm	≥ 5	5	3
		≥ 3 - < 5	3	
		< 3	1	
pH	A good pH value in milkfish cultivation is between 6.5 – 9.	7.5 – 8	5	2
		7 – < 7.5 or > 8 – 8.5	3	
		< 7 or > 8.5	1	
Salinity (mg/L)	Good salinity for milkfish cultivation ranges from 0-35.	29 - 31	5	2
		27 - < 29 or > 31 - 33	3	
		< 27 or > 33	1	
Nitrate (mg/L)	Phytoplankton can grow optimally at a nitrate content of 0.9 ± 3.5 mg/l, while at concentrations below 0.01 or above 4.5 mg/l, it can be a limiting factor for phytoplankton growth (Oktora, 2000).	< 0.008	5	1
		> 0.008 - 0.4	3	
		> 0.4	1	
Nitrite (mg/L)	High nitrite causes a decrease in water pH and is toxic to marine biota	0	5	1
		< 0.1	3	
		≥ 0.1	1	
Phosphate Total (mg/L)	It is needed for the growth and metabolism of phytoplankton and marine organisms.	≤ 0.014	5	2
		0.015 - ≤ 0.8	3	
		> 0.8	1	
Ammonia (mg/L)	The lethal concentration (LC50) of ammonia is 1.10 to 22.8 ppm resulting in 5% mortality and 20% growth reduction for cultured fish	0 - 0.2	5	1
		> 0.2 - 0.5	3	
		> 0.5	1	
BOD (mg/L)	The level of pollution is low if the BOD value is 0 – 10 mg/L, while the level of pollution is moderate if it is 10 – 20 mg/l, > 20 mg/L.	≤ 10	5	1
		> 10 - 45	3	
		> 45	1	
Seabed materials	The media affect the survival of milkfish, thus affecting the success of the enlargement business.	Gravel	5	2
		Grit-silt (muddy)	3	
		Silt	1	

Note: * The parameter was adapted Government Regulation (PP) No. 22 of 2021 and modified from Kumar et al. (2017); Olatayo (2014),

** Physicochemical parameters that are considered essential and dominant give greater weight in affecting milkfish growth.

To obtain seawater compatibility value (SC), it was measured from summaries of the weight (W) score that multiplied by the parameter score (S_n) for each parameter (n) (Formula 1). The seawater compatibility interval class (Table 2).

$$SC = \sum (S_n \times W)$$

Table 2. Water suitability classification criteria

Status Code	Scoring Criteria	Compatibility Status
S1	> 146.7	Excellent
S2	93.3 – 146.7	Proper
N	< 93.3	Improper

RESULT AND DISCUSSION

Previously, aquaculture in Tanjung Mas was carried out using inland ponds with embankments directly bordering the sea or other ponds. However, in the early 2000s, this activity began to be abandoned because damaged by abrasion and sea-level rise (Surya et al., 2019). Around 2008, several pond farmers developed aquaculture activities using the KJT system. Currently, the majority of the farmers conduct aquaculture business as a side job when the fishing season is disturbed by weather. However, because milkfish cultivation profit using the KJT system was higher than catching fish, the business became popular and income. KJT is made using bamboos construction that is plugged into a seabed forming a cage block. The nets used by the farmers have hole diameters ranging from 0.5 cm – 0.5 cm for nursery and 1 cm – 1 cm for enlargement (Figure 1).

Dikomentari [U6]: RESULTS AND DISCUSSION
- •Tables or graphs (one selected) must represent different results
- • The results of data analysis must be strong in answering the analysis gap
- •Display of results other than those narrated in table-graph-image-modeling
- •The research novelty has not been clear enough
- • It is recommended not to repeat the references in the introduction, using previous research findings.
- • References used should be taken from reputable journals.

It is necessary to explain the specifications of the findings in this study that show

Dikomentari [au7]: 1.Table data is different each other
2.Data represent the research objective and answere the gaps
3.Tables and figures are managed to display the data as simply as possible
4.There are no repeated reference in result and discussion
5.All references are reputable
6.All research finding presented in the result and discussion part

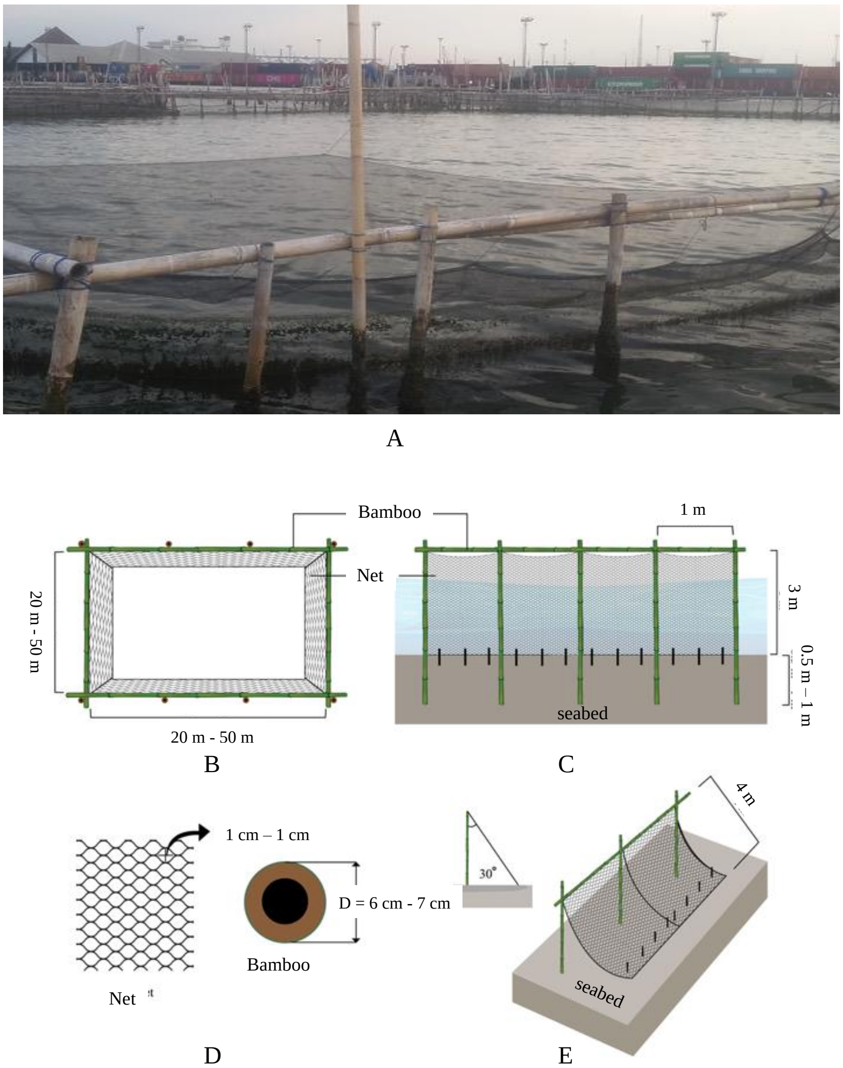


Figure 1. Detailed design of stick-net cage specification used for milkfish cultivation in Tanjung Mas: A) existing stick-net cage; B) upper view of the net-cage; B) construction design; C) materials specification; D) net position on the seabed.

KJT using three layers of nets surround a 1 ha of fishpond with a depth of 3 m. It takes about five rollers of net sizing 30 m x 5 m. The advantage of using KJT is the capability of the construction model that supports nutrient circulation in the seawater. It makes the availability of natural feed for milkfish and reduces additional fed for cultivation (Cornejo et al., 2020). Pollutants from outside and ammonia from feed fermentation inside the cage circulate in the pond, as illustrated in Figure 2 (Cha & Lee, 2018).

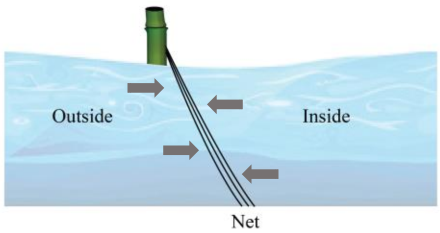


Figure 2. Materials flow illustration through net-cage construction

KJT disadvantages are performed by uncontrolled physicochemical conditions inside the cage and are adequately dependent on natural factors. Consequently, the farmers cannot adjust waters condition to speed up milkfish growth. It is necessary to maintain the optimal physical and chemical conditions in the environment according to the age of the milkfish to get optimal growth (Failaman et al., 2021; Mandal et al., 2018).

Seawater aquaculture requires appropriate environmental conditions that support the growth and development of milkfish. In addition, KJT in Tanjung Mas is placed around industrial and household waste streams that contain toxic contaminants that may interfere with milkfish growth or are inappropriate for human consumption. On the other hand, milkfish cultivation may also impact the condition of the seawaters around the pond due to feed and milkfish manure that settles at the pond's seabed.

Water Suitability Analysis to Support KJT System Cultivation

The carrying capacity of the seawater environment is determining factor for milkfish cultivation. Physically, the Mati River's estuary (the only river in Tanjung Mas) supports milkfish cultivation. However, the differences in the milkfish pond's physical conditions, including water current, temperature, seabed substrate conditions, are observed as illustrated in Figure 3.

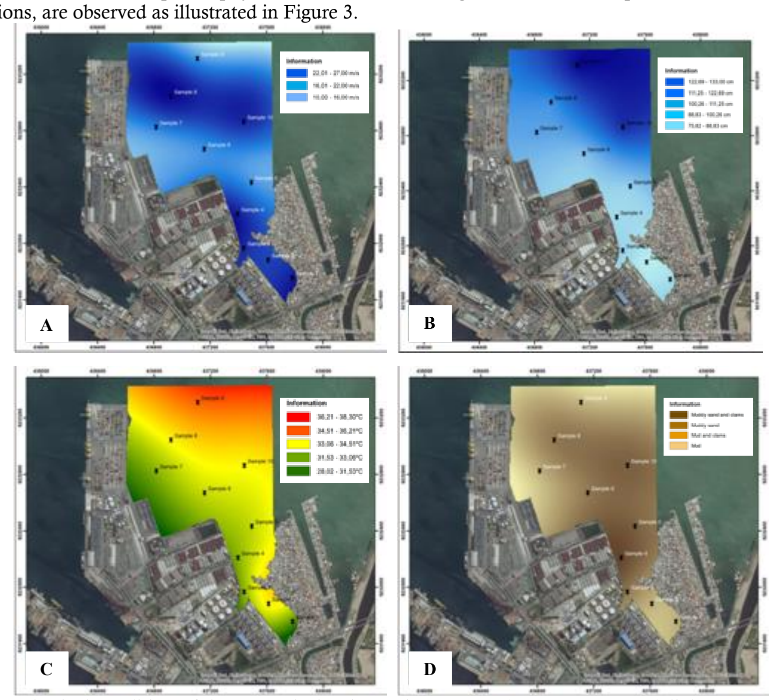


Figure 3 Physical condition of the research sites in Tanjung Mas: A) water current; B) light penetration; C) temperature and D) seabed sediment in Tanjung Mas fishpond areas.

The seawater depth varies between 4 m – 6 m; however, it is still suitable for milkfish cultivation. Milkfish juveniles will generally live in shallow seawater for two to three weeks, then migrate to mangrove forests, river estuaries, or lakes. The adult will return to the sea to breed. Meanwhile, the substrate samples in Tanjung Mas seawaters range from silt to gravel containing shell fragments and sand. However, the seabed's substrate does not directly affect the milkfish growth because the KJT system is placed on the open seas with nets to a maximum depth of 3 m. In contrast to the inland ponds, which only have a depth from 1 m up to 1.5 m that makes milkfish are directly in contact with the bottom substrate of the seawaters.

Light penetration of water brightness (low debris) indicates good conditions to support milkfish cultivation, even though it is located in the industrial and household waste disposal system. The light penetration significantly correlates to the photosynthesis rate of phytoplankton in providing natural feed for milkfish growth. The abundance of phytoplankton is also supported by relatively low water current and calming waves that keep the water clear from seabed substrate. The seawater currents speed in Tanjung Mas was ranged around 10 m/s – 25 m/s and categorized as low water flow. The coastal area in Tanjung Mas is an estuary of Mati River that has a low discharge because the water sources only come from city drainage and water polder. Water current plays a vital role in nutrient circulation, carrying dissolved and suspended materials, feed distribution, total oxygen solubility, and salinity. Tanjung Mas have seawater with a salinity level of 30‰ – 34‰, which supports milkfish cultivation. Salinity conditions in Tanjung Mas are not much different from the average salinity value of Indonesian waters ranging from 32‰ – 34‰ (Hu et al., 2019). Fluctuations in salinity levels are caused by the high evaporation rate of the surface waters in the east monsoon and rainfall, especially in the west monsoon season (Ratnawati et al., 2018) and the discharge of river water that enters the ocean (Hamzah et al., 2020). Their statement is in line with this research that the first observation station has a lower salinity because it is located in the delta flow of the Mati River.

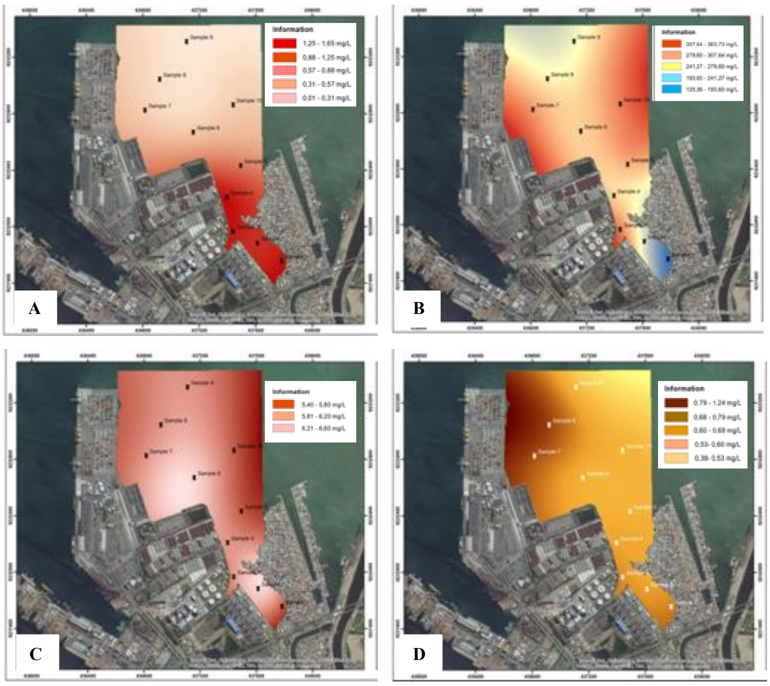
The water temperature of the KJT location in Tanjung Mas ranges between 31ºC – 37ºC. This temperature is not suitable for milkfish cultivation because the optimal temperature for milkfish growth goes from 27ºC – 30ºC (Astuti & Warsa, 2020). The high temperature in the KJT areas may be influenced by the long dry season that increases the water surface temperature due to the high intensity of sunlight. Temperatures that are too high or too low directly affect milkfish foraging behavior, reduce sensitivity and inhibit juvenile growth (Failaman et al., 2021; Hanke et al., 2019). An increase in temperature raises the decomposition and fermentation of organic matter, producing ammonia that is toxic to fish. The temperature rise also causes stratification or coating of water, which affects the mixing of seabed material and disturbs nutrition distribution (Li et al., 2020). However, the temperature is also needed in oxygen mixing from the surface to the deep waters (Lobine et al., 2021). Seawater temperature also affects surface currents, the distribution of plankton, and the survival of marine life to control the condition of aquatic ecosystems.

An increase in water temperature affects the metabolism and respiration of aquatic organisms and further increases oxygen consumption (Bonachea, 2021; Nie et al., 2017). An increase in water temperature of 10 C causes an increase in oxygen consumption by aquatic organisms about 2-3 times. However, an increase in temperature accompanied by a decrease in dissolved oxygen levels is often unable to meet the oxygen needs of aquatic organisms to carry out metabolism, thus affecting their growth (Audzijonyte et al., 2019; Das et al., 2018; Nelson, 2016; van Rijn et al., 2017). Physical conditions may affect the chemical requirements of pond waters. The analysis of chemical parameters shows that in addition to natural physical factors, anthropogenic activities also cause chemical conditions between pond areas. The measurement results show varying values (Table 3) and uneven distribution for each physical and chemical parameter (Figure 3 & 4) at each observation station.

Table 3. Recapitulation of water suitability parameter data (Site Capability) at each observation station

Parameter	Station									
	1	2	3	4	5	6	7	8	9	10
Seawater depth (m)	4.00	4.00	4.00	4.00	4.00	4.00	5.00	5.00	6.00	4.00
Light Penetration (cm)	80,50	70.00	89.00	81.30	78,50	79,50	98,5	91,50	14,12	13,45
Turbidity (NTU)	3.15	3.26	2.58	3.51	3.26	2.96	2.97	2.68	2.38	1.66
Water current (m/s)	25.00	20.00	23.00	25.00	10.00	10.00	12.00	27.00	10.00	23.00
Temperature (C)	31.00	34.00	32.00	32.00	33.00	33.00	32.00	34.00	37.00	34.00
DO (mg/l)	6.40	5.44	6.00	5.84	6.32	5.68	6.16	6.00	5.92	6.24
pH	6.50	6.80	6.40	6.90	7.30	7.10	7.10	7.20	7.30	7.50
Salinity (‰)	30.00	31.00	32.00	32.00	32.00	32.00	33.00	34.00	34.00	33.00
Nitrate (mg/L)	0.68	0.57	0.62	0.55	0.45	0.46	0.90	0.94	0.40	0.68
Nitrite (mg/L)	0.03	0.04	0.06	0.04	0.02	0.02	0.01	0.01	0.01	0.01
Phosphate (mg/L)	0.99	0.41	0.26	0.27	0.11	0.20	0.07	0.08	0.06	0.08
Ammonia (mg/L)	1.57	1.40	1.54	1.57	0.92	0.36	0.29	0.16	0.07	0.30
BOD (mg/L)	124.70	249.40	364.50	306.90	326.10	306.90	345.30	287.80	268.60	364.50
Seabed materials	S	S	S-Cs	Gs-Cs	Gs	S-Cs	S	S-Cs	S	GS

Note: Cs = clam shell shards; Gs = Grit-silt (muddy); and S = Silt


A
B
C
D

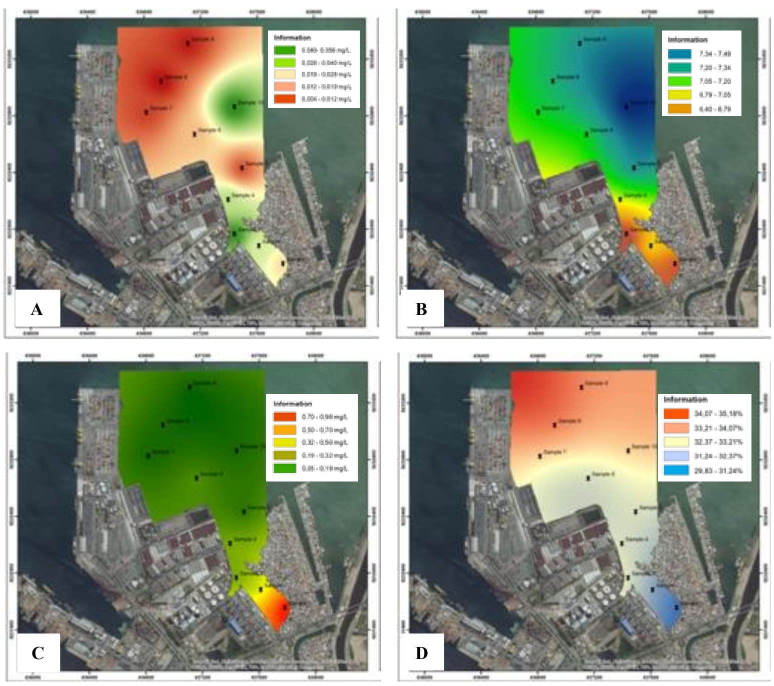

A
B
C
D

Figure 4. Chemical factors condition of the research sites in Tanjung Mas: A) ammonia distribution; B) BOD level; C) DO ; D) nitrate; E) nitrite; F) pH; G) phosphate; H) salinity Tanjung Mas fishpond areas.

The majority of chemical factors in the KJT aquatic environment are suitable for milkfish growth. Furthermore, dissolved oxygen (DO) levels meet seawater quality standards and support the development of cultured fish. Adequate dissolved oxygen levels may be produced from plankton photosynthesis and air diffusion (Horak et al., 2018). In addition, oxygen is a limiting factor for water quality because it plays an essential role in the fermentation of organic and inorganic materials at the seabed (Orsi, 2018).

The needed O_2 for decomposition and fermentation can be identified from biochemical oxygen demand (BOD) content. A higher concentration in the fishpond indicates the possibility of high organic matter in the waters (Jorgensen & Marshall, 2016). The results of BOD measurements at ten observation stations showed a value of 124.7 mg/L – 364.5 mg/L, especially at stations 3 – 9. Based on the BOD criteria, it can be seen that the seawaters around Tanjung Mas are classified as high polluted by organic compounds. It is probably caused by the decomposition process of milkfish feed, which is sedimented at the seabed. In addition, the map (Figure 4B) shows that high BOD concentrations are distributed mainly near the industrial's outfall areas even though the pH around the Tanjung Mas water area is in the neutral range of 6 – 7 and supports milkfish cultivation. In nature, the pH value ranges from 4 – 9, where the unbalancing of the pH affects aquaculture fish or the presence of seawater organisms.

The fermentation process of organic materials releases N into seawaters in the form of nitrate (NO_3), nitrite (NO_2), and ammonia (NH_4) (Oshiki et al., 2016; Spataru, 2021, 2017). The concentration of NO_3 in Tanjung Mas, was ranged from 0.3947 mg/L - 0.9386 mg/L, while nitrite was 0.0058 mg/L – 0.0338 mg/L, and ammonia was 0.073 mg/L – 1.568 mg/L. High concentrations of NO_3 and NO_2 in the seawaters can stimulate the growth and development of phytoplankton and become an indicator of fishpond fertility (Hardikar et al., 2019). NO_2 is also an indicator of decreasing N contamination because its formation comes from the oxidation of $NH_{4,}$ which is toxic. Then, an availability of NO_2 comes from the oxidation of NH_4 to NO_2 carried out by Nitrosomonas bacteria, while the oxidation of NO_2 to NO_3 is carried out by Nitrobacter (Santoro et al., 2021). NO_2 is usually found in lower amounts than NO_3 because it is unstable and easily reacts with oxygen.

The findings obtained in this study showed that the measured NH_4 levels were quite high at seven observation stations (stations-1, 2, 3, 4, 5, 6, and 10). The location is on the Mati River, which carries domestic waste from settlements. Organic materials from domestic waste increase the rate of decomposition and fermentation of organic materials to produce NH_4 as a by-product. The increase in NH_4 contamination is positively correlated with anthropogenic factors, primarily related to the residential, agricultural, livestock, and industrial sectors (Bessa et al., 2021; Sproson et al., 2021). In addition, the problem faced in Tanjung Mas waters is the lack of suitable sanitation, causing pollution and the balance of the pond waters ecosystem.

Low NH_4 concentrations were measured at stations 7, 8, and 9 because they are located far from settlements and industrial outfall, have more than 5 m depth and are near the open sea. This condition improves water circulation due to ocean currents and a more homogeneous seawater diffusion process.

Domestic waste may be one of the main factors that increase phosphate concentrations in the KJT waters area. Various studies have shown that human activities, including household waste, have increased the concentration of contaminants in the oceans, such as nitrogen (Jickells et al., 2017), phosphate (Badawy et al., 2018; Thiombane et al., 2019), to heavy metals (Bessa et al., 2021; Chu et al., 2019). It is indicated by the distribution of phosphate levels at stations 1 to 5, which is higher than the other five observation stations. Phosphate is a nutrient that is a determining factor in phytoplankton in the sea and is usually found in the form of organic compounds (Bristow et al., 2017).

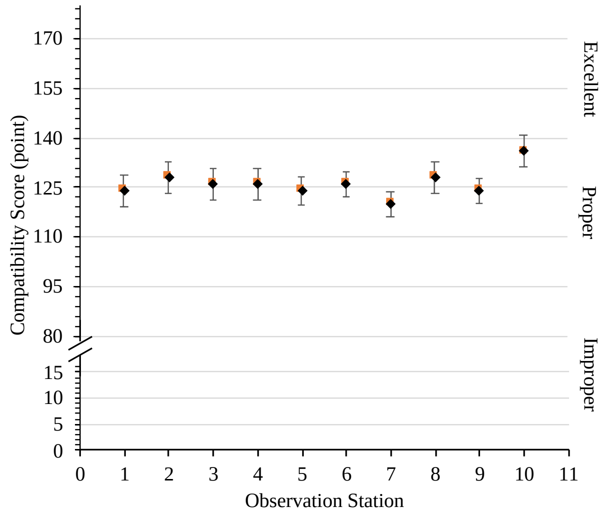


Table 4. Compatibility for milkfish cultivation in Tanjung Mas waters area based on the observation station.

The water compatibility value (Table 4) shows that all observation stations were categorized at the proper level (S2). It indicates that the Tanjung Mas water area is sufficient and can be developed as a KJT cultivation area. However, limiting factors require special attention to increasing milkfish productivity, such as N and P levels and BOD.

Analysis of KJT System Carrying Capacity Based on Waters Capacity

The total area of potential waters in the Tanjung Mas for KJT is 119.51 Ha, but referring to the government regulation, it is only 20% that can be used for aquaculture. Then the optimum area for the KJT aquaculture system that can be developed is only about 23,902 Ha. However, based on the observation, the existence of KJT has overcapacity. Twenty-two cages occupy it with more than 53.45 Ha of waters area. Furthermore, it can be seen that the utilization of the waters has exceeded the carrying capacity because the practical potential of the waters area for the KJT system is only 2.4 cage/ Ha for only ten cage units. Therefore, it is necessary to reduce the number of KJT units by looking at the existing conditions.

High occupied waters area with dense cultured milkfish may overshoot the waters capacity and potentially trigger mass death of the marine organism. The condition of the waters directly adjacent to the sea provides an advantage for faster purification. However, the continuous input of domestic and industrial pollutants and low river discharge resulted in a low nature purification rate. It must be a common concern, considering that the waters in the KJT area are the output of several waste installations from the community (domestic) and industries.

KJT is an adaptive tool/ effort for fish-farmers to adapt the climate change which reduces their income. Maint reason for using KJT in Tanjung Mas is more caused by large profits obtained from aquaculture using low cost production. This study also shows that the community does not yet have awareness about the implementation of sustainable milkfish cultivation by concerning carrying capacity of the environment and product quality. Even though, the KJT is contaminated by domestic and industrial waste. In other words, economic reasons take precedence over health and environmental suitability to produce profitable cultivation comodities.

CONCLUSION

In general, the physicochemical factors in Tanjung Mas water areas are proper and support milkfish cultivation. However, the existing condition shows that water utilization for milkfish aquaculture activities using KJT has exceeded the carrying capacity. It potentially disturbs milkfish growth and may lead to the unbalancing ecosystem and trigger the death of the marine organism. On the other hand, high pollution from industries and household waste has become a significant problem affecting milkfish growth and becoming a health issue. High P and NH_4 were primarily detected in the observation station near the industrial outfall and Mati River estuary, containing domestic waste. It needs an improvement of waste management system from industrial and household by providing sewage purification utilities and scheduling waste disposal based on tidal conditions after purification treatment.

ACKNOWLEDGMENT

The acknowledgment is delivered to the Ministry of Education, Culture, and Higher Education for funding the research through the Penelitian Terapan Unggulan Perguruan Tinggi (PTUPT) Scheme, grant number: 43.14.7/UN37/PPK.6.8/2021. Hopefully, the research results can be helpful for the improvement of coastal areas management.

Dikomentari [U8]: Include the contract number of the funding letter.

REFERENCE

Dikomentari [U9]: 1. Please provide at least **30 references** which 80% of them are taken from **the last 10 years (>2011)** articles of no-predatory journals, written in accordance with the APA Standard. You may go to Google Scholar and find the right format for APA Style provided.

2. For books, please refer to the original/primary book reference no matter the date.

3. All of the listed references must be cited in the body of the article, and vice versa.

Dikomentari [au10]: 1. All of the references were arranged using Mendeley and automatically cross-checked.
2.. there are no reference which published more than 2014
3. all citation is in APA 7th edition format and adapted to JPII template

Ahmed, N., Thompson, S., & Glaser, M. (2019). Global Aquaculture Productivity, Environmental Sustainability, and Climate Change Adaptability. *Environmental Management*, *63*(2), 159–172.

Andreas, H., Abidin, H. Z., Sarsito, D. A., & Pradipta, D. (2018). Adaptation of Early Climate Change Disaster' to the Northern Coast of Java Island Indonesia. *Engineering Journal, 22*(3), 207–219.

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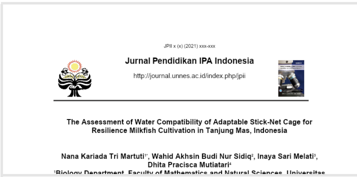

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Paper title: The Assessment of Water **Compatibility of Adaptable Stick-Net Cage for Resilience Milkfish Cultivation in Tanjung Mas, Indonesia**

Parts of review	**Guidelines**	**Yes**	**Partly**	**No**	**Reviewer's note for improvement**	**Author's responds (highlight of revision)**
Title	• Does the subject matter fit within the scope of journal?	√				
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Back-ground	• Is the background informative and sufficient (include the background problem and objectives)?		√		It is advisable for authors to address general practice of inland milkfish cultivation.	
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	• Others				In Table 1, the following (1-4) points should be clarified; 1.The explanation on scoring assumption on parameter of Light penetration (cm), *while 0.7-1.4….* this seems incomplete sentences	

					2. Degree symbol is missing for temperature. 3. In-text citation for Nitrate (Oktora, 2000) is not present in references. 4. The explanation on scoring assumption on parameter of BOD (mg/L), > *20mg/L….* this seems incomplete sentences Instead of formula, use the term equation. as the following example $SC = \Sigma(S_n \times W)$ …………. (1)	
Results & Discussion	• Are the tables, graphs and pictures understandable, well presented and numbered consecutively?		√		Poor text and legends visibility in all captured satellite images. Please observe typo in all text in the manuscript, for example, 1. Spelling error "Maint" 2. *Even though, the KJT is contaminated by domestic and industrial waste.* The use of *Even though* seems inappropriate in this context.	
	• Do the data analysis and the interpretation appropriate to the problem and answer the objectives?	√			Table 3 should be mentioned earlier somewhere in paragaraph of subtopic *water suitability analysis to suppoer KJT cultivation system* There's mixture of commas and full stops in Table 3. The description of salinity in discussion explained in % while in Table 1 in (mg/L), please confirm.	
	• Does the "discussion" section of the manuscript adequately relate to the current and relevant litarature?		√		It is advisable to provide in-text citation to support the following statement; *Around 2008, several pond farmers developed aquaculture activities using the KJT system.*	

					The author may improve the explanation in paragraph 1 of result and discussion by rearrange the phrase that describe the causes that make the farmers shift to KJT method (which had been mentioned) I would suggest the authors to present the results and discussion to several subtopic particularly the water analysis.The authors may discuss to physical and chemical parameters accordingly.	
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Conclusion	• Is the conclusion clear and in the form of a narration instead of pointers?		√			
	• Isn't the conclusion a summary and consistent between problems, objectives and conclusion?			√	A conclusion should summarized the findings with no additional new points that never had stated anywhere beforehand. For example, *It needs an improvement of waste management system from industrial and household by providing sewage purification utilities and scheduling waste disposal based on tidal conditions after purification treatment.* The above points was important and should be suggest in discussion, not in conclusion.	
References	• Do the references and citations match?	√			in-text citation for Nitrate (Oktora, 2000) has not been observed in references.	

	• Are the writing of references correct?	√				
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The Assessment of Water Compatibility of Adaptable Stick-Net Cage for Resilience Milkfish Cultivation in Tanjung Mas, Indonesia

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Abstract

Milkfish cultivation becomes the main livelihood of farmers in coastal areas. However, the land for milkfish cultivation is shrinking due to land use for settlements, industries, and sea-level rise. A Stick-net cage is an aquaculture solution in limited space for an inland fishpond. It can be placed in seashore areas while maintaining the quality of the aquatic environment and nutrient circulation. This study aims to analyze water compatibility in the stick-net cage areas for supporting sustainable aquaculture activities. An exploratory observational study was conducted in Tanjung Mas Village, Semarang, Central Java, Indonesia. Ten sampling areas were determined purposively by considering the point locations toward household wastewater and industrial outfalls. Based on these criteria, the ten stations used as sample areas were divided into industrial outfall areas (1st – 5th station) and areas close to the open sea (6th – 10th station). Physical parameters in the sampling areas, including temperature, water-current, turbidity, and clearness, met seawater standards for milkfish cultivation. Chemical indicators, such as NH_4 and P in water, were very high, which may cause by domestic and industrial waste contamination, and increased organic fermentation activity on the seabed. However, the existing stick-net cages have exceeded the capacity of the coastal water areas. In general, the physicochemical parameters in the Tanjung Mas waters area are suitable for milkfish cultivation. However, it is necessary to reduce the amount of pond density to give growth space for milkfish. In addition, wastewater management and treatment plants should be built up to reduce waters contamination.

Keywords: coastal management, sustainable livelihood, water compatibility

INTRODUCTION

Semarang is a coastal city that produces milkfish in Central Java, with 328.65 tons in 2020. Milkfish is the main cultivated fish commodity in Semarang and the livelihood for more than 1500 pond farmers with a total income of 6.32 trillion per year (Central Java Statistics Agency [BPS], 2021). One area in Semarang that relies on milkfish cultivation as its primary income source is the fish-farmers community in Tanjung Mas.

Inland pond for milkfish cultivation is at risk of being damaged by high waves and sea-level rise as the effect of climate change (Ahmed et al., 2019). Over the last ten years, abrasion has caused a shift in the coastline in Semarang by more than 0.5 km (Irsadi et al., 2019) and the loss of ponds in coastal areas (Andreas et al., 2018). In addition, the increase of industry, housing, and commercial spaces have decreased pond cultivation areas in Semarang. As a result, milkfish farmers experience a decline in milkfish production, threatening business stability (Martuti et al., 2020) and lowering resilience against climate change (Bosma et al., 2017; Purwaningsih & Hermawan, 2021). land-use conflicts, and potential threats from anthropogenic factors, including industrial and household waste (Henriksson et al., 2019). A case study in the Tanjung Mas waters area, shows that the high risk milkfish cultivation due to climate change and land-use conflict has prompted milkfish farmers to change to using cages planted in coastal waters.

An adaptation activity in milkfish cultivation has been initiated by farmers in Tanjung Mas, Semarang, who take initiation to build stick-net cages (*Keramba Jaring Tancap* [KJT]) in shallow water areas. KJT is arranged using bamboo sticks stuck to the seabed and installed with the net on the edges to the bottom. Furthermore, KJT is a community adaptation product in facing the climate change which reduces their income. However, this solution is developed more based on the large profits obtained from aquaculture, but ignoring the environment sustainability. Eventhough, this cultivation technique claimed able to maintain water quality, nutrient circulation, and physical conditions to support milkfish growth (Sambu, 2017). Therefore, a study on the importance of assessing the environmental conditions and the effect of KJT on water bodies need to be conducted.

An aessment about environment sustainability and the effect of KJT in Tanjung Mas waters bodies is rarity conducted, whereas, the deltas area in that area becomes an outlet for domestic and industrial waste. It is possible that the waste pollution interferes milkfish growth during cultivation. Furthermore, technology transformation from inland milkfish cultivation to KJT needs to be studied in-depth, especially the factors affecting pond water quality (Ganesh et al., 2020). In addition, chemical and organic contamination may increase in estuarine ecosystem that affect fish growth as a result of replaced cultivation activity. In recent studies, the anthropogenic factors, such as chemical pesticides, drugs (Chang et al., 2019), and feed (Srithongouthai & Tada, 2017) in milkfish cultivation affects physicochemical conditions of the aquatic ecosystem.

Inland aquaculture practice currently ignores the carrying capacity of the aquatic environment, causing a decline in the estuary ecosystem quality (Gusmawati et al., 2018; Hukom et al., 2020; Proisy et al., 2018). Hence, aquaculture management strategies using KJT must be conducted in line with the principle of sustainable development through balancing the social aspects, economic resources management, and environmental sustainability (Boyd et al., 2020). Therefore, this study aims to analyze the suitability of water conditions and biophysical aspects to support sustainable aquaculture activities in the Tanjung Mas coastal area. This study is expected to raise awareness among aquaculture actors regarding the suitability of the coastal area in their territory.

METHOD

This research was an explorational observation conducted in the KJT aquaculture area, administratively included in the Tanjung Mas, Semarang, Central Java, Indonesia. Data was taken in June – August or during the dry season to photograph the pond waters' original condition accurately.

Sampling site determination.

Sampling was carried out at 10 points spread from the end of the Mati River to the vicinity of the KJT location at the river's delta. The sample point was determined purposively by considering 1) the location of household wastewater discharge, the outfall of industries around the river, and the site of the KJT. Based on these criteria, the 10 sample area points were divided into 1) industrial waste and outfall areas (points 1-5), as assumed that the waters are directly contaminated by sewage, and 2) the areas close to the open sea (points 6-10), as assumed that the open sea has a mechanism to eliminate the waste as an effect of the ocean currents (Figure 1).

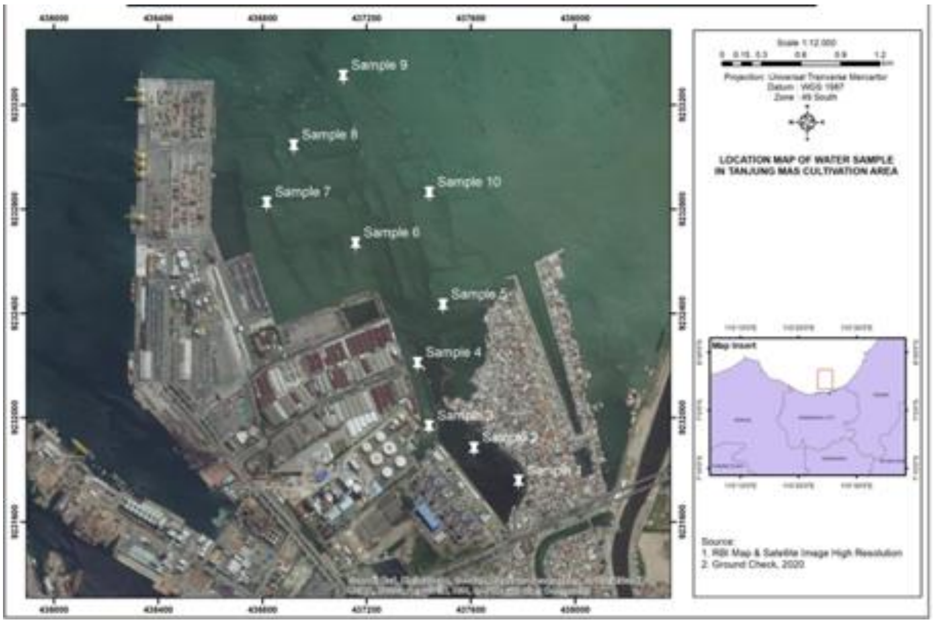


Figure 1. Map of the location for determining the water suitability analysis sample

Water samples were collected compositely from the pond area by taking 1 L of water each from five points or sides and the pond center. The water was then combined and homogenized before being used for further analysis. The water samples are stored in dark bottles to avoid chemical damage and physical changes due to light.

Water Suitability Analysis

Data on water conditions that support milkfish cultivation in this study are grouped into two parameters, physical and chemical (Table 1). The parameters were selected from the Government Regulation (PP) No. 22 of 2021 about seawater quality standards for cultivation (Table 1).

Table 1. Water suitability analysis (Site Capability)

Physicochemical parameters (n)	Scoring assumption*	Parameter values (S_n)	Rubric Score**	Weight (W)
Seawater depth (m)	Sea depths between 0 – 10 provide circulation of nutrients and plankton needed for fish growth	≤ 5	5	3
		5 – 10	3	
		≥ 10	1	
Light penetration (cm)	Into the water for milkfish cultivation ranges from 30 – 40 cm, while 0.7 – 1.4.	≤ 3	5	1
		3 – 5	3	
		≥ 5	1	
Turbidity (NTU)	Turbidity is related to the penetration of light needed by phytoplankton for photosynthesis. A reasonable waters threshold is < 5.	≤ 5	5	1
		> 5 – 20	3	
		> 20	1	
Water current (m/s)	Current plays a role in water circulation, which affects the amount of dissolved oxygen and nutrients in the water.	20 – 40	5	3
		10 – < 20 or > 40 – 70	3	
		< 10 or > 70	1	
Temperature (C)	The optimum temperature for milkfish growth is between 23 C – 35 C. Water temperature affects the growth and development of milkfish.	28 – 30	5	2
		26 – < 28 or > 30 – 31	3	

Physicochemical parameters (n)	Scoring assumption*	Parameter values (S_n)	Rubric Score**	Weight (W)
		< 26 or > 31	1	
DO (mg/l)	DO levels suitable for marine life are in the range of > 5 mg/L or 4 – 8 ppm	≥ 5	5	3
		≥ 3 - < 5	3	
		< 3	1	
pH	A good pH value in milkfish cultivation is between 6.5 – 9.	7.5 – 8	5	2
		7 – < 7.5 or	3	
		> 8 – 8.5		
		< 7 or > 8.5	1	
Salinity (mg/L)	Good salinity for milkfish cultivation ranges from 0-35.	29 – 31	5	2
		27 - < 29 or	3	
		> 31 – 33		
		< 27 or > 33	1	
Nitrate (mg/L)	Phytoplankton can grow optimally at a nitrate content of 0.9 ± 3.5 mg/l, while at concentrations below 0.01 or above 4.5 mg/l, it can be a limiting factor for phytoplankton growth (Oktora, 2000).	< 0.008	5	1
		> 0.008 - 0.4	3	
		> 0.4	1	
Nitrite (mg/L)	High nitrite causes a decrease in water pH and is toxic to marine biota	0	5	1
		< 0.1	3	
		≥ 0.1	1	
Phosphate Total (mg/L)	It is needed for the growth and metabolism of phytoplankton and marine organisms.	≤ 0.014	5	2
		0.015 - ≤ 0.8	3	
		> 0.8	1	
Ammonia (mg/L)	The lethal concentration (LC50) of ammonia is 1.10 to 22.8 ppm resulting in 5% mortality and 20% growth reduction for cultured fish	0 - 0.2	5	1
		> 0.2 - 0.5	3	
		> 0.5	1	
BOD (mg/L)	The level of pollution is low if the BOD value is 0 – 10 mg/L, while the level of pollution is moderate if it is 10 – 20 mg/l, > 20 mg/L.	≤ 10	5	1
		> 10 – 45	3	
		> 45	1	
Seabed materials	The media affect the survival of milkfish, thus affecting the success of the enlargement business.	Gravel	5	2
		Grit-silt (muddy)	3	
		Silt	1	

Note: * The parameter was adapted Government Regulation (PP) No. 22 of 2021 and modified from Kumar et al. (2017); Olatayo (2014),

** Physicochemical parameters that are considered essential and dominant give greater weight in affecting milkfish growth.

To obtain seawater compatibility value (SC), it was measured from summaries of the weight (W) score that multiplied by the parameter score (S_n) for each parameter (n) (Formula 1). The seawater compatibility interval class (Table 2).

$$SC = \sum (S_n \times W)$$

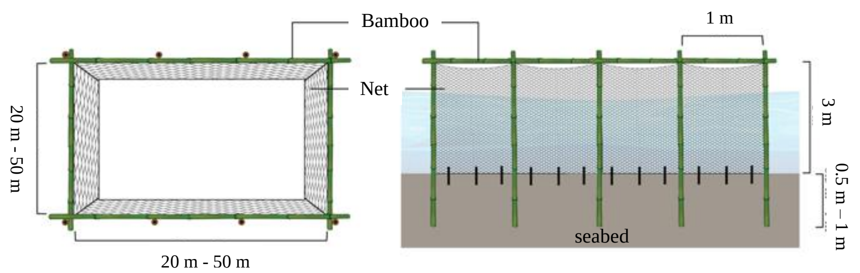
Table 2. Water suitability classification criteria

Status Code	Scoring Criteria	Compatibility Status
S1	> 146.7	Excellent
S2	93.3 – 146.7	Proper
N	< 93.3	Improper

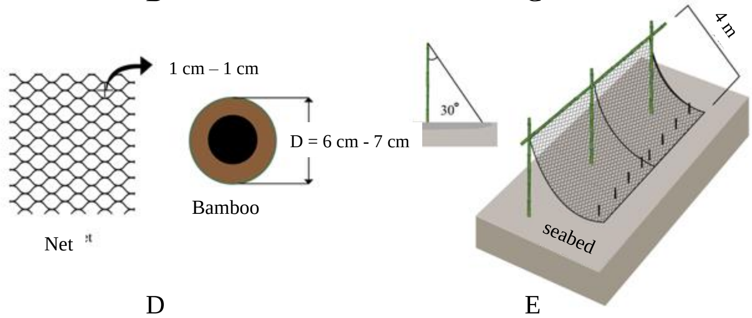
RESULT AND DISCUSSION

Previously, aquaculture in Tanjung Mas was carried out using inland ponds with embankments directly bordering the sea or other ponds. However, in the early 2000s, this activity began to be abandoned because damaged by abrasion and sea-level rise (Surya et al., 2019). Around 2008, several pond farmers developed aquaculture activities using the KJT system. Currently, the majority of the farmers conduct aquaculture business as a side job when the fishing season is disturbed by weather. However, because milkfish cultivation profit using the KJT system was higher than catching fish, the business became popular and income. KJT is made using bamboos construction that is plugged into a seabed forming a cage block. The nets used by the farmers have hole diameters ranging from 0.5 cm – 0.5 cm for nursery and 1 cm – 1 cm for enlargement (Figure 2).

A



B C



D E

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Figure 2. Detailed design of stick-net cage specification used for milkfish cultivation in Tanjung Mas: A) existing stick-net cage; B) upper view of the net-cage; B) construction design; C) materials specification; D) net position on the seabed.

KJT using three layers of nets surround a 1 ha of fishpond with a depth of 3 m. It takes about five rollers of net sizing 30 m x 5 m. The advantage of using KJT is the capability of the construction model that supports nutrient circulation in the seawater. It makes the availability of natural feed for milkfish and reduces additional fed for cultivation (Cornejo et al., 2020). Pollutants from outside and ammonia from feed fermentation inside the cage circulate in the pond, as illustrated in Figure 3 (Cha & Lee, 2018).

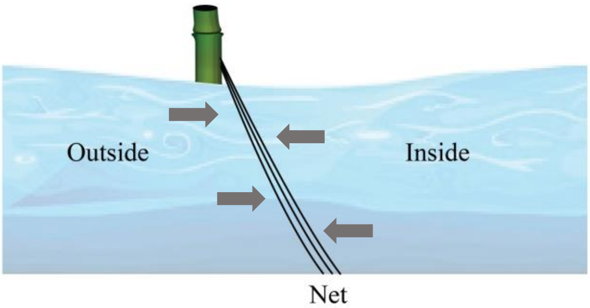


Figure 3. Materials flow illustration through net-cage construction

KJT disadvantages are performed by uncontrolled physicochemical conditions inside the cage and are adequately dependent on natural factors. Consequently, the farmers cannot adjust waters condition to speed up milkfish growth. It is necessary to maintain the optimal physical and chemical conditions in the environment according to the age of the milkfish to get optimal growth (Failaman et al., 2021; Mandal et al., 2018).

Seawater aquaculture requires appropriate environmental conditions that support the growth and development of milkfish. In addition, KJT in Tanjung Mas is placed around industrial and household waste streams that contain toxic contaminants that may interfere with milkfish growth or are inappropriate for human consumption. On the other hand, milkfish cultivation may also impact the condition of the seawaters around the pond due to feed and milkfish manure that settles at the pond's seabed.

Water Suitability Analysis to Support KJT System Cultivation

The carrying capacity of the seawater environment is determining factor for milkfish cultivation. Physically, the Mati River's estuary (the only river in Tanjung Mas) supports milkfish cultivation. However, the differences in the milkfish pond's physical conditions, including water current, temperature, seabed substrate conditions, are observed as illustrated in Figure 4.

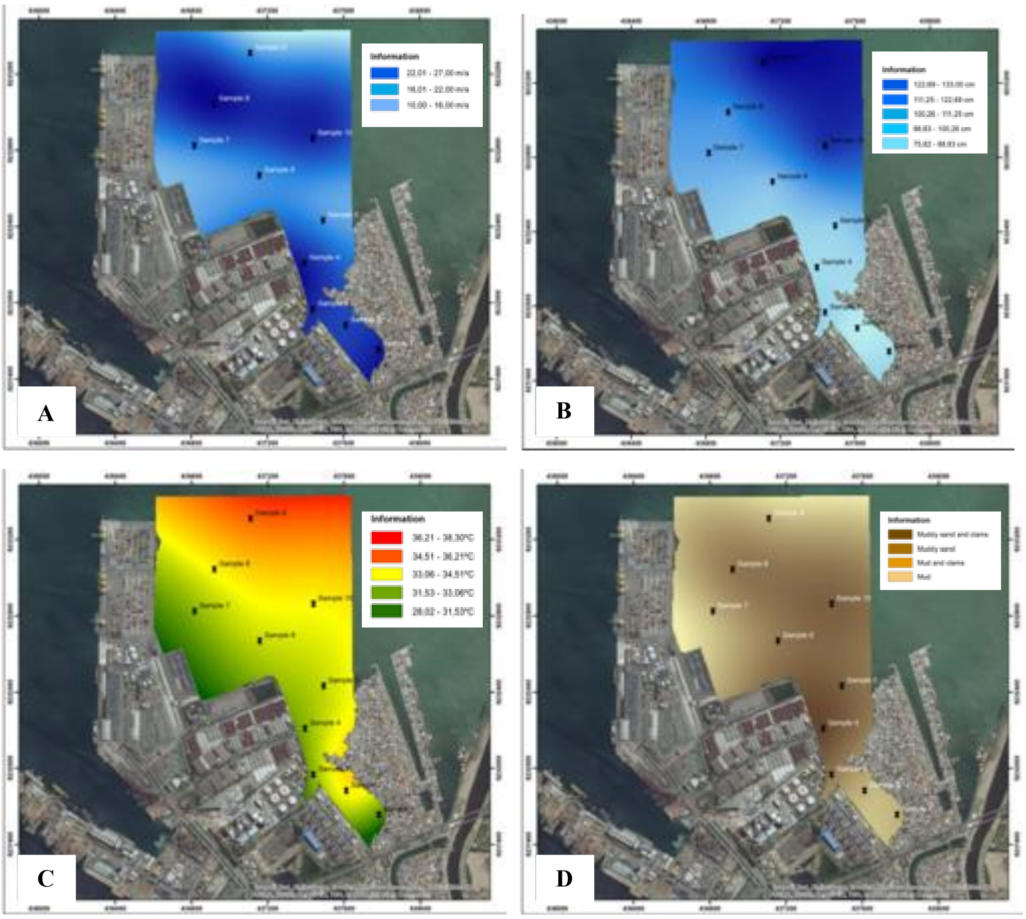


Figure 4 Physical condition of the research sites in Tanjung Mas: A) water current; B) light penetration; C) temperature and D) seabed sediment in Tanjung Mas fishpond areas.

The seawater depth varies between 4 m – 6 m; however, it is still suitable for milkfish cultivation. Milkfish juveniles will generally live in shallow seawater for two to three weeks, then migrate to mangrove forests, river estuaries, or lakes. The adult will return to the sea to breed. Meanwhile, the substrate samples in Tanjung Mas seawaters range from silt to gravel containing shell fragments and sand. However, the seabed's substrate does not directly affect the milkfish growth because the KJT system is placed on the open seas with nets to a maximum depth of 3 m. In contrast to the inland ponds, which only have a depth from 1 m up to 1.5 m that makes milkfish are directly in contact with the bottom substrate of the seawaters.

Light penetration of water brightness (low debris) indicates good conditions to support milkfish cultivation, even though it is located in the industrial and household waste disposal system. The light penetration significantly correlates to the photosynthesis rate of phytoplankton in providing natural feed for milkfish growth. The abundance of phytoplankton is also supported by relatively low water current and calming waves that keep the water clear from seabed substrate. The seawater currents speed in Tanjung Mas was ranged around 10 m/s – 25 m/s and categorized as low water flow. The coastal area in Tanjung Mas is an estuary of Mati River that has a low discharge because the water sources only come from city drainage and water polder. Water current plays a vital role in nutrient circulation, carrying dissolved and suspended materials, feed distribution, total oxygen solubility, and salinity. Tanjung Mas have seawater with a salinity level of 30‰ – 34‰, which supports milkfish cultivation. Salinity conditions in Tanjung Mas are not much different from the average salinity value of Indonesian waters ranging from 32‰ – 34‰ (Hu et al., 2019). Fluctuations in salinity levels are caused by the high evaporation rate of the surface waters in the east monsoon and rainfall, especially in the west monsoon season (Ratnawati et al., 2018) and the discharge of river water that enters the ocean (Hamzah et al., 2020). Their statement is in line with this research that the first observation station has a lower salinity because it is located in the delta flow of the Mati River.

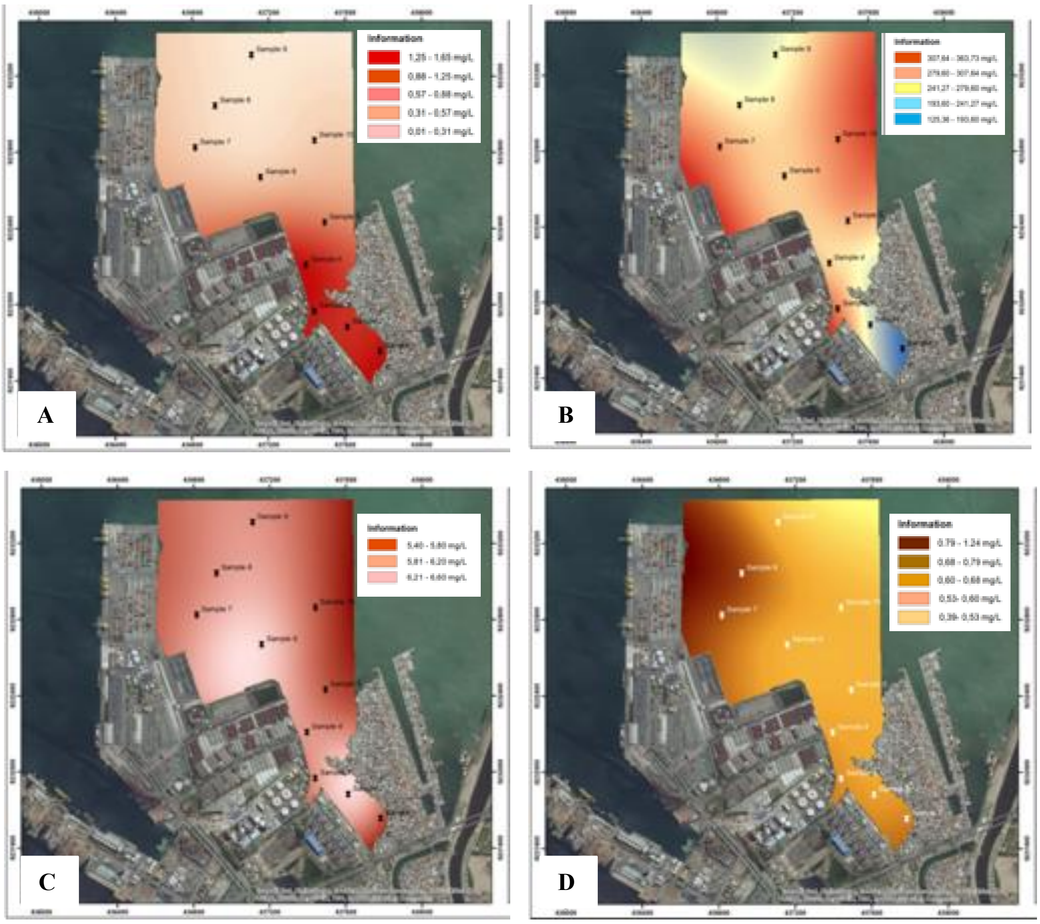
The water temperature of the KJT location in Tanjung Mas ranges between 31°C – 37°C. This temperature is not suitable for milkfish cultivation because the optimal temperature for milkfish growth goes from 27°C – 30°C (Astuti & Warsa, 2020). The high temperature in the KJT areas may be influenced by the long dry season that increases the water surface temperature due to the high intensity of sunlight. Temperatures that are too high or too low directly affect milkfish foraging behavior, reduce sensitivity and inhibit juvenile growth (Failaman et al., 2021; Hanke et al., 2019). An increase in temperature raises the decomposition and fermentation of organic matter, producing ammonia that is toxic to fish. The temperature rise also causes stratification or coating of water, which affects the mixing of seabed material and disturbs nutrition distribution (Li et al., 2020). However, the temperature is also needed in oxygen mixing from the surface to the deep waters (Lobine et al., 2021). Seawater temperature also affects surface currents, the distribution of plankton, and the survival of marine life to control the condition of aquatic ecosystems.

An increase in water temperature affects the metabolism and respiration of aquatic organisms and further increases oxygen consumption (Bonachea, 2021; Nie et al., 2017). An increase in water temperature of 10 C causes an increase in oxygen consumption by aquatic organisms about 2-3 times. However, an increase in temperature accompanied by a decrease in dissolved oxygen levels is often unable to meet the oxygen needs of aquatic organisms to carry out metabolism, thus affecting their growth (Audzijonyte et al., 2019; Das et al., 2018; Nelson, 2016; van Rijn et al., 2017). Physical conditions may affect the chemical requirements of pond waters. The analysis of chemical parameters shows that in addition to natural physical factors, anthropogenic activities also cause chemical conditions between pond areas. The measurement results show varying values (Table 3) and uneven distribution for each physical and chemical parameter (Figure 4 & 5) at each observation station.

Table 3. Recapitulation of water suitability parameter data (Site Capability) at each observation station

Parameter	Station									
	1	2	3	4	5	6	7	8	9	10
Seawater depth (m)	4.00	4.00	4.00	4.00	4.00	4.00	5.00	5.00	6.00	4.00
Light Penetration (cm)	80,50	70.00	89.00	81.30	78,50	79,50	98,5	91,50	14,12	13,45
Turbidity (NTU)	3.15	3.26	2.58	3.51	3.26	2.96	2.97	2.68	2.38	1.66
Water current (m/s)	25.00	20.00	23.00	25.00	10.00	10.00	12.00	27.00	10.00	23.00
Temperature (C)	31.00	34.00	32.00	32.00	33.00	33.00	32.00	34.00	37.00	34.00
DO (mg/l)	6.40	5.44	6.00	5.84	6.32	5.68	6.16	6.00	5.92	6.24
pH	6.50	6.80	6.40	6.90	7.30	7.10	7.10	7.20	7.30	7.50
Salinity (‰)	30.00	31.00	32.00	32.00	32.00	32.00	33.00	34.00	34.00	33.00
Nitrate (mg/L)	0.68	0.57	0.62	0.55	0.45	0.46	0.90	0.94	0.40	0.68
Nitrite (mg/L)	0.03	0.04	0.06	0.04	0.02	0.02	0.01	0.01	0.01	0.01
Phosphate (mg/L)	0.99	0.41	0.26	0.27	0.11	0.20	0.07	0.08	0.06	0.08
Ammonia (mg/L)	1.57	1.40	1.54	1.57	0.92	0.36	0.29	0.16	0.07	0.30
BOD (mg/L)	124.70	249.40	364.50	306.90	326.10	306.90	345.30	287.80	268.60	364.50
Seabed materials	S	S	S-Cs	Gs-Cs	Gs	S-Cs	S	S-Cs	S	GS

Note: Cs = clam shell shards; Gs = Grit-silt (muddy); and S = Silt


A
Information
1,25 - 1,65 mg/L
0,88 - 1,25 mg/L
0,57 - 0,88 mg/L
0,31 - 0,57 mg/L
0,01 - 0,31 mg/L
B
Information
307,64 - 363,73 mg/L
279,60 - 307,64 mg/L
241,27 - 279,60 mg/L
193,60 - 241,27 mg/L
125,36 - 193,60 mg/L
C
Information
5,40 - 5,80 mg/L
5,81 - 6,20 mg/L
6,21 - 6,60 mg/L
D
Information
0,79 - 1,24 mg/L
0,68 - 0,79 mg/L
0,60 - 0,68 mg/L
0,53- 0,60 mg/L
0,39- 0,53 mg/L

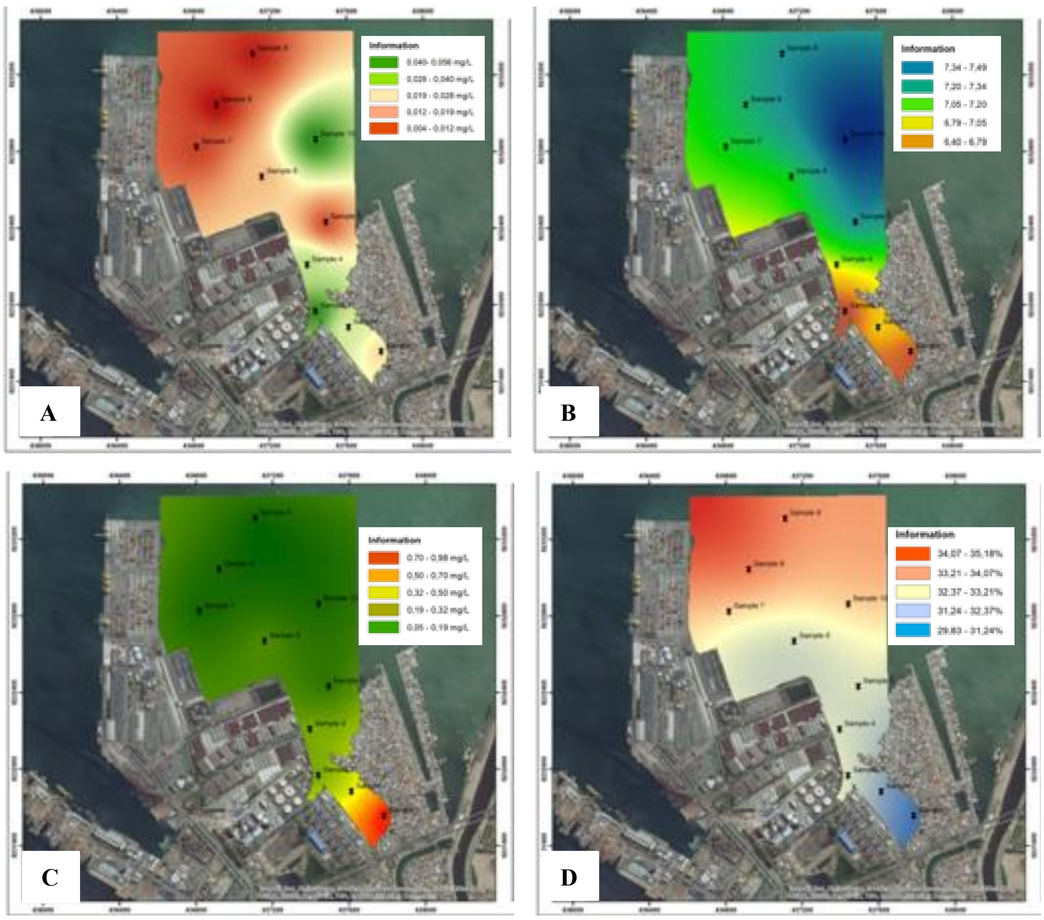

A
Information
0,040- 0,056 mg/L
0,028 - 0,040 mg/L
0,019 - 0,028 mg/L
0,012 - 0,019 mg/L
0,004 - 0,012 mg/L
B
Information
7,34 - 7,49
7,20 - 7,34
7,05 - 7,20
6,79 - 7,05
6,40 - 6,79
C
Information
0,70 - 0,98 mg/L
0,50 - 0,70 mg/L
0,32 - 0,50 mg/L
0,19 - 0,32 mg/L
0,05 - 0,19 mg/L
D
Information
34,07 - 35,18%
33,21 - 34,07%
32,37 - 33,21%
31,24 - 32,37%
29,83 - 31,24%

Figure 5. Chemical factors condition of the research sites in Tanjung Mas: A) ammonia distribution; B) BOD level; C) DO ; D) nitrate; E) nitrite; F) pH; G) phosphate; H) salinity Tanjung Mas fishpond areas.

The majority of chemical factors in the KJT aquatic environment are suitable for milkfish growth. Furthermore, dissolved oxygen (DO) levels meet seawater quality standards and support the development of cultured fish. Adequate dissolved oxygen levels may be produced from plankton photosynthesis and air diffusion (Horak et al., 2018). In addition, oxygen is a limiting factor for water quality because it plays an essential role in the fermentation of organic and inorganic materials at the seabed (Orsi, 2018).

The needed O_2 for decomposition and fermentation can be identified from biochemical oxygen demand (BOD) content. A higher concentration in the fishpond indicates the possibility of high organic matter in the waters (Jorgensen & Marshall, 2016). The results of BOD measurements at ten observation stations showed a value of 124.7 mg/L – 364.5 mg/L, especially at stations 3 – 9. Based on the BOD criteria, it can be seen that the seawaters around Tanjung Mas are classified as high polluted by organic compounds. It is probably caused by the decomposition process of milkfish feed, which is sedimented at the seabed. In addition, the map (Figure 4B) shows that high BOD concentrations are distributed mainly near the industrial's outfall areas even though the pH around the Tanjung Mas water area is in the neutral range of 6 – 7 and supports milkfish cultivation. In nature, the pH value ranges from 4 – 9, where the unbalancing of the pH affects aquaculture fish or the presence of seawater organisms.

The fermentation process of organic materials releases N into seawaters in the form of nitrate (NO_3), nitrite (NO_2), and ammonia (NH_4) (Oshiki et al., 2016; Spataru, 2021, 2017). The concentration of NO_3 in Tanjung Mas, was ranged from 0.3947 mg/L - 0.9386 mg/L, while nitrite was 0.0058 mg/L – 0.0338 mg/L, and ammonia was 0.073 mg/L – 1.568 mg/L. High concentrations of NO_3 and NO_2 in the seawaters can stimulate the growth and development of phytoplankton and become an indicator of fishpond fertility (Hardikar et al., 2019). NO_2 is also an indicator of decreasing N contamination because its formation comes from the oxidation of NH_4, which is toxic. Then, an availability of NO_2 comes from the oxidation of NH_4 to NO_2 carried out by Nitrosomonas bacteria, while the oxidation of NO_2 to NO_3 is carried out by Nitrobacter (Santoro et al., 2021). NO_2 is usually found in lower amounts than NO_3 because it is unstable and easily reacts with oxygen.

The findings obtained in this study showed that the measured NH_4 levels were quite high at seven observation stations (stations-1, 2, 3, 4, 5, 6, and 10). The location is on the Mati River, which carries domestic waste from settlements. Organic materials from domestic waste increase the rate of decomposition and fermentation of organic materials to produce NH_4 as a by-product. The increase in NH_4 contamination is positively correlated with anthropogenic factors, primarily related to the residential, agricultural, livestock, and industrial sectors (Bessa et al., 2021; Sproson et al., 2021). In addition, the problem faced in Tanjung Mas waters is the lack of suitable sanitation, causing pollution and the balance of the pond waters ecosystem.

Low NH_4 concentrations were measured at stations 7, 8, and 9 because they are located far from settlements and industrial outfall, have more than 5 m depth and are near the open sea. This condition improves water circulation due to ocean currents and a more homogeneous seawater diffusion process.

Domestic waste may be one of the main factors that increase phosphate concentrations in the KJT waters area. Various studies have shown that human activities, including household waste, have increased the concentration of contaminants in the oceans, such as nitrogen (Jickells et al., 2017), phosphate (Badawy et al., 2018; Thiombane et al., 2019), to heavy metals (Bessa et al., 2021; Chu et al., 2019). It is indicated by the distribution of phosphate levels at stations 1 to 5, which is higher than the other five observation stations. Phosphate is a nutrient that is a determining factor in phytoplankton in the sea and is usually found in the form of organic compounds (Bristow et al., 2017).

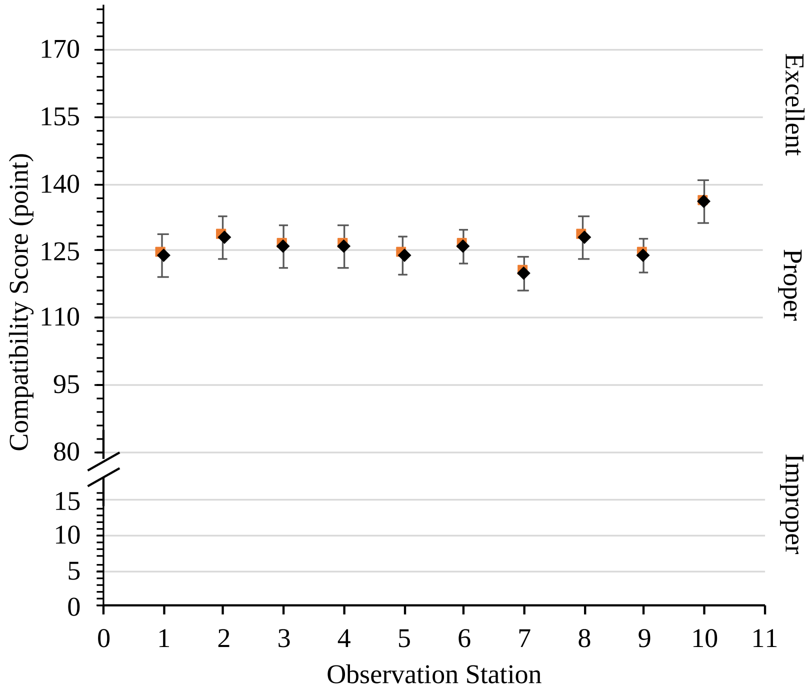


Figure 6. Compatibility for milkfish cultivation in Tanjung Mas waters area based on the observation station.

The water compatibility value (Figure 6) shows that all observation stations were categorized at the proper level (S2). It indicates that the Tanjung Mas water area is sufficient and can be developed as a KJT cultivation area. However, limiting factors require special attention to increasing milkfish productivity, such as N and P levels and BOD.

Analysis of KJT System Carrying Capacity Based on Waters Capacity

The total area of potential waters in the Tanjung Mas for KJT is 119.51 Ha, but referring to the government regulation, it is only 20% that can be used for aquaculture. Then the optimum area for the KJT aquaculture system that can be developed is only about 23,902 Ha. However, based on the observation, the existence of KJT has overcapacity. Twenty-two cages occupy it with more than 53.45 Ha of waters area. Furthermore, it can be seen that the utilization of the waters has exceeded the carrying capacity because the practical potential of the waters area for the KJT system is only 2.4 cage/ Ha for only ten cage units. Therefore, it is necessary to reduce the number of KJT units by looking at the existing conditions.

High occupied waters area with dense cultured milkfish may overshoot the waters capacity and potentially trigger mass death of the marine organism. The condition of the waters directly adjacent to the sea provides an advantage for faster purification. However, the continuous input of domestic and industrial pollutants and low river discharge resulted in a low nature purification rate. It must be a common concern, considering that the waters in the KJT area are the output of several waste installations from the community (domestic) and industries.

KJT is an adaptive tool/ effort for fish-farmers to adapt the climate change which reduces their income. Maint reason for using KJT in Tanjung Mas is more caused by large profits obtained from aquaculture using low cost production. This study also shows that the community does not yet have awareness about the implementation of sustainable milkfish cultivation by concerning carrying capacity of the environment and product quality. Even though, the KJT is contaminated by domestic and industrial waste. In other words, economic reasons take precedence over health and environmental suitability to produce profitable cultivation comodities.

CONCLUSION

In general, the physicochemical factors in Tanjung Mas water areas are proper and support milkfish cultivation. However, the existing condition shows that water utilization for milkfish aquaculture activities using KJT has exceeded the carrying capacity. It potentially disturbs milkfish growth and may lead to the unbalancing ecosystem and trigger the death of the marine organism. On the other hand, high pollution from industries and household waste has become a significant problem affecting milkfish growth and becoming a health issue. High P and NH_4 were primarily detected in the observation station near the industrial outfall and Mati River estuary, containing domestic waste. It needs an improvement of waste management system from industrial and household by providing sewage purification utilities and scheduling waste disposal based on tidal conditions after purification treatment.

ACKNOWLEDGMENT

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Paper title: The Assessment of Water **Compatibility of Adaptable Stick-Net Cage for Resilience Milkfish Cultivation in Tanjung Mas, Indonesia**

Parts of review	**Guidelines**	**Yes**	**Partly**	**No**	**Reviewer's note for improvement**	**Author's responds (highlight of revision)**
Title	• Does the subject matter fit within the scope of journal?	√				
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Back-ground	• Is the background informative and sufficient (include the background problem and objectives)?		√			Added more information in the paragraph 3 and 4, highlighted by yellow
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Methods	• Is the methodology chosen suitable to the nature of the topic studied?		√			
	• Is the methodology of the research described clearly?(including study design, location, subjects, data collection, data analysis)		√			Added the information about sampling area assumption
	• Is there adequate information about the data collection tools used? (only for empirical studies)		√			
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Cultivation in Tanjung Mas, Indonesia

Parts of review	**Guidelines**	**Yes**	**Partly**	**No**	**Reviewer's note for improvement**	**Author's responds (highlight of revision)**
Title	• Does the subject matter fit within the scope of journal?	√				
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Abstract	• Does the abstract contain informative, including Background, Methods, Results and Conclusion?	√				
Back-ground	• Is the background informative and sufficient (include the background problem and objectives)?		√		It is advisable for authors to address general practice of inland milkfish cultivation.	Added information in Introduction paragraph 2
	• Is research question of the study clear and understandable?	√				
	• Does the rationale of the study clearly explained using relevant literature?	√				
	• Is the "aim" of the manuscript clear and understandable?	√				
Methods	• Is the methodology chosen suitable to the nature of the topic studied?	√				
	• Is the methodology of the research described clearly?(including study design, location, subjects, data collection, data analysis)	√				
	• Is there adequate information about the data collection tools used? (only for empirical studies)		√		The author should give a brief information on machine/tools used for water analysis.	Added information in Table 1
	• Are the validity and reliability of data collection tools established? (only for empirical studies)		√			
	• Are the data collection tools suitable for the methodology of the study? (only for empirical studies)		√			
	• Others				In Table 1, the following (1-4) points should be clarified; 1.The explanation on scoring assumption on parameter of Light penetration (cm), *while 0.7-1.4….* this seems incomplete sentences 2. Degree symbol is	All of the review comments was used for manuscript adjustment (yellow highlighted)

					missing for temperature. 3. In-text citation for Nitrate (Oktora, 2000) is not present in references. 4. The explanation on scoring assumption on parameter of BOD (mg/L), > *20mg/L….* this seems incomplete sentences Instead of formula, use the term equation. as the following example $SC = \Sigma(S_n \times W)$ …………. (1)	
Results & Discussion	• Are the tables, graphs and pictures understandable, well presented and numbered consecutively?		√		Poor text and legends visibility in all captured satellite images. Please observe typo in all text in the manuscript, for example, 1. Spelling error "Maint" 2. *Even though, the KJT is contaminated by domestic and industrial waste.* The use of *Even though* seems inappropriate in this context.	revised
	• Do the data analysis and the interpretation appropriate to the problem and answer the objectives?	√			Table 3 should be mentioned earlier somewhere in paragaraph of subtopic *water suitability analysis to suppoer KJT cultivation system* There's mixture of commas and full stops in Table 3. The description of salinity in discussion explained in % while in Table 1 in (mg/L), please confirm.	Adjusted
	• Does the "discussion" section of the manuscript adequately relate to the current and relevant litarature?		√		It is advisable to provide in-text citation to support the following statement; *Around 2008, several pond farmers developed aquaculture activities using the KJT system.* The author may improve	The information was collected from an interview with the local farmers,

					the explanation in paragraph 1 of result and discussion by rearrange the phrase that describe the causes that make the farmers shift to KJT method (which had been mentioned) I would suggest the authors to present the results and discussion to several subtopic particularly the water analysis.The authors may discuss to physical and chemical parameters accordingly.	Adjusted Thank you for the advise, but because of the physical and chemical factor are related one and other, it will left a hold in the connection when it be separated.
	• Are the findings discussed adequately considering the research question(s), sub-question(s) or hypothesis?		√		The findings were adequately discussed. However, reference to support the findings were not sufficient. For instance, the following: *In contrast to the inland ponds, which only have a depth from 1 m up to 1.5 m that makes milkfish are directly in contact with the bottom substrate of the seawaters.* The above were important points but has no evidence to support it. Please support all the importants points that elucidated from the findings (where relevant) with references.	The data was actually collected from interview and field observation, but we can not include the data in this manuscript
Conclusion	• Is the conclusion clear and in the form of a narration instead of pointers?		√			
	• Isn't the conclusion a summary and consistent between problems, objectives and conclusion?			√	A conclusion should summarized the findings with no additional new points that never had stated anywhere beforehand. For example, *It needs an improvement of waste management system from industrial and household by providing sewage purification utilities and scheduling waste disposal based on tidal conditions after purification treatment.* The above points was important and should be suggest in discussion, not in conclusion.	done

References	• Do the references and citations match?	√			in-text citation for Nitrate (Oktora, 2000) has not been observed in references.	deleted
	• Are the writing of references correct?	√				
Quality Criteria	• Do the title, problem, objectives, methods and conclusion are in line? Is it well organized?	√				
	• The quality of the language is satisfactory	√				
	• The work relevant and novel	√			The work is relevant but not able to confirm the novelty.	Added the urgency in introduction And emphasizing novelty in last paragraph of the result and discussion
	• Are there strong consistencies among the parts of the manuscript? (introduction, methods, results and discussion, and conclusion)	√				

The Assessment of Water Compatibility of Adaptable Stick-Net Cage for Resilience Milkfish Cultivation in Tanjung Mas, Indonesia

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Abstract

Milkfish cultivation becomes the main livelihood of farmers in coastal areas. However, the land for milkfish cultivation is shrinking due to land use for settlements, industries, and sea-level rise. A Stick-net cage is an aquaculture solution in limited space for an inland fishpond. It can be placed in seashore areas while maintaining the quality of the aquatic environment and nutrient circulation. This study aims to analyze water compatibility in the stick-net cage areas for supporting sustainable aquaculture activities. An exploratory observational study was conducted in Tanjung Mas Village, Semarang, Central Java, Indonesia. Ten sampling areas were determined purposively by considering the point locations toward household wastewater and industrial outfalls. Based on these criteria, the ten stations used as sample areas were divided into industrial outfall areas (1st – 5th station) and areas close to the open sea (6th – 10th station). Physical parameters in the sampling areas, including temperature, water-current, turbidity, and clearness, met seawater standards for milkfish cultivation. Chemical indicators, such as NH_4 and P in water, were very high, which may cause by domestic and industrial waste contamination, and increased organic fermentation activity on the seabed. However, the existing stick-net cages have exceeded the capacity of the coastal water areas. In general, the physicochemical parameters in the Tanjung Mas waters area are suitable for milkfish cultivation. However, it is necessary to reduce the amount of pond density to give growth space for milkfish. In addition, wastewater management and treatment plants should be built up to reduce waters contamination.

Keywords: coastal management, sustainable livelihood, water compatibility

INTRODUCTION

Semarang is a coastal city that produces milkfish in Central Java, with 328.65 tons in 2020. Milkfish is the main cultivated fish commodity in Semarang and the livelihood for more than 1500 pond farmers with a total income of 6.32 trillion per year (Central Java Statistics Agency [BPS], 2021). One area in Semarang that relies on milkfish cultivation as its primary income source is the fish-farmers community in Tanjung Mas.

Inland pond for milkfish cultivation is at risk of being damaged by high waves and sea-level rise as the effect of climate change (Ahmed et al., 2019). In-land milkfish cultivation is practiced on community land, in coastal areas that are insulated by soil-embankment planted with mangroves. The depth of fish ponds ranges from one to three meters, so dredging must continue due to sedimentation. The quality of the in land pond water is strongly influenced by fresh-water circulation and river flow. Over the last ten years, abrasion has caused a shift in the coastline in Semarang by more than 0.5 km (Irsadi et al., 2019) and the loss of ponds in coastal areas (Andreas et al., 2018). In addition, the increase of industry, housing, and commercial spaces have decreased pond cultivation areas in Semarang. As a result, milkfish farmers experience a decline in milkfish production, threatening business stability (Martuti et al., 2020) and lowering resilience against climate change (Bosma et al., 2017; Purwaningsih & Hermawan, 2021), land-use conflicts, and potential threats from anthropogenic factors, including industrial and household waste (Henriksson et al., 2019). A case study in the Tanjung Mas waters area, shows that the high risk milkfish cultivation due to climate change and land-use conflict has prompted milkfish farmers to change to using cages planted in coastal waters.

An adaptation activity in milkfish cultivation has been initiated by farmers in Tanjung Mas, Semarang, who take initiation to build stick-net cages (*Keramba Jaring Tancap* [KJT]) in shallow water areas. KJT is arranged using bamboo sticks stuck to the seabed and installed with the net on the edges to the bottom. Furthermore, KJT is a community adaptation product in facing the climate change which reduces their income. However, this solution is developed more based on the large profits obtained from aquaculture, but ignoring the environment sustainability. Eventhough, this cultivation technique claimed able to maintain water quality, nutrient circulation, and physical conditions to support milkfish growth (Sambu, 2017). Therefore, a study on the importance of assessing the environmental conditions and the effect of KJT on water bodies need to be conducted.

An aessment about environment sustainability and the effect of KJT in Tanjung Mas waters bodies is rarity conducted, whereas, the deltas area in that area becomes an outlet for domestic and industrial waste. It is possible that the waste pollution interferes milkfish growth during cultivation. Furthermore, technology transformation from inland milkfish cultivation to KJT needs to be studied in-depth, especially the factors affecting pond water quality (Ganesh et al., 2020). In addition, chemical and organic contamination may increase in estuarine ecosystem that affect fish growth as a result of replaced cultivation activity. In recent studies, the anthropogenic factors, such as chemical pesticides, drugs (Chang et al., 2019), and feed (Srithongouthai & Tada, 2017) in milkfish cultivation affects physicochemical conditions of the aquatic ecosystem.

Inland aquaculture practice currently ignores the carrying capacity of the aquatic environment, causing a decline in the estuary ecosystem quality (Gusmawati et al., 2018; Hukom et al., 2020; Proisy et al., 2018). Hence, aquaculture management strategies using KJT must be conducted in line with the principle of sustainable development through balancing the social aspects, economic resources management, and environmental sustainability (Boyd et al., 2020). Therefore, this study aims to analyze the suitability of water conditions and biophysical aspects to support sustainable aquaculture activities in the Tanjung Mas coastal area. This study is expected to raise awareness among aquaculture actors regarding the suitability of the coastal area in their territory.

METHOD

This research was an explorational observation conducted in the KJT aquaculture area, administratively included in the Tanjung Mas, Semarang, Central Java, Indonesia. Data was taken in June – August or during the dry season to photograph the pond waters' original condition accurately.

Sampling site determination.

Sampling was carried out at 10 points spread from the end of the Mati River to the vicinity of the KJT location at the river's delta. The sample point was determined purposively by considering 1) the location of household wastewater discharge, the outfall of industries around the river, and the site of the KJT. Based on these criteria, the 10 sample area points were divided into 1) industrial waste and outfall areas (points 1-5), as assumed that the waters are directly contaminated by sewage, and 2) the areas close to the open sea (points 6-10), as assumed that the open sea has a mechanism to eliminate the waste as an effect of the ocean currents (Figure 1).

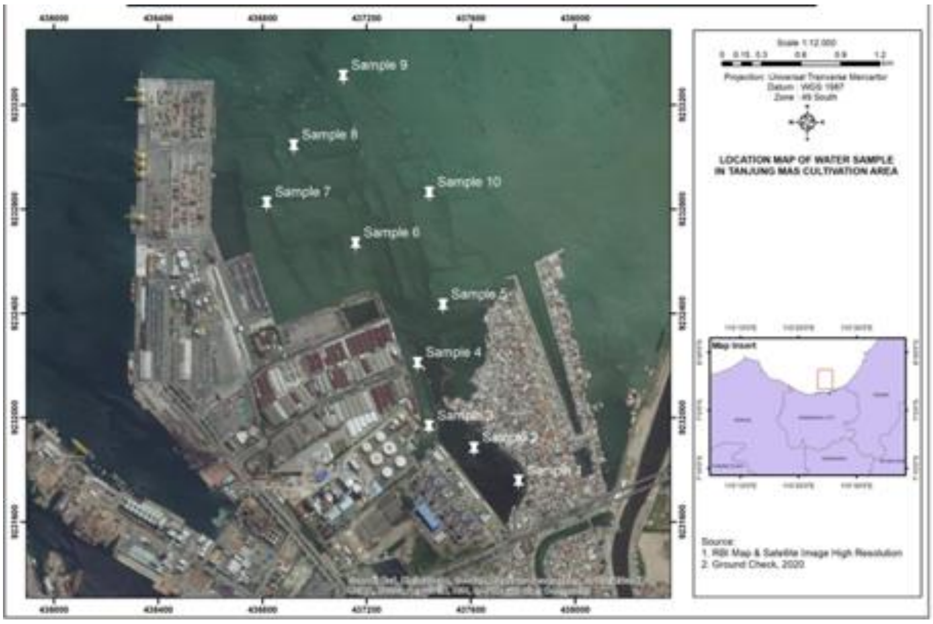


Figure 1. Map of the location for determining the water suitability analysis sample

Water samples were collected compositely from the pond area by taking 1 L of water each from five points or sides and the pond center. The water was then combined and homogenized before being used for further analysis. The water samples are stored in dark bottles to avoid chemical damage and physical changes due to light.

Water Suitability Analysis

Data on water conditions that support milkfish cultivation in this study are grouped into two parameters, physical and chemical (Table 1). The parameters were selected from the Government Regulation (PP) No. 22 of 2021 about seawater quality standards for cultivation (Table 1).

Table 1. Water suitability analysis (Site Capability)

Physicochemical parameters (n)	Scoring assumption and instrument	Parameter values (S_n)	Rubric Score**	Weight (W)
Seawater depth (m)	Sea depths between 0 – 10 provide circulation of nutrients and plankton needed for fish growth	≤ 5	5	3
		5 – 10	3	
	Measurement tool: roller metline, in situ	≥ 10	1	
Light penetration (cm)	Minimum light penetration for milkfish cultivation ranges from 30 – 40 cm.	≤ 3	5	1
	Measurement tool: secchi dish	3 – 5	3	
		≥ 5	1	
Turbidity (NTU)	Turbidity is related to the penetration of light needed by phytoplankton for photosynthesis. A reasonable waters threshold is < 5.	≤ 5	5	1
		> 5 – 20	3	
		> 20	1	
	Measurement tool: multiparameter water quality analyzer, in situ			
Water current (m/s)	Current plays a role in water circulation, which affects the amount of dissolved oxygen and nutrients in the water.	20 – 40	5	3
		10 – < 20 or > 40 – 70	3	
	Measurement tool: water current meter	< 10 or > 70	1	
Temperature (C)		28 – 30	5	2

Physicochemical parameters (n)	Scoring assumption and instrument	Parameter values (S_n)	Rubric Score**	Weight (W)
	The optimum temperature for milkfish growth is between 23 °C – 35 °C. Water temperature affects the growth and development of milkfish.	26 – < 28 or > 30 – 31	3	
	Measurement tool: multiparameter water quality analyzer, in situ	< 26 or > 31	1	
DO (mg/l)	DO levels suitable for marine life are in the range of > 5 mg/L or 4 – 8 ppm	≥ 5	5	3
		≥ 3 - < 5	3	
	Measurement tool: multiparameter water quality analyzer, in situ	< 3	1	
pH	A good pH value in milkfish cultivation is between 6.5 – 9.	7.5 – 8	5	2
		7 – < 7.5 or > 8 – 8.5	3	
	Measurement tool: pH meter	< 7 or > 8.5	1	
Salinity (%)	Good salinity for milkfish cultivation ranges from 0-35.	29 – 31	5	2
		27 - < 29 or > 31 – 33	3	
	Measurement tool: refractometer	< 27 or > 33	1	
Nitrate (mg/L)	Phytoplankton can grow optimally at a nitrate content of 0.9 ± 3.5 mg/l, while at concentrations below 0.01 or above 4.5 mg/l, it can be a limiting factor for phytoplankton growth.	< 0.008	5	1
		> 0.008 - 0.4	3	
		> 0.4	1	
	Measurement tool: multiparameter water quality analyzer, Laboratory analysis			
Nitrite (mg/L)	High nitrite causes a decrease in water pH and is toxic to marine biota	0	5	1
		< 0.1	3	
	Measurement tool: multiparameter water quality analyzer, Laboratory analysis	≥ 0.1	1	
Phosphate Total (mg/L)	It is needed for the growth and metabolism of phytoplankton and marine organisms.	≤ 0.014	5	2
		0.015 - ≤ 0.8	3	
	Measurement tool: multiparameter water quality analyzer, Laboratory analysis	> 0.8	1	
Ammonia (mg/L)	The lethal concentration (LC50) of ammonia is 1.10 to 22.8 ppm resulting in 5% mortality and 20% growth reduction for cultured fish	0 - 0.2	5	1
		> 0.2 - 0.5	3	
		> 0.5	1	
	Measurement tool: multiparameter water quality analyzer, Laboratory analysis			
BOD (mg/L)	The level of pollution is categorized low if the BOD value is 0 – 10 mg/L, while the level of pollution is moderate if it is 10 – 20 mg/l, and high polluted for > 20 mg/L.	≤ 10	5	1
		> 10 – 45	3	
		> 45	1	
	Measurement tool: multiparameter water quality analyzer, Laboratory analysis			

Physicochemical parameters (n)	Scoring assumption and instrument	Parameter values (S_n)	Rubric Score**	Weight (W)
Seabed materials	The media affect the survival of milkfish, thus affecting the success of the enlargement business. Measurement tool: Ekman grab, in situ	Gravel	5	2
		Grit-silt (muddy)	3	
		Silt	1	

Note: * The parameter was adapted Government Regulation (PP) No. 22 of 2021 and modified from Kumar et al. (2017); Olatayo (2014),

** Physicochemical parameters that are considered essential and dominant give greater weight in affecting milkfish growth.

To obtain seawater compatibility value (SC), it was measured from summaries of the weight (W) score that multiplied by the parameter score (S_n) for each parameter (n) (Equation 1). The seawater compatibility interval class (Table 2).

$$SC = \sum(S_n \times W) \qquad (1)$$

Table 2. Water suitability classification criteria

Status Code	Scoring Criteria	Compatibility Status
S1	> 146.7	Excellent
S2	93.3 – 146.7	Proper
N	< 93.3	Improper

RESULT AND DISCUSSION

Previously, aquaculture in Tanjung Mas was carried out using inland ponds with embankments directly bordering the sea or other ponds. However, in the early 2000s, this activity began to be abandoned because damaged by abrasion and sea-level rise (Surya et al., 2019). Based on the interview, KJT system was first developed in Tanjung mas by local farmers in 2008 as an adaptive strategies againt destructed inland cultivation. Currently, the majority of the farmers conduct aquaculture business as a side job when the fishing season is disturbed by weather. However, because milkfish cultivation profit was higher than catching fish, KJT system became popular and made the farmers shift their main job as fishermans o KJT cultivation. KJT is made using bamboos construction that is plugged into a seabed forming a cage block. The nets used by the farmers have hole diameters ranging from 0.5 cm – 0.5 cm for nursery and 1 cm – 1 cm for enlargement (Figure 2).

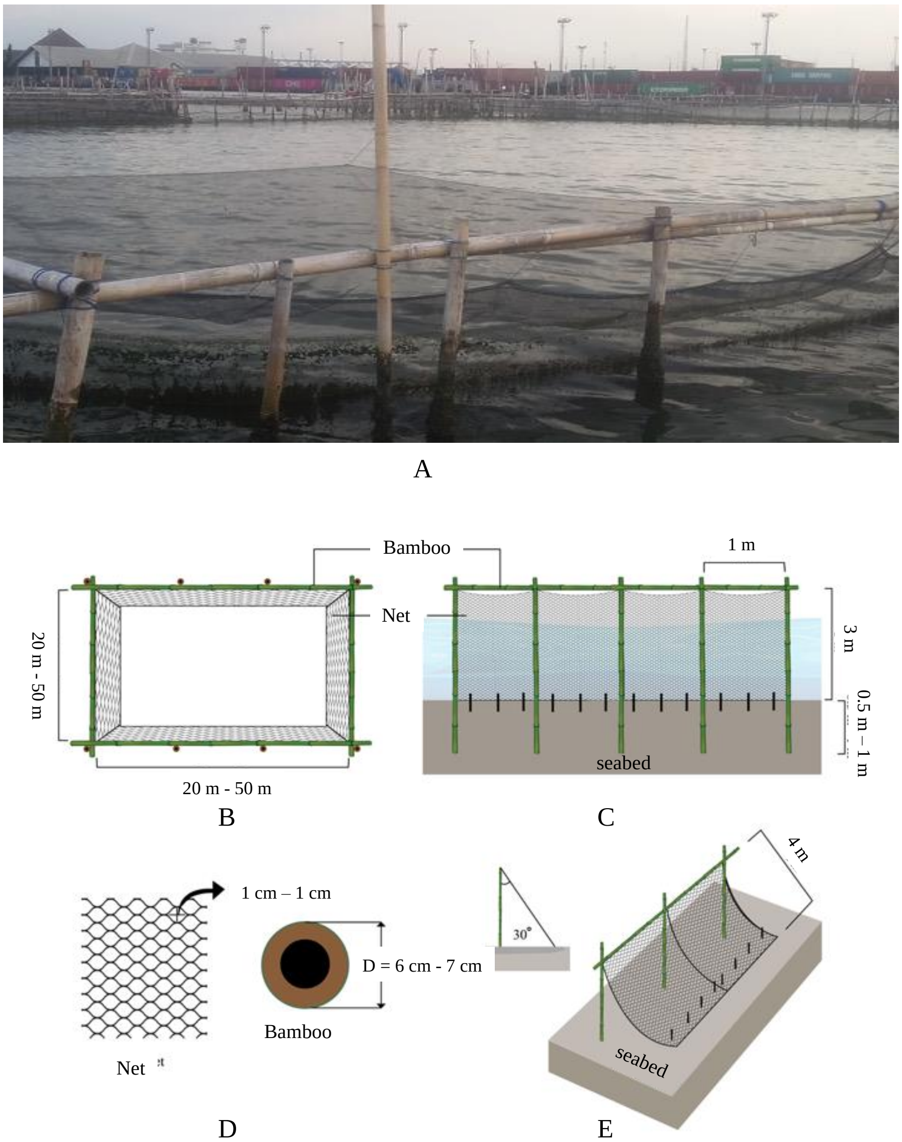


Figure 2. Detailed design of stick-net cage specification used for milkfish cultivation in Tanjung Mas: A) existing stick-net cage; B) upper view of the net-cage; B) construction design; C) materials specification; D) net position on the seabed.

KJT using three layers of nets surround a 1 ha of fishpond with a depth of 3 m. It takes about five rollers of net sizing 30 m x 5 m. The advantage of using KJT is the capability of the construction model that supports nutrient circulation in the seawater. It makes the availability of natural feed for milkfish and reduces additional fed for cultivation (Cornejo et al., 2020). Pollutants from outside and ammonia from feed fermentation inside the cage circulate in the pond, as illustrated in Figure 3 (Cha & Lee, 2018).

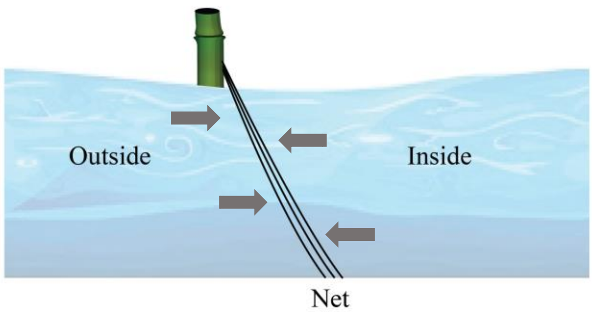


Figure 3. Materials flow illustration through net-cage construction

KJT disadvantages are performed by uncontrolled physicochemical conditions inside the cage and are adequately dependent on natural factors. Consequently, the farmers cannot adjust waters condition to speed up milkfish growth. It is necessary to maintain the optimal physical and chemical conditions in the environment according to the age of the milkfish to get optimal growth (Failaman et al., 2021; Mandal et al., 2018).

Seawater aquaculture requires appropriate environmental conditions that support the growth and development of milkfish. In addition, KJT in Tanjung Mas is placed around industrial and household waste streams that contain toxic contaminants that may interfere with milkfish growth or are inappropriate for human consumption. On the other hand, milkfish cultivation may also impact the condition of the seawaters around the pond due to feed and milkfish manure that settles at the pond's seabed.

Water Suitability Analysis to Support KJT System Cultivation

The carrying capacity of the seawater environment is determining factor for milkfish cultivation. Physically, the Mati River's estuary (the only river in Tanjung Mas) supports milkfish cultivation. However, the differences in the milkfish pond's physical conditions, including water current, temperature, seabed substrate conditions, are observed as illustrated in Figure 4.

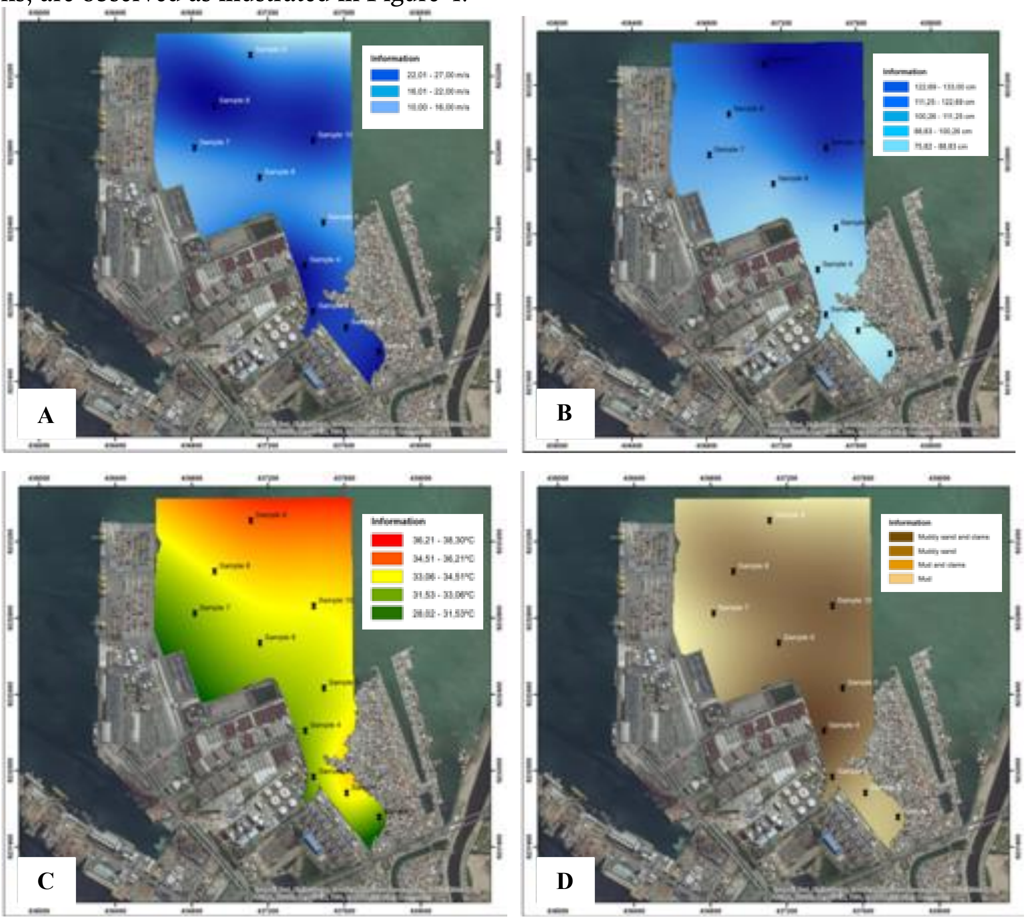


Figure 4 Physical condition of the research sites in Tanjung Mas: A) water current; B) light penetration; C) temperature and D) seabed sediment in Tanjung Mas fishpond areas.

The seawater depth varies between 4 m – 6 m; however, it is still suitable for milkfish cultivation. Milkfish juveniles will generally live in shallow seawater for two to three weeks, then migrate to mangrove forests, river estuaries, or lakes. The adult will return to the sea to breed. Meanwhile, the substrate samples in Tanjung Mas seawaters range from silt to gravel containing shell fragments and sand. However, the seabed's substrate does not directly affect the milkfish growth because the KJT system is placed on the open seas with nets to a maximum depth of 3 m (field observation). In contrast to the inland ponds in Semarang coastal area, which only have a depth from 1 m up to 1.5 m that makes milkfish are directly in contact with the bottom substrate of the seawaters.

Light penetration of water brightness (low debris) indicates good conditions to support milkfish cultivation, even though it is located in the industrial and household waste disposal system. The light penetration significantly correlates to the photosynthesis rate of phytoplankton in providing natural feed for milkfish growth. The abundance of phytoplankton is also supported by relatively low water current and calming waves that keep the water clear from seabed substrate. The seawater currents speed in Tanjung Mas was ranged around 10 m/s – 25 m/s and categorized as low water flow. The coastal area in Tanjung Mas is an estuary of Mati River that has a low discharge because the water sources only come from city drainage and water polder. Water current plays a vital role in nutrient circulation, carrying dissolved and suspended materials, feed distribution, total oxygen solubility, and salinity. Tanjung Mas have seawater with a salinity level of 30‰ – 34‰, which supports milkfish cultivation. Salinity conditions in Tanjung Mas are not much different from the average salinity value of Indonesian waters ranging from 32‰ – 34‰ (Hu et al., 2019). Fluctuations in salinity levels are caused by the high evaporation rate of the surface waters in the east monsoon and rainfall, especially in the west monsoon season (Ratnawati et al., 2018) and the discharge of river water that enters the ocean (Hamzah et al., 2020). Their statement is in line with this research that the first observation station has a lower salinity because it is located in the delta flow of the Mati River.

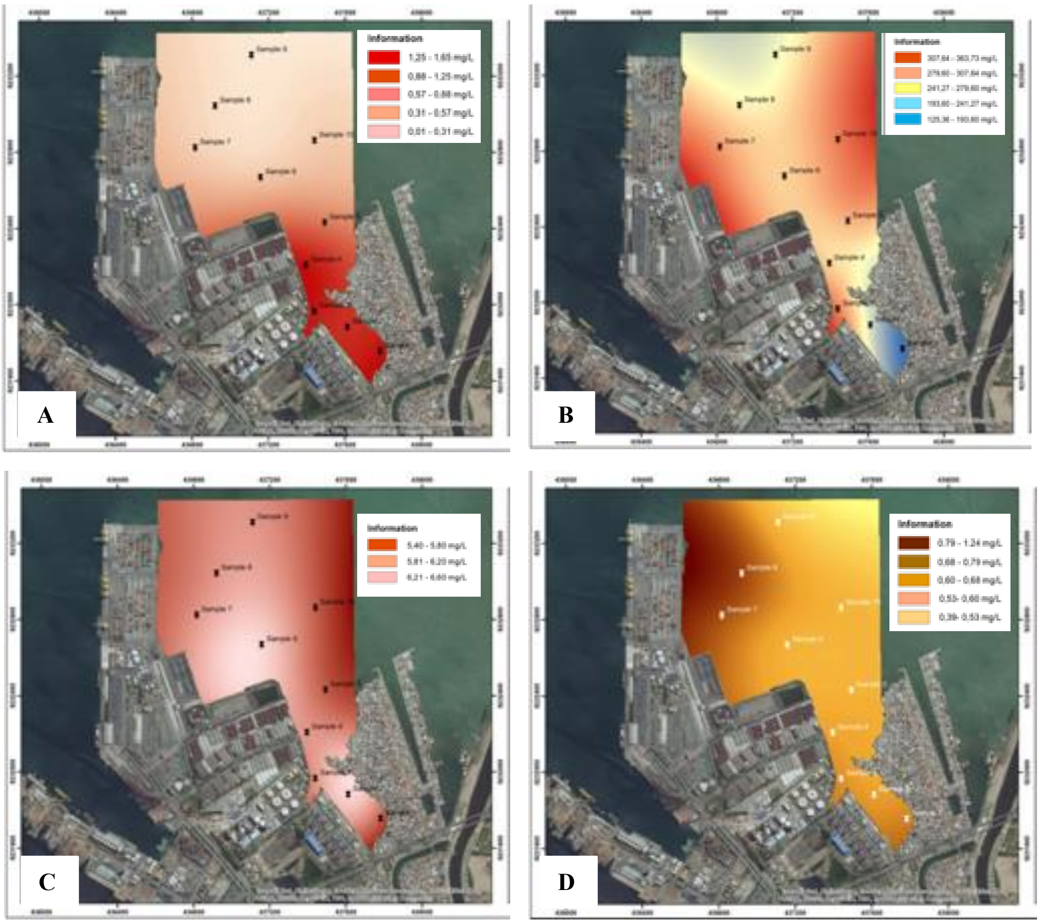
The water temperature of the KJT location in Tanjung Mas ranges between 31ºC – 37ºC. This temperature is not suitable for milkfish cultivation because the optimal temperature for milkfish growth goes from 27ºC – 30ºC (Astuti & Warsa, 2020). The high temperature in the KJT areas may be influenced by the long dry season that increases the water surface temperature due to the high intensity of sunlight. Temperatures that are too high or too low directly affect milkfish foraging behavior, reduce sensitivity and inhibit juvenile growth (Failaman et al., 2021; Hanke et al., 2019). An increase in temperature raises the decomposition and fermentation of organic matter, producing ammonia that is toxic to fish. The temperature rise also causes stratification or coating of water, which affects the mixing of seabed material and disturbs nutrition distribution (Li et al., 2020). However, the temperature is also needed in oxygen mixing from the surface to the deep waters (Lobine et al., 2021). Seawater temperature also affects surface currents, the distribution of plankton, and the survival of marine life to control the condition of aquatic ecosystems.

An increase in water temperature affects the metabolism and respiration of aquatic organisms and further increases oxygen consumption (Bonachea, 2021; Nie et al., 2017). An increase in water temperature of 10 C causes an increase in oxygen consumption by aquatic organisms about 2-3 times. However, an increase in temperature accompanied by a decrease in dissolved oxygen levels is often unable to meet the oxygen needs of aquatic organisms to carry out metabolism, thus affecting their growth (Audzijonyte et al., 2019; Das et al., 2018; Nelson, 2016; van Rijn et al., 2017). Physical conditions may affect the chemical requirements of pond waters. The analysis of chemical parameters shows that in addition to natural physical factors, anthropogenic activities also cause chemical conditions between pond areas. The measurement results show varying values (Table 3) and uneven distribution for each physical and chemical parameter (Figure 4 & 5) at each observation station.

Table 3. Recapitulation of water suitability parameter data (Site Capability) at each observation station

Parameter	Station									
	1	2	3	4	5	6	7	8	9	10
Seawater depth (m)	4.00	4.00	4.00	4.00	4.00	4.00	5.00	5.00	6.00	4.00
Light Penetration (cm)	80,50	70.00	89.00	81.30	78,50	79,50	98,5	91,50	14,12	13,45
Turbidity (NTU)	3.15	3.26	2.58	3.51	3.26	2.96	2.97	2.68	2.38	1.66
Water current (m/s)	25.00	20.00	23.00	25.00	10.00	10.00	12.00	27.00	10.00	23.00
Temperature (C)	31.00	34.00	32.00	32.00	33.00	33.00	32.00	34.00	37.00	34.00
DO (mg/l)	6.40	5.44	6.00	5.84	6.32	5.68	6.16	6.00	5.92	6.24
pH	6.50	6.80	6.40	6.90	7.30	7.10	7.10	7.20	7.30	7.50
Salinity (‰)	30.00	31.00	32.00	32.00	32.00	32.00	33.00	34.00	34.00	33.00
Nitrate (mg/L)	0.68	0.57	0.62	0.55	0.45	0.46	0.90	0.94	0.40	0.68
Nitrite (mg/L)	0.03	0.04	0.06	0.04	0.02	0.02	0.01	0.01	0.01	0.01
Phosphate (mg/L)	0.99	0.41	0.26	0.27	0.11	0.20	0.07	0.08	0.06	0.08
Ammonia (mg/L)	1.57	1.40	1.54	1.57	0.92	0.36	0.29	0.16	0.07	0.30
BOD (mg/L)	124.70	249.40	364.50	306.90	326.10	306.90	345.30	287.80	268.60	364.50
Seabed materials	S	S	S-Cs	Gs-Cs	Gs	S-Cs	S	S-Cs	S	GS

Note: Cs = clam shell shards; Gs = Grit-silt (muddy); and S = Silt


A
B
C
D

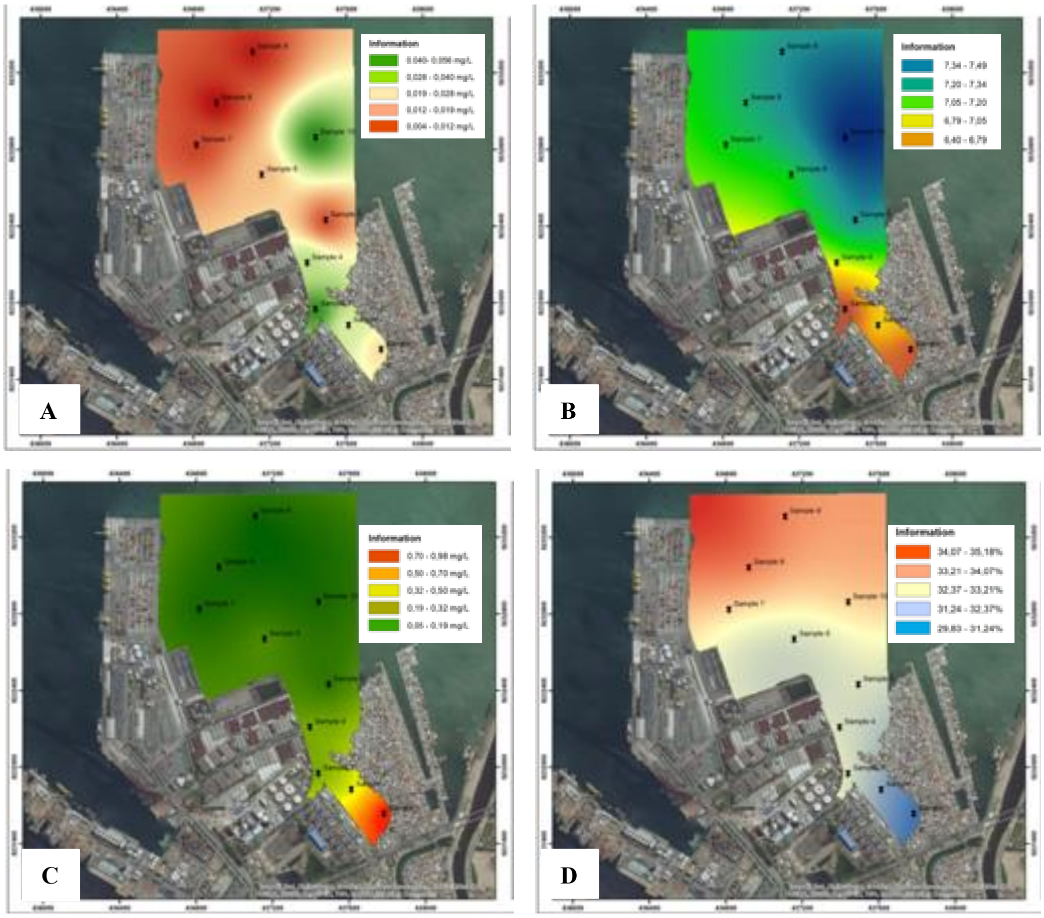

A
B
C
D

Figure 5. Chemical factors condition of the research sites in Tanjung Mas: A) ammonia distribution; B) BOD level; C) DO ; D) nitrate; E) nitrite; F) pH; G) phosphate; H) salinity Tanjung Mas fishpond areas.

The majority of chemical factors in the KJT aquatic environment are suitable for milkfish growth. Furthermore, dissolved oxygen (DO) levels meet seawater quality standards and support the development of cultured fish. Adequate dissolved oxygen levels may be produced from plankton photosynthesis and air diffusion (Horak et al., 2018). In addition, oxygen is a limiting factor for water quality because it plays an essential role in the fermentation of organic and inorganic materials at the seabed (Orsi, 2018).

The needed O_2 for decomposition and fermentation can be identified from biochemical oxygen demand (BOD) content. A higher concentration in the fishpond indicates the possibility of high organic matter in the waters (Jorgensen & Marshall, 2016). The results of BOD measurements at ten observation stations showed a value of 124.7 mg/L – 364.5 mg/L, especially at stations 3 – 9. Based on the BOD criteria, it can be seen that the seawaters around Tanjung Mas are classified as high polluted by organic compounds. It is probably caused by the decomposition process of milkfish feed, which is sedimented at the seabed. In addition, the map (Figure 4B) shows that high BOD concentrations are distributed mainly near the industrial's outfall areas even though the pH around the Tanjung Mas water area is in the neutral range of 6 – 7 and supports milkfish cultivation. In nature, the pH value ranges from 4 – 9, where the unbalancing of the pH affects aquaculture fish or the presence of seawater organisms.

The fermentation process of organic materials releases N into seawaters in the form of nitrate (NO_3), nitrite (NO_2), and ammonia (NH_4) (Oshiki et al., 2016; Spataru, 2021, 2017). The concentration of NO_3 in Tanjung Mas, was ranged from 0.3947 mg/L - 0.9386 mg/L, while nitrite was 0.0058 mg/L – 0.0338 mg/L, and ammonia was 0.073 mg/L – 1.568 mg/L. High concentrations of NO_3 and NO_2 in the seawaters can stimulate the growth and development of phytoplankton and become an indicator of fishpond fertility (Hardikar et al., 2019). NO_2 is also an indicator of decreasing N contamination because its formation comes from the oxidation of NH_4, which is toxic. Then, an availability of NO_2 comes from the oxidation of NH_4 to NO_2 carried out by Nitrosomonas bacteria, while the oxidation of NO_2 to NO_3 is carried out by Nitrobacter (Santoro et al., 2021). NO_2 is usually found in lower amounts than NO_3 because it is unstable and easily reacts with oxygen.

The findings obtained in this study showed that the measured NH_4 levels were quite high at seven observation stations (stations-1, 2, 3, 4, 5, 6, and 10). The location is on the Mati River, which carries domestic waste from settlements. Organic materials from domestic waste increase the rate of decomposition and fermentation of organic materials to produce NH_4 as a by-product. The increase in NH_4 contamination is positively correlated with anthropogenic factors, primarily related to the residential, agricultural, livestock, and industrial sectors (Bessa et al., 2021; Sproson et al., 2021). In addition, the problem faced in Tanjung Mas waters is the lack of suitable sanitation, causing pollution and the balance of the pond waters ecosystem.

Low NH_4 concentrations were measured at stations 7, 8, and 9 because they are located far from settlements and industrial outfall, have more than 5 m depth and are near the open sea. This condition improves water circulation due to ocean currents and a more homogeneous seawater diffusion process.

Domestic waste may be one of the main factors that increase phosphate concentrations in the KJT waters area. Various studies have shown that human activities, including household waste, have increased the concentration of contaminants in the oceans, such as nitrogen (Jickells et al., 2017), phosphate (Badawy et al., 2018; Thiombane et al., 2019), to heavy metals (Bessa et al., 2021; Chu et al., 2019). It is indicated by the distribution of phosphate levels at stations 1 to 5, which is higher than the other five observation stations. Phosphate is a nutrient that is a determining factor in phytoplankton in the sea and is usually found in the form of organic compounds (Bristow et al., 2017).

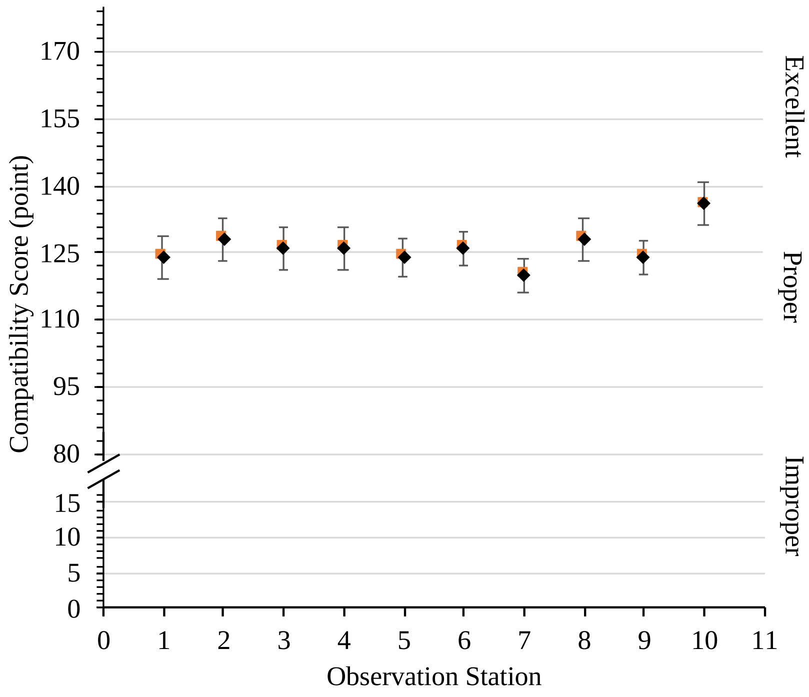


Figure 6. Compatibility for milkfish cultivation in Tanjung Mas waters area based on the observation station.

The water compatibility value (Figure 6) shows that all observation stations were categorized at the proper level (S2). It indicates that the Tanjung Mas water area is sufficient and can be developed as a KJT cultivation area. However, limiting factors require special attention to increasing milkfish productivity, such as N and P levels and BOD.

Analysis of KJT System Carrying Capacity Based on Waters Capacity

The total area of potential waters in the Tanjung Mas for KJT is 119.51 Ha, but referring to the government regulation, it is only 20% that can be used for aquaculture. Then the optimum area for the KJT aquaculture system that can be developed is only about 23,902 Ha. However, based on the observation, the existence of KJT has overcapacity. Twenty-two cages occupy it with more than 53.45 Ha of waters area. Furthermore, it can be seen that the utilization of the waters has exceeded the carrying capacity because the practical potential of the waters area for the KJT system is only 2.4 cage/ Ha for only ten cage units. Therefore, it is necessary to reduce the number of KJT units by looking at the existing conditions.

High occupied waters area with dense cultured milkfish may overshoot the waters capacity and potentially trigger mass death of the marine organism. The condition of the waters directly adjacent to the sea provides an advantage for faster purification. However, the continuous input of domestic and industrial pollutants and low river discharge resulted in a low nature purification rate. It must be a common concern, considering that the waters in the KJT area are the output of several waste installations from the community (domestic) and industries.

Physicochemistry and KJT management in Tanjung Mas depicts new insight of milkfish cultivation in polluted areas. The study results show the potential of KJT as applicable aquaculture in the face of climate change. KJT is also superior to in land ponds, because it is able to guarantee the circulation of physicochemical and nutrients so as to provide better opportunities for adaptation to climate change.KJT is an adaptive tool/ effort for fish-farmers to adapt the climate change which reduces their income. Maint reason for using KJT in Tanjung Mas is more caused by large profits obtained from aquaculture using low cost production. Interasting fact in this study also shows that the community does not yet have awareness about the implementation of sustainable milkfish cultivation by concerning carrying capacity of the environment and product quality. In other words, economic reasons take precedence over health and environmental suitability to produce profitable cultivation commodities, even though, the KJT is contaminated by domestic and industrial waste. It needs an improvement of waste management system from industrial and household by providing sewage purification utilities and scheduling waste disposal based on tidal conditions after purification treatment.

CONCLUSION

In general, the physicochemical factors in Tanjung Mas water areas are proper and support milkfish cultivation. However, the existing condition shows that water utilization for milkfish aquaculture activities using KJT has exceeded the carrying capacity. It potentially disturbs milkfish growth and may lead to the unbalancing ecosystem and trigger the death of the marine organism. On the other hand, high pollution from industries and household waste has become a significant problem affecting milkfish growth and becoming a health issue. High P and NH_4 were primarily detected in the observation station near the industrial outfall and Mati River estuary, containing domestic waste.

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THE ASSESSMENT OF WATER COMPATIBILITY OF ADAPTABLE STICK-NET CAGE FOR RESILIENCE MILKFISH CULTIVATION IN TANJUNG MAS, INDONESIA

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The Assessment of Water Compatibility of Adaptable Stick-Net Cage for Resilience Milkfish Cultivation in Tanjung Mas, Indonesia

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Abstract

Milkfish cultivation becomes the main livelihood of farmers in coastal areas. However, the land for milkfish cultivation is shrinking due to land use for settlements, industries, and sea-level rise. A Stick-net cage is an aquaculture solution in limited space for an inland fishpond. It can be placed in seashore areas while maintaining the quality of the aquatic environment and nutrient circulation. This study aims to analyze water compatibility in the stick-net cage areas for supporting sustainable aquaculture activities. An exploratory observational study was conducted in Tanjung Mas Village, Semarang, Central Java, Indonesia. Ten sampling areas were determined purposively by considering the point locations toward household wastewater and industrial outfalls. Based on these criteria, the ten stations used as sample areas were divided into industrial outfall areas (1^{st} – 5^{th} station) and areas close to the open sea (6^{th} – 10^{th} station). Physical parameters in the sampling areas, including temperature, water-current, turbidity, and clearness, met seawater standards for milkfish cultivation. Chemical indicators, such as NH_4 and P in water, were very high, which may be caused by domestic and industrial waste contamination and increased organic fermentation activity on the seabed. However, the existing stick-net cages have exceeded the capacity of the coastal water areas. In general, the physicochemical parameters in the Tanjung Mas water area are suitable for milkfish cultivation. However, it is necessary to reduce the amount of pond density to give growth space for milkfish. In addition, wastewater management and treatment plants should be built up to reduce water contamination.

Keywords: coastal management, sustainable livelihood, water compatibility

INTRODUCTION

Semarang is a coastal city that produces milkfish in Central Java, with 328.65 tons in 2020. Milkfish is the main cultivated fish commodity in Semarang and the livelihood for more than 1500 pond farmers with a total income of 6.32 trillion per year (Central Java Statistics Agency [BPS], 2021). One area in Semarang that relies on milkfish cultivation as its primary income source is the fish-farmer community in Tanjung Mas.

Inland pond for milkfish cultivation is at risk of being damaged by high waves and sea-level rise as the effect of climate change (Ahmed et al., 2019). In-land milkfish cultivation is practiced on community land, in coastal areas that are insulated by soil-embankment planted with mangroves. The depth of fishponds ranges from one to three meters, so dredging must continue due to sedimentation. The quality of the inland pond water is strongly influenced by fresh-water circulation and river flow. Over the last ten years, abrasion has caused a shift in the coastline in Semarang by more than 0.5 km (Irsadi et al., 2019) and the loss of ponds in coastal areas (Andreas et al., 2018). In addition, the increase of industry, housing, and commercial spaces have decreased pond cultivation areas in Semarang. As a result, milkfish farmers experience a decline in milkfish production, threatening business stability (Martuti et al., 2020) and lowering resilience against climate change (Bosma et al., 2017; Purwaningsih & Hermawan, 2021), land-use conflicts, and potential threats from anthropogenic factors, including industrial and household waste (Henriksson et al., 2019). A case study in the Tanjung Mas water area shows that the high-risk milkfish cultivation due to climate change and land-use conflict has prompted milkfish farmers to change to using cages planted in coastal waters.

An adaptation activity in milkfish cultivation has been initiated by farmers in Tanjung Mas, Semarang, who take initiation to build stick-net cages (*Keramba Jaring Tancap* [KJT]) in shallow water areas. KJT is arranged using bamboo sticks stuck to the seabed and installed with the net on the edges to the bottom. Furthermore, KJT is a community adaptation product in facing climate change which reduces their income. However, this solution is developed more based on the large profits obtained from aquaculture but ignoring environmental sustainability. Even though, this cultivation technique is claimed to be able to maintain water quality, nutrient circulation, and physical conditions to support milkfish growth (Sambu, 2017). Therefore, a study on the importance of assessing the environmental conditions and the effect of KJT on water bodies needs to be conducted.

An assessment about environmental sustainability and the effect of KJT in the Tanjung Mas water area is rarity conducted, whereas the delta area in that area becomes an outlet for domestic and industrial waste. The waste pollution may interfere with milkfish growth during cultivation. Furthermore, technology transformation from inland milkfish cultivation to KJT needs to be studied in-depth, especially the factors affecting pond water quality (Ganesh et al., 2020). In addition, chemical and organic contamination may increase in the estuarine ecosystem that affects fish growth because of replaced cultivation activity. In recent studies, the anthropogenic factors, such as chemical pesticides, drugs (Chang et al., 2019), and feed (Srithongouthai & Tada, 2017) in milkfish cultivation affects the physicochemical conditions of the aquatic ecosystem.

Inland aquaculture practice currently ignores the carrying capacity of the aquatic environment, which causes a decline in the estuary ecosystem quality (Gusmawati et al., 2018; Hukom et al., 2020; Proisy et al., 2018). Hence, aquaculture management strategies using KJT must be conducted in line with the principle of sustainable development through balancing the social aspects, economic resources management, and environmental sustainability (Boyd et al., 2020). Therefore, this study aims to analyze the suitability of water conditions and biophysical aspects to support sustainable aquaculture activities in the Tanjung Mas coastal area. This study is expected to raise awareness among aquaculture actors regarding the suitability of the coastal area in their territory.

METHOD

This research was an explorational observation conducted in the KJT aquaculture area, administratively included in the Tanjung Mas, Semarang, Central Java, Indonesia. Data were taken in June – August or during the dry season to photograph the pond water original condition accurately.

Sampling site determination.

Sampling was carried out at 10 points spread from the end of the Mati River to the vicinity of the KJT location at the river's delta. The sample point was determined purposively by considering 1) the location of household wastewater discharge, the outfall of industries around the river, and the site of the KJT. Based on these criteria, the 10 sample area points were divided into 1) industrial waste and outfall areas (points 1-5), as assumed that the waters are directly contaminated by sewage, and 2) the areas close to the open sea (points 6-10), as assumed that the open sea has a mechanism to eliminate the waste as an effect of the ocean currents (Figure 1).

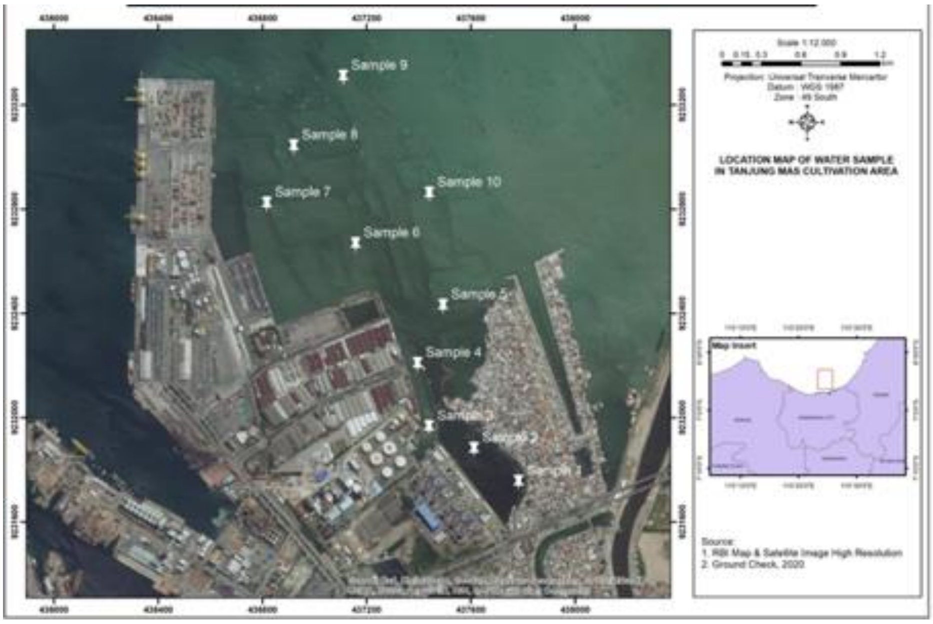


Figure 1. Map of the location for determining the water suitability analysis sample

Water samples were collected compositely from the pond area by taking 1 L of water each from five points or sides and the pond center. The water was then combined and homogenized before being used for further analysis. The water samples are stored in dark bottles to avoid chemical damage and physical changes due to light.

Water Suitability Analysis

Data on water conditions that support milkfish cultivation in this study were grouped into two parameters, physical and chemical (Table 1). The parameters were selected from the Government Regulation (PP) No. 22 of 2021 about seawater quality standards for cultivation (Table 1).

Table 1. Water suitability analysis (Site Capability)

Physicochemical parameters (n)	Scoring assumption and instrument	Parameter values (S_n)	Rubric Score**	Weight (W)
Seawater depth (m)	Sea depths between 0 – 10 provide circulation of nutrients and plankton needed for fish growth	≤ 5	5	3
		5 – 10	3	
	Measurement tool: roller metline, in situ	≥ 10	1	
Light penetration (cm)	Minimum light penetration for milkfish cultivation ranges from 30 – 40 cm.	≤ 3	5	1
		3 – 5	3	
	Measurement tool: Secchi disk	≥ 5	1	
Turbidity (NTU)	Turbidity is related to the penetration of light needed by phytoplankton for photosynthesis. A reasonable water threshold is < 5.	≤ 5	5	1
		> 5 – 20	3	
		> 20	1	
	Measurement tool: multiparameter water quality analyzer, in situ			
Water current (m/s)	Current plays a role in water circulation, which affects the amount of dissolved oxygen and nutrients in the water.	20 – 40	5	3
		10 – < 20 or > 40 – 70	3	
	Measurement tool: water current meter	< 10 or > 70	1	
Temperature (C)	The optimum temperature for milkfish growth is between 23 °C – 35 °C. Water	28 – 30	5	2
		26 – < 28 or	3	

Physicochemical parameters (n)	Scoring assumption and instrument	Parameter values (S_n)	Rubric Score**	Weight (W)
	temperature affects the growth and development of milkfish. Measurement tool: multiparameter water quality analyzer, in situ	> 30 – 31 < 26 or > 31	 1	
DO (mg/l)	DO levels suitable for marine life are in the range of > 5 mg/L or 4 – 8 ppm Measurement tool: multiparameter water quality analyzer, in situ	≥ 5 ≥ 3 - < 5 < 3	5 3 1	3
pH	A good pH value in milkfish cultivation is between 6.5 – 9. Measurement tool: pH meter	7.5 – 8 7 – < 7.5 or > 8 – 8.5 < 7 or > 8.5	5 3 1	2
Salinity (%)	Good salinity for milkfish cultivation ranges from 0-35. Measurement tool: refractometer	29 – 31 27 - < 29 or > 31 – 33 < 27 or > 33	5 3 1	2
Nitrate (mg/L)	Phytoplankton can grow optimally at a nitrate content of 0.9 ± 3.5 mg/l, while at concentrations below 0.01 or above 4.5 mg/l, it can be a limiting factor for phytoplankton growth. Measurement tool: multiparameter water quality analyzer, Laboratory analysis	< 0.008 > 0.008 - 0.4 > 0.4	5 3 1	1
Nitrite (mg/L)	High nitrite causes a decrease in water pH and is toxic to marine biota Measurement tool: multiparameter water quality analyzer, Laboratory analysis	0 < 0.1 ≥ 0.1	5 3 1	1
Phosphate Total (mg/L)	It is needed for the growth and metabolism of phytoplankton and marine organisms. Measurement tool: multiparameter water quality analyzer, Laboratory analysis	≤ 0.014 0.015 - ≤ 0.8 > 0.8	5 3 1	2
Ammonia (mg/L)	The lethal concentration (LC50) of ammonia is 1.10 to 22.8 ppm resulting in 5% mortality and 20% growth reduction for cultured fish Measurement tool: multiparameter water quality analyzer, Laboratory analysis	0 - 0.2 > 0.2 - 0.5 > 0.5	5 3 1	1
BOD (mg/L)	The level of pollution is categorized low if the BOD value is 0 – 10 mg/L, while the level of pollution is moderate if it is 10 – 20 mg/l, and high polluted for > 20 mg/L. Measurement tool: multiparameter water quality analyzer, Laboratory analysis	≤ 10 > 10 – 45 > 45	5 3 1	1
Seabed materials		Gravel Grit-silt (muddy)	5 3	2

Physicochemical parameters (n)	Scoring assumption and instrument	Parameter values (S_n)	Rubric Score**	Weight (W)
	The media affect the survival of milkfish; thus it affects the success of the enlargement business. Measurement tool: Ekman grab, in situ	Silt	1	

Note: * The parameter was adapted Government Regulation (PP) No. 22 of 2021 and modified from Kumar et al. (2017); Olatayo (2014),

** Physicochemical parameters that are considered essential and dominant give greater weight in affecting milkfish growth.

To obtain seawater compatibility value (SC), it was measured from summaries of the weight (W) score that multiplied by the parameter score (S_n) for each parameter (n) (Equation 1). The seawater compatibility interval class (Table 2).

$$SC = \sum(S_n \times W) \quad (1)$$

Table 2. Water suitability classification criteria

Status Code	Scoring Criteria	Compatibility Status
S1	> 146.7	Excellent
S2	93.3 – 146.7	Proper
N	< 93.3	Improper

RESULT AND DISCUSSION

Previously, aquaculture in Tanjung Mas was carried out using inland ponds with embankments directly bordering the sea or other ponds. However, in the early 2000s, this activity began to be abandoned because damaged by abrasion and sea-level rise (Surya et al., 2019). Based on the interview, the KJT system was first developed in Tanjung Mas by local farmers in 2008 as an adaptive strategy against destructed inland cultivation. Currently, most of the farmers conduct aquaculture business as a side job when the fishing season is disturbed by weather. However, because milkfish cultivation profit was higher than catching fish, the KJT system became popular and made the farmers shift their main job as Fishermans on KJT cultivation. KJT is made using bamboos construction that is plugged into a seabed forming a cage block. The nets used by the farmers have hole diameters ranging from 0.5 cm – 0.5 cm for nursery and 1 cm – 1 cm for enlargement (Figure 2).

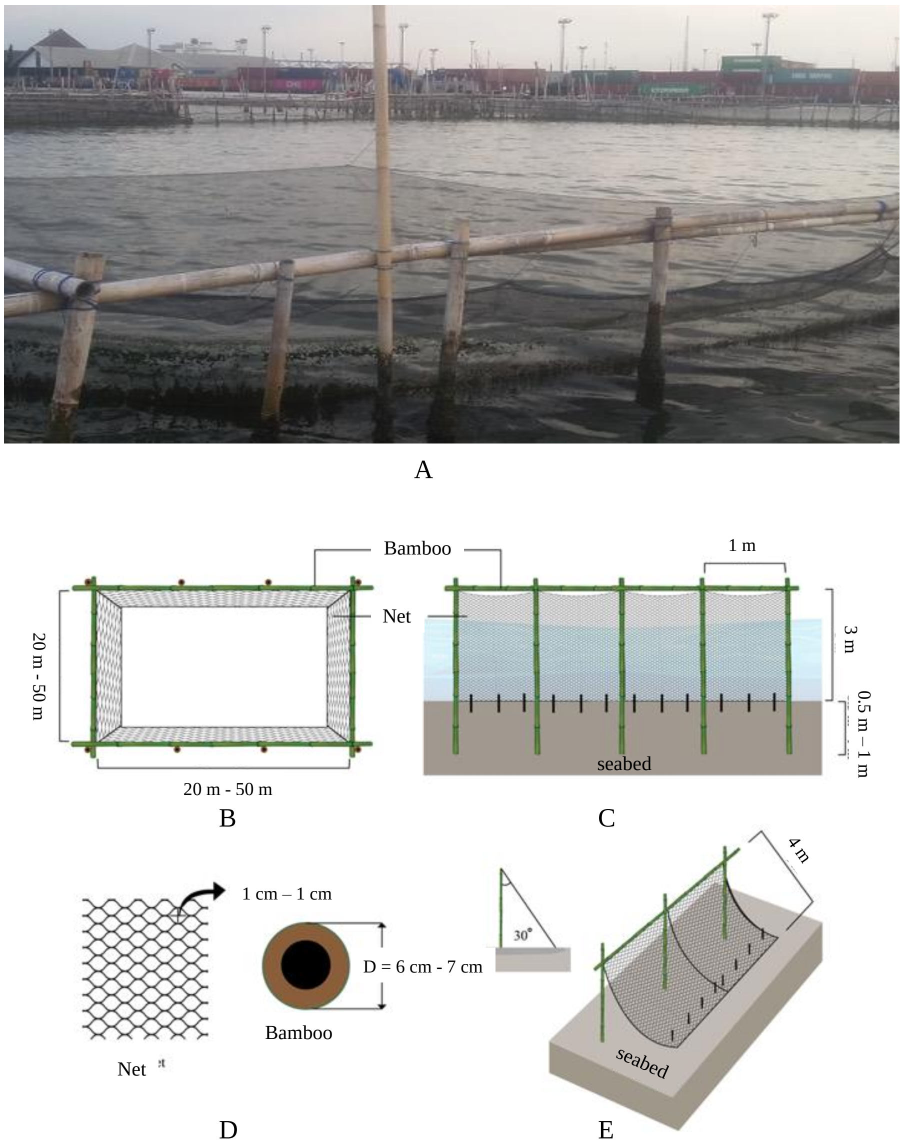


Figure 2. Detailed design of stick-net cage specification used for milkfish cultivation in Tanjung Mas: A) existing stick-net cage; B) upper view of the net-cage; B) construction design; C) material specification; D) net position on the seabed.

KJT using three layers of nets surround a 1 ha of fishpond with a depth of 3 m. It takes about five rollers of net sizing 30 m x 5 m. The advantage of using KJT is the capability of the construction model that supports nutrient circulation in the seawater. It makes the availability of natural feed for milkfish and reduces additional fed for cultivation (Cornejo et al., 2020). Pollutants from outside and ammonia from feed fermentation inside the cage circulate in the pond, as illustrated in Figure 3 (Cha & Lee, 2018).

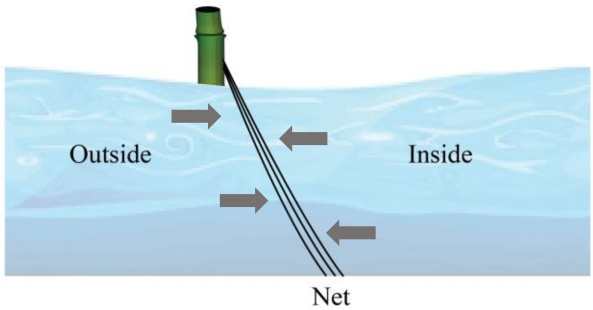


Figure 3. Materials flow illustration through net-cage construction

KJT disadvantages are performed by uncontrolled physicochemical conditions inside the cage and are adequately dependent on natural factors. Consequently, the farmers cannot adjust water conditions to speed up milkfish growth. It is necessary to maintain the optimal physical and chemical conditions in the environment according to the age of the milkfish to get optimal growth (Failaman et al., 2021; Mandal et al., 2018).

Seawater aquaculture requires appropriate environmental conditions that support the growth and development of milkfish. In addition, KJT in Tanjung Mas is placed around industrial and household waste streams that contain toxic contaminants that may interfere with milkfish growth or are inappropriate for human consumption. On the other hand, milkfish cultivation may also impact the condition of the seawaters around the pond due to feed and milkfish manure that settles at the pond seabed.

Water Suitability Analysis to Support KJT System Cultivation

The carrying capacity of the seawater environment is determining factor for milkfish cultivation. Physically, the Mati River's estuary (the only river in Tanjung Mas) supports milkfish cultivation. However, the differences in the milkfish pond's physical conditions, including water current, temperature, seabed substrate conditions, are observed as illustrated in Figure 4.

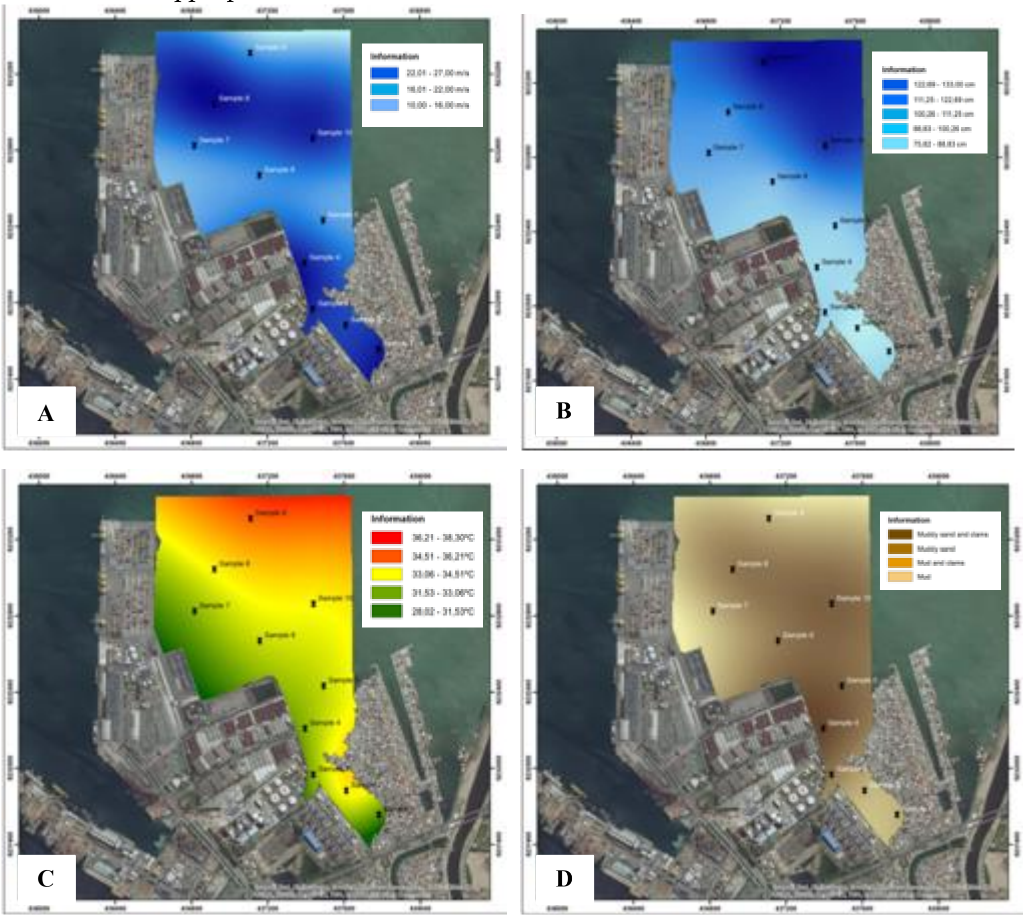


Figure 4 Physical condition of the research sites in Tanjung Mas: A) water current; B) light penetration; C) temperature and D) seabed sediment in Tanjung Mas fishpond areas.

The seawater depth varies between 4 m – 6 m; however, it is still suitable for milkfish cultivation. Milkfish juveniles will generally live in the shallow seawater for two to three weeks, then migrate to mangrove forests, river estuaries, or lakes. The adult will return to the sea to breed. Meanwhile, the substrate samples in Tanjung Mas seawaters range from silt to gravel containing shell fragments and sand. However, the seabed substrate does not directly affect the milkfish growth because the KJT system is placed on the open seas with nets to a maximum depth of 3 m (field observation). This is in contrast to the inland ponds in the Semarang coastal area, which only have a depth from 1 m up to 1.5 m that makes milkfish directly in contact with the bottom substrate of the seawaters.

Light penetration of water brightness (low debris) indicates good conditions to support milkfish cultivation, even though it is in the industrial and household waste disposal system. The light penetration significantly correlates to the photosynthesis rate of phytoplankton in providing natural feed for milkfish growth. The abundance of phytoplankton is also supported by relatively low water current and calming waves that keep the water clear from seabed substrate. The seawater current speed in Tanjung Mas ranges around 10 m/s – 25 m/s and is categorized as low water flow. The coastal area in Tanjung Mas is an estuary of the Mati River that has a low discharge because the water sources only come from city drainage and water polder. Water current plays a vital role in nutrient circulation, carrying dissolved and suspended materials, feed distribution, total oxygen solubility, and salinity. Tanjung Mas has seawater with a salinity level of 30‰ – 34‰, which supports milkfish cultivation. Salinity conditions in Tanjung Mas are not much different from the average salinity value of Indonesian waters ranging from 32‰ – 34‰ (Hu et al., 2019). Fluctuations in salinity levels are caused by the high evaporation rate of the surface waters in the east monsoon and rainfall, especially in the west monsoon season (Ratnawati et al., 2018) and the discharge of river water that enters the ocean (Hamzah et al., 2020). Their statement is in line with this research that the first observation station has a lower salinity because it is located in the delta flow of the Mati River.

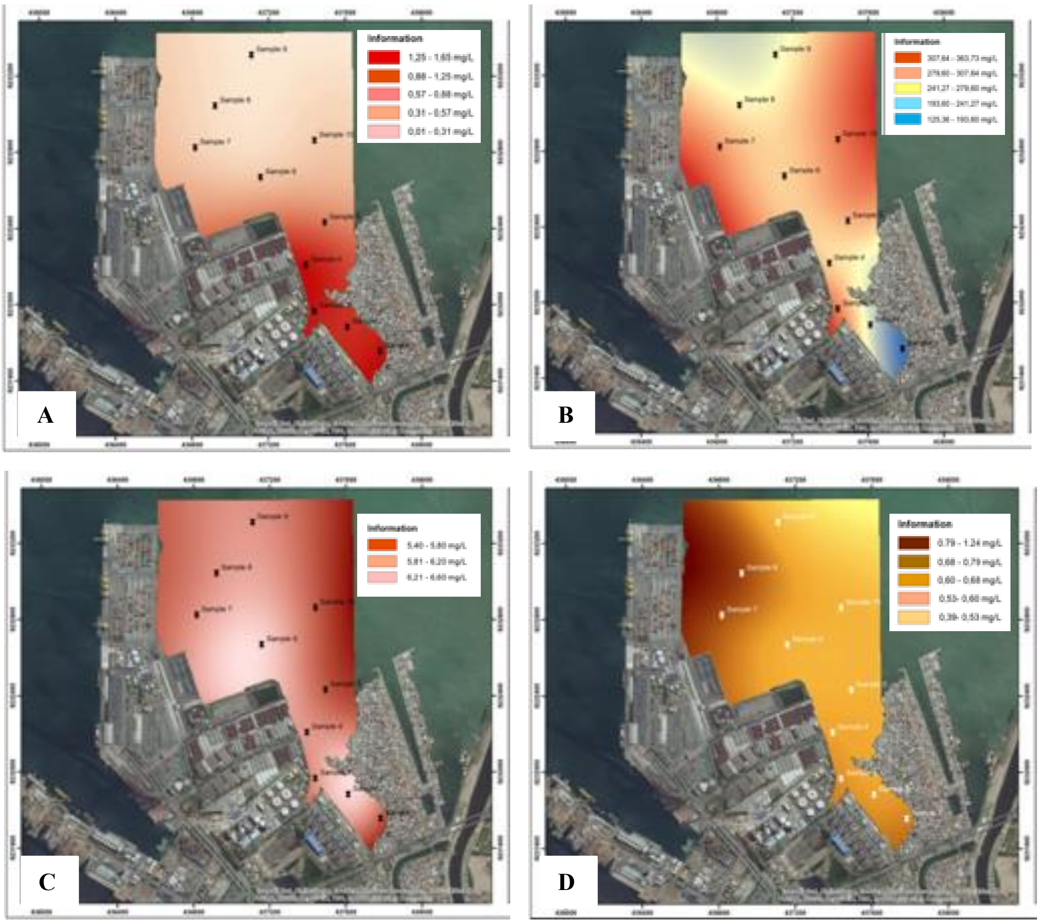
The water temperature of the KJT location in Tanjung Mas ranges between 31ºC – 37ºC. This temperature is not suitable for milkfish cultivation because the optimal temperature for milkfish growth goes from 27ºC – 30ºC (Astuti & Warsa, 2020). The high temperature in the KJT areas may be influenced by the long dry season that increases the water surface temperature due to the high intensity of sunlight. Temperatures that are too high or too low directly affect milkfish foraging behavior, reduce sensitivity and inhibit juvenile growth (Failaman et al., 2021; Hanke et al., 2019). An increase in temperature raises the decomposition and fermentation of organic matter, producing ammonia that is toxic to fish. The temperature rise also causes stratification or coating of water, which affects the mixing of seabed material and disturbs nutrition distribution (Li et al., 2020). However, the temperature is also needed in oxygen mixing from the surface to the deep waters (Lobine et al., 2021). Seawater temperature also affects surface currents, the distribution of plankton, and the survival of marine life to control the condition of aquatic ecosystems.

An increase in water temperature affects the metabolism and respiration of aquatic organisms and further increases oxygen consumption (Bonachea, 2021; Nie et al., 2017). An increase in water temperature of 10 C causes an increase in oxygen consumption by aquatic organisms about 2-3 times. However, an increase in temperature accompanied by a decrease in dissolved oxygen levels is often unable to meet the oxygen needs of aquatic organisms to carry out metabolism, thus it affects their growth (Audzijonyte et al., 2019; Das et al., 2018; Nelson, 2016; van Rijn et al., 2017). Physical conditions may affect the chemical requirements of pond waters. The analysis of chemical parameters shows that in addition to natural physical factors, anthropogenic activities also cause chemical conditions between pond areas. The measurement results show varying values (Table 3) and uneven distribution for each physical and chemical parameter (Figure 4 & 5) at each observation station.

Table 3. Recapitulation of water suitability parameter data (Site Capability) at each observation station

Parameter	Station									
	1	2	3	4	5	6	7	8	9	10
Seawater depth (m)	4.00	4.00	4.00	4.00	4.00	4.00	5.00	5.00	6.00	4.00
Light Penetration (cm)	80,50	70.00	89.00	81.30	78,50	79,50	98,5	91,50	14,12	13,45
Turbidity (NTU)	3.15	3.26	2.58	3.51	3.26	2.96	2.97	2.68	2.38	1.66
Water current (m/s)	25.00	20.00	23.00	25.00	10.00	10.00	12.00	27.00	10.00	23.00
Temperature (C)	31.00	34.00	32.00	32.00	33.00	33.00	32.00	34.00	37.00	34.00
DO (mg/l)	6.40	5.44	6.00	5.84	6.32	5.68	6.16	6.00	5.92	6.24
pH	6.50	6.80	6.40	6.90	7.30	7.10	7.10	7.20	7.30	7.50
Salinity (‰)	30.00	31.00	32.00	32.00	32.00	32.00	33.00	34.00	34.00	33.00
Nitrate (mg/L)	0.68	0.57	0.62	0.55	0.45	0.46	0.90	0.94	0.40	0.68
Nitrite (mg/L)	0.03	0.04	0.06	0.04	0.02	0.02	0.01	0.01	0.01	0.01
Phosphate (mg/L)	0.99	0.41	0.26	0.27	0.11	0.20	0.07	0.08	0.06	0.08
Ammonia (mg/L)	1.57	1.40	1.54	1.57	0.92	0.36	0.29	0.16	0.07	0.30
BOD (mg/L)	124.70	249.40	364.50	306.90	326.10	306.90	345.30	287.80	268.60	364.50
Seabed materials	S	S	S-Cs	Gs-Cs	Gs	S-Cs	S	S-Cs	S	GS

Note: Cs = clam shell shards; Gs = Grit-silt (muddy); and S = Silt


Information
1,25 - 1,65 mg/L
0,88 - 1,25 mg/L
0,57 - 0,88 mg/L
0,31 - 0,57 mg/L
0,01 - 0,31 mg/L
A
Information
307,64 - 363,73 mg/L
279,60 - 307,64 mg/L
241,27 - 279,60 mg/L
193,60 - 241,27 mg/L
125,36 - 193,60 mg/L
B
Information
5,40 - 5,80 mg/L
5,81 - 6,20 mg/L
6,21 - 6,60 mg/L
C
Information
0,79 - 1,24 mg/L
0,68 - 0,79 mg/L
0,60 - 0,68 mg/L
0,53- 0,60 mg/L
0,39- 0,53 mg/L
D

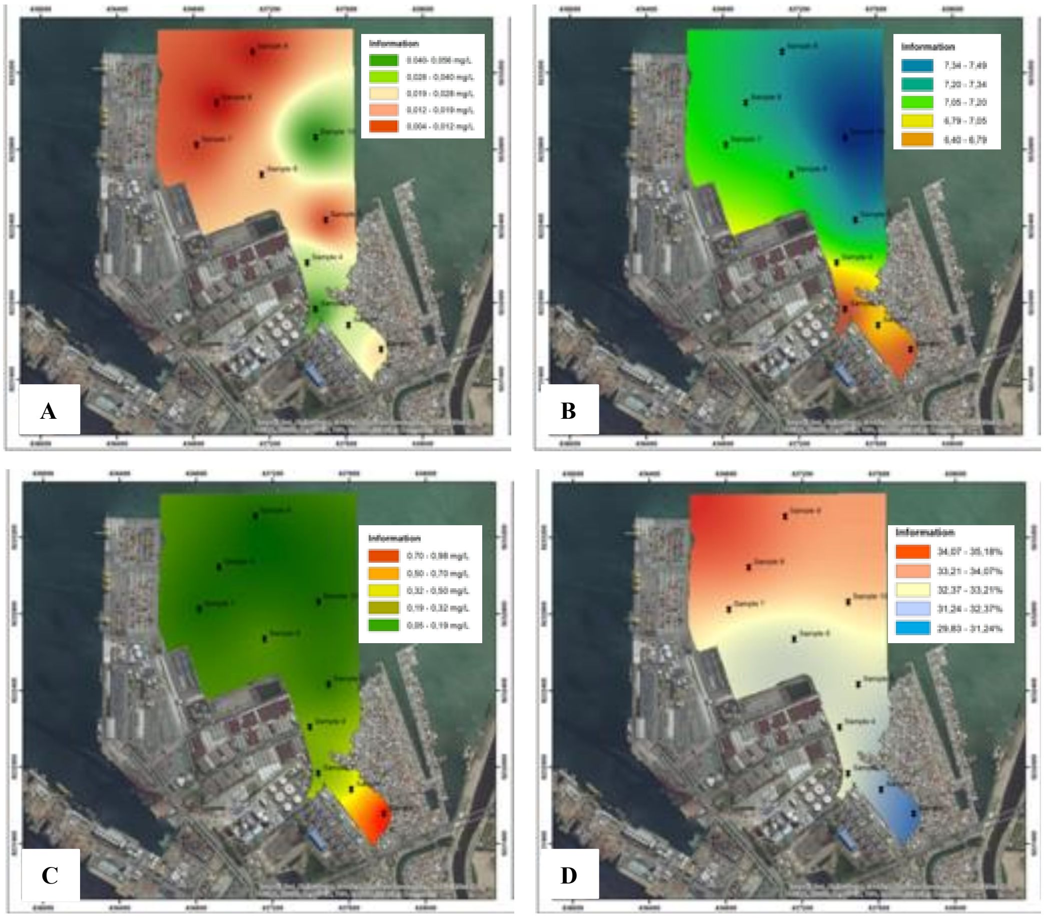

Information
0,040- 0,056 mg/L
0,028 - 0,040 mg/L
0,019 - 0,028 mg/L
0,012 - 0,019 mg/L
0,004 - 0,012 mg/L
A
Information
7,34 - 7,49
7,20 - 7,34
7,05 - 7,20
6,79 - 7,05
6,40 - 6,79
B
Information
0,70 - 0,98 mg/L
0,50 - 0,70 mg/L
0,32 - 0,50 mg/L
0,19 - 0,32 mg/L
0,05 - 0,19 mg/L
C
Information
34,07 - 35,18%
33,21 - 34,07%
32,37 - 33,21%
31,24 - 32,37%
29,83 - 31,24%
D

Figure 5. Chemical factors condition of the research site in Tanjung Mas: A) ammonia distribution; B) BOD level; C) DO; D) nitrate; E) nitrite; F) pH; G) phosphate; H) salinity of Tanjung Mas fishpond areas.

Many chemical factors in the KJT aquatic environment are suitable for milkfish growth. Furthermore, dissolved oxygen (DO) levels meet seawater quality standards and support the development of cultured fish. Adequate dissolved oxygen levels may be produced from plankton photosynthesis and air diffusion (Horak et al., 2018). In addition, oxygen is a limiting factor for water quality because it plays an essential role in the fermentation of organic and inorganic materials at the seabed (Orsi, 2018).

The needed O_2 for decomposition and fermentation can be identified from biochemical oxygen demand (BOD) content. A higher concentration in the fishpond indicates the possibility of high organic matter in the waters (Jorgensen & Marshall, 2016). The results of BOD measurements at ten observation stations show a value of 124.7 mg/L – 364.5 mg/L, especially at stations 3 – 9. Based on the BOD criteria, the seawaters around Tanjung Mas are classified as high polluted by organic compounds. It is probably caused by the decomposition process of milkfish feed, which is sedimented at the seabed. In addition, the map (Figure 4B) shows that high BOD concentrations are distributed mainly near the industrial outfall areas even though the pH around the Tanjung Mas water area is in the neutral range of 6 – 7 and supports milkfish cultivation. In nature, the pH value ranges from 4 – 9, where the unbalancing of the pH affects aquaculture fish or the presence of seawater organisms.

The fermentation process of organic materials releases N into seawaters in the form of nitrate (NO_3), nitrite (NO_2), and ammonia (NH_4) (Oshiki et al., 2016; Spataru, 2021, 2017). The concentration of NO_3 in Tanjung Mas ranges from 0.3947 mg/L - 0.9386 mg/L, while nitrite 0.0058 mg/L – 0.0338 mg/L, and ammonia 0.073 mg/L – 1.568 mg/L. High concentrations of NO_3 and NO_2 in the seawaters can stimulate the growth and development of phytoplankton and become an indicator of fishpond fertility (Hardikar et al., 2019). NO_2 is also an indicator of decreasing N contamination because its formation comes from the oxidation of NH_4, which is toxic. Then, an availability of NO_2 comes from the oxidation of NH_4 to NO_2 carried out by Nitrosomonas bacteria, while the oxidation of NO_2 to NO_3 is carried out by Nitrobacter (Santoro et al., 2021). NO_2 is usually found in lower amounts than NO_3 because it is unstable and easily reacts with oxygen.

The findings obtained in this study show that the measured NH_4 levels are quite high at seven observation stations (stations 1, 2, 3, 4, 5, 6, and 10). The location is at the Mati River, which carries domestic waste from settlements. Organic materials from domestic waste increase the rate of decomposition and fermentation of organic materials to produce NH_4 as a by-product. The increase in NH_4 contamination is positively correlated with anthropogenic factors, primarily related to the residential, agricultural, livestock, and industrial sectors (Bessa et al., 2021; Sproson et al., 2021). In addition, the problem faced in the Tanjung Mas water area is the lack of suitable sanitation, which causes pollution and the balance of the pond waters ecosystem.

Low NH_4 concentrations were measured at stations 7, 8, and 9 because they are located far from settlements and industrial outfall, have more than 5 m depth, and are near the open sea. This condition improves water circulation due to ocean currents and a more homogeneous seawater diffusion process.

Domestic waste may be one of the main factors that increase phosphate concentrations in the KJT water area. Various studies have shown that human activities, including household waste, have increased the concentration of contaminants in the oceans, such as nitrogen (Jickells et al., 2017), phosphate (Badawy et al., 2018; Thiombane et al., 2019), and heavy metals (Bessa et al., 2021; Chu et al., 2019). It is indicated by the distribution of phosphate levels at stations 1 to 5, which is higher than the other five observation stations. Phosphate is a nutrient that is a determining factor in phytoplankton in the sea and is usually found in the form of organic compounds (Bristow et al., 2017).

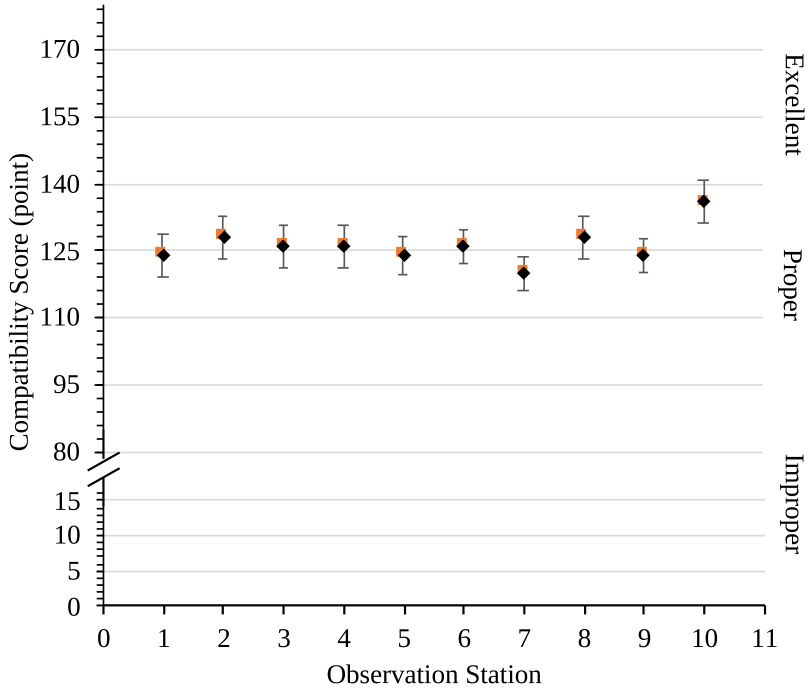


Figure 6. Compatibility for milkfish cultivation in Tanjung Mas water area based on the observation station.

The water compatibility value (Figure 6) shows that all observation stations are categorized at the proper level (S2). It indicates that the Tanjung Mas water area is sufficient and can be developed as a KJT cultivation area. However, limiting factors require special attention to increasing milkfish productivity, such as N and P levels and BOD.

Analysis of KJT System Carrying Capacity Based on Waters Capacity

The total area of potential waters in the Tanjung Mas for KJT is 119.51 Ha, but referring to the government regulation, it is only 20% that can be used for aquaculture. Then the optimum area for the KJT aquaculture system that can be developed is only about 23,902 Ha. However, based on the observation, the existence of KJT has overcapacity. Twenty-two cages occupy it with more than 53.45 Ha of water area. Furthermore, the utilization of the waters has exceeded the carrying capacity because the practical potential of the water area for the KJT system is only 2.4 cage/ Ha for only ten cage units. Therefore, it is necessary to reduce the number of KJT units by looking at the existing conditions.

High occupied water areas with dense cultured milkfish may overshoot the water's capacity and potentially trigger mass death of the marine organism. The condition of the waters directly adjacent to the sea provides an advantage for faster purification. However, the continuous input of domestic and industrial pollutants and low river discharge resulted in a low nature purification rate. It must be a common concern, considering that the waters in the KJT area are the output of several waste installations from the community (domestic) and industries.

Physiochemistry and KJT management in Tanjung Mas depicts new insight into milkfish cultivation in polluted areas. The study results show the potential of KJT as applicable aquaculture in the face of climate change. KJT is also superior to inland ponds because it can guarantee the circulation of physicochemical and nutrients to provide better opportunities for adaptation to climate change. KJT is an adaptive tool/effort for fish farmers to adapt the climate change which reduces their income. A main reason for using KJT in Tanjung Mas is more caused by large profits obtained from aquaculture using low-cost production. An interesting fact in this study also shows that the community does not yet have awareness about the implementation of sustainable milkfish cultivation by concerning the carrying capacity of the environment and product quality. In other words, economic reasons take precedence over health and environmental suitability to produce profitable cultivation commodities, even though, the KJT is contaminated by domestic and industrial waste. It needs an improvement of waste management system from industrial and household by providing sewage purification utilities and scheduling waste disposal based on tidal conditions after purification treatment.

CONCLUSION

In general, the physicochemical factors in Tanjung Mas water areas are proper and support milkfish cultivation. However, the existing condition shows that water utilization for milkfish aquaculture activities using KJT has exceeded the carrying capacity. It potentially disturbs milkfish growth and may lead to the unbalancing ecosystem and trigger the death of the marine organism. On the other hand, high pollution from industries and household waste has become a significant problem affecting milkfish growth and becoming a health issue. High P and NH_4 are primarily detected in the observation station near the industrial outfall and the Mati River estuary, containing domestic waste.

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The officials of Jurnal Pendidikan IPA Indonesia (JPII) (Nationally Accreditted and Indexed by Scopus) give special thanks for submitting article for December 2021 Edition. Based on reviewers' decision, we as the officials stated that:

Article Title : **The Assessment of Water Compatibility of Adaptable Stick-Net Cage for Resilience Milkfish Cultivation in Tanjung Mas, Indonesia**

Authors : Nana Kariada Tri Martuti, Wahid Akhsin Budi Nur Sidiq, Inaya Sari Melati, Dhita Pracisca Mutiatari

is **accepted** and is going to be published in JPII December 2021 Edition.

The admision letter is made for appropriate use only. Thank you for the cooperation.

Semarang, 15th December, 2021
Editor-in-Chief of JPII,

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