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Monitoring the water quality of Belawan Sea for rearing asian seabass *Lates calcarifer* in a floating net cage system

Monitoring kualitas perairan laut Belawan untuk pembesaran ikan kakap putih *Lates calcarifer* sistem keramba jaring apung

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ABSTRACT

Belawan is a coastal area located in Medan Belawan District, North Sumatra Province. The aim of the research is to determine the feasibility status of the study location if it is developed as a location for floating net cages (KJA). The research was carried out in the sea waters of Belawan in August–September 2022. The research parameters observed during the research were hydrooceanographic data and water quality data including physical parameters, chemical parameters, biological parameters. Determination of water quality status using the STORET Index, CCME WQI Index and principal component analysis (PCA). Observation parameters during the research were clinical symptoms, histological observations and growth performance of Asian sea bass. The research results show that tides, COD and turbidity are parameters that do not comply with water quality standards. The types of phytoplankton consist of 15 species and 4 classes, namely Cyanophyceae, Chlorophyceae, Bacyllariophyceae and Dynophyceae. Observation total vibrio count (TVC) shows that in all water samples it is Log 10^5 CFU/mL and in snapper organs (gills, liver, kidneys) there are Log 10^4-10^5 CFU/g. The results of the research can be concluded that for each zone in Belawan waters there is no difference in the level of pollution between zones in terms of the STORET index (moderately polluted) and the CCME WQI index (marginal) with limiting factors namely COD and turbidity. Belawan waters are in less than suitable condition in August–September for snapper cultivation activities in floating net cages (KJA) characterized by low SR and ADG values.

Keywords: Belawan Waters, CCME WQI index, STORET index, principal component analysis (PCA), water quality monitoring

ABSTRAK

Belawan termasuk kawasan pesisir yang terletak di Kecamatan Medan Belawan, Provinsi Sumatera Utara. Tujuan dari penelitian adalah untuk menentukan status kelayakan lokasi kajian jika dikembangkan sebagai lokasi keramba jaring apung (KJA). Penelitian dilaksanakan di perairan laut Belawan, Kota Medan yaitu pada bulan Agustus–September 2022. Metode pengambilan sampel dilakukan secara *purposive sampling*. Adapun parameter penelitian yang diamati selama penelitian yaitu data hidro oseanografi dan data kualitas air meliputi parameter fisika (konduktivitas, TDS, salinitas, suhu, kecerahan, kekeruhan), parameter kimia (DO, BOD, COD, amonia, pH), parameter biologi (plankton, TVC). Penilaian kualitas perairan menggunakan Indeks STORET, Indeks CCME WQI dan *principal component analysis* (PCA). Parameter pengamatan saat penelitian yaitu gejala klinis, pengamatan histologi dan kinerja pertumbuhan ikan kakap putih. Hasil penelitian menunjukkan bahwa pasang surut, COD dan kekeruhan merupakan parameter yang tidak sesuai dengan baku mutu kualitas air. Adapun jenis fitoplankton terdiri dari 15 spesies dan 4 kelas yaitu Cyanophyceae, Chlorophyceae, Bacyllariophyceae dan Dynophyceae. Pengamatan *total vibrio count* (TVC) menunjukkan bahwa pada seluruh sampel air yaitu Log 10^5 CFU/mL dan pada organ ikan kakap (insang, hati, ginjal) yaitu Log 10^4-10^5 CFU/g. Hasil penelitian dapat disimpulkan bahwa setiap zona dalam perairan Belawan tergolong tercemar sedang dan tidak terdapat perbedaan tingkat pencemaran ditinjau dari indeks STORET dan indeks CCME WQI dengan faktor pembatas yaitu COD dan kekeruhan. Berdasarkan hal tersebut, Perairan Belawan dalam kondisi kurang layak untuk kegiatan budidaya ikan kakap di keramba jaring apung (KJA) ditandai dengan nilai SR dan ADG yang rendah.

Kata kunci: indeks CCME WQI, indeks STORET, monitoring kualitas air, Perairan Belawan, *principal component analysis* (PCA)

INTRODUCTION

The Belawan waters are located on the eastern coast of North Sumatra Province, partly within the Medan city area and partly in the Deli Serdang district. Various activities in the port area are thought to contribute to pollution, including cargo ship loading and unloading, workforce mobilization at the port, transportation of loading equipment, truck transportation, water transport facilities, surrounding industrial activities, and domestic waste from residential areas (DLH, 2021). Water quality is heavily influenced by anthropogenic pollutant activities, such as domestic, urban, and industrial activities. Household activities (washing, cooking, and bathing) introduce chemical residues into the water and alter its quality (Kalal *et al*., 2021).

Agricultural activities can also affect the environment by discharging fertilizers and pesticides. Human and industrial activities release unwanted substances into the environment (Verma, 2019). The high use of chemicals in manufacturing, construction, and other industries, including agricultural fertilizers, directly releases polluted water into nearby waters, significantly contributing to water quality degradation (Cloete *et al*., 2014). According to Raman *et al*. (2013), interactions between host, environment, and pathogens can lead to disease. Water physicochemical parameters such as pH, nutrients, and the presence of toxic compounds can influence bacterial population density (Gorlach-Lira *et al*., 2013).

Environmental stressors, such as temperature or hypoxia, can affect host-pathogen interactions, leading to disease (Purcell *et al*., 2016). Virulence is the result of specific host-pathogen interactions and not an inherent property of the microbe or host. For example, avirulent microbes can become virulent or pathogenic in hosts with weakened immune systems (Méthot & Alizon, 2014). The microbiological quality of aquaculture systems plays a crucial role in determining the success or failure of aquaculture ventures (Kim & Lee, 2017). Water quality monitoring is defined as the periodic collection of information at specific locations to produce data that can be used to determine the condition of the water quality (Cloete *et al*., 2014). '

Monitoring and evaluation are crucial steps in understanding pollutant patterns and trends and their impact on aquatic ecosystems. According to research by Matta *et al*. (2015), this has proven to be an essential measure. Furthermore, Price *et al*. (2015) highlighted the necessity of water monitoring when farmed biota must live under natural conditions without disturbing the aquatic ecosystem. Additionally, continuous monitoring of fish health and the environment is critical, as highlighted by Zaenuddin *et al*. (2019), to anticipate diseases that may reduce aquaculture productivity.

Asian seabass (*Lates calcarifer*) offers several advantages as a cultured species. These include rapid growth, tolerance to varying salinity, density, and temperature conditions, making it well-suited for cage culture in marine, estuarine, and coastal waters, as noted by Aswathy *et al*. (2020). Data on marine aquaculture production in Medan for 2021 recorded a total production of 1,100 kg, with seabass accounting for 800 kg and grouper for 300 kg. However, in 2022, a significant decline in marine aquaculture production was observed, with only seabass being produced, totaling 390 kg (DPP, 2022). The aim of this study is to determine the suitability of the study location for the development of a floating net cage (FNC) system for Asian seabass aquaculture.

MATERIALS AND METHODS

Time and place of the study

The study was conducted in the coastal waters of Belawan, Medan City (Figure 1). Water samples were collected from the surface water during a two-month period from August to September 2022 to represent the rainy season.

Data collection

This research involved monitoring activities, and data collection was carried out using both primary and secondary data. Primary data collection involved laboratory observations (DO, BOD, COD, ammonia, turbidity, plankton count, and TVC) and direct field measurements (temperature, pH, salinity, conductivity, TDS). Secondary data included supporting data obtained from the Fisheries Training and Extension Center (BPPP) in Medan, the Agriculture and Fisheries Department of Medan City, and the maritime BMKG (Meteorological, Climatological, and Geophysical Agency) in Belawan. The supporting data obtained from BMKG included hydro-oceanographic data (current velocity, wave height, tides) and climate data (rainfall intensity, number of rainy days).

Determination of sampling point

The selection of sampling points was based on anthropogenic activities in the study area that have the potential to negatively impact the surrounding environment. The coordinates of the sampling locations are presented in Table 1.

Observation parameters

Water quality

Measurement of water quality parameters, including physical, chemical, and biological parameters, was conducted both in situ and ex situ. Detailed information can be found in Table 2.

Visual observation

Fish health monitoring was conducted through visual inspection to assess the condition of external organs such as fins, body, gills, and fish behavior.

Fish growth performance

Absolute weight gain (AWG) was calculated based on the formula by Effendie (1997):

$$AWG = W_t - W_0$$

Note:

W_t = Average fish weight at time t (g)

W_0 = Average fish weight at the start of the experiment (g)

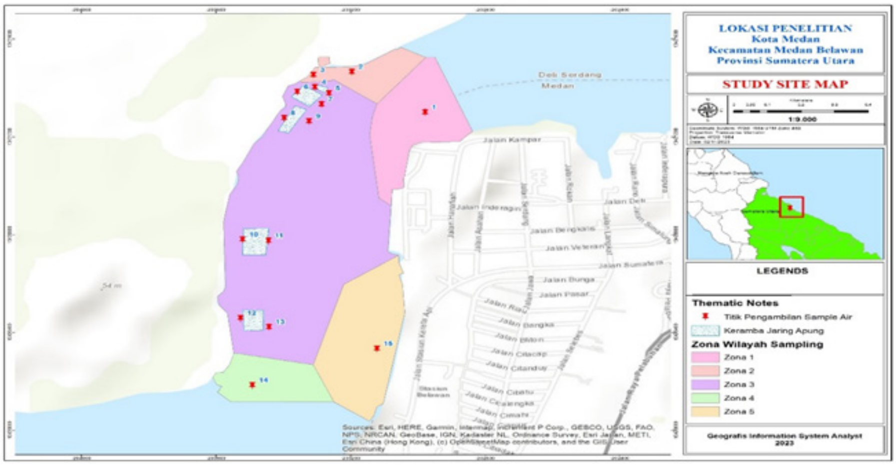

Figure 1. Research location in Belawan Waters, Belawan District, North Sumatra.

Table 1. Names and coordinates of observation stations.

Sampling point	Region division	Location Name	X Coordinate	Y Coordinate
1	Zone 1	Titi panjang pier	98°40’55,106”E	3°, 47’18,101”N
2	Zone 2	Housing 1	98°40’46,656”E	3°, 47’23,206”N
3	Zone 2	Housing 2	98°40’42,992”E	3°, 47’22,780”N
4	Zone 3	FNC 1 (a)	98°40’43,146”E	3°, 47’21,154”N
5	Zone 3	FNC 1 (b)	98°40’44,488”E	3°, 47’20,336”N
6	Zone 3	FNC 2 (a)	98°40’41,446”E	3°, 47’20,513”N
7	Zone 3	FNC 2 (b)	98°40’43,788”E	3°, 47’18,874”N
8	Zone 3	FNC 3 (a)	98°40’40,221”E	3°, 47’17,021”N
9	Zone 3	FNC 3 (b)	98°40’42,611”E	3°, 47’16,639”N
10	Zone 3	FNC 4 (a)	98°40’36,359”E	3°, 47’0,948”N
11	Zone 3	FNC 4 (b)	98°40’38,832”E	3°, 47’0,795”N
12	Zone 3	FNC 5 (a)	98°40’36,236”E	3°, 47’50,526”N
13	Zone 3	FNC 5 (b)	98°40’38,972”E	3°, 47’49,376”N
14	Zone 4	Oil Warehouse	98°40’37,437”E	3°, 47’41,656”N
15	Zone 5	Bandar Deli Port	98°40’42,690”E	3°, 47’42,294”N

Absolute length gain (ALG) was calculated using the formula by Effendie (1997):

$$PL = L_t - L_0$$

Note:
L_t = Average fish length at time t (cm)
L_0 = Average fish length at the start of the experiment (g)

Average daily growth (ADG) was calculated using the formula by Effendie (1997) as follows:

$$ADG = \frac{W_t - W_0}{t}$$

Note:
ADG = Average daily growth (g/day)
W_t = Weight at the end of observation (g/fish)
W_0 = Bobot pada awal pengamatan (g/ekor)
t = Time (duration of rearing)

Survival rate (SR)

Fish survival rate (SR) was calculated using the formula by Huisman (1987) as follows:

$$SR\ (\%) = \frac{Nt}{No} \times 100$$

Note:
N_t = Number of surviving fish at the end of observation
N_0 = Number of fish at the start of observation

Data analysis

STORET index

The principle of the STORET method is to compare water quality data with the standard water quality criteria that are adjusted according to its designated use. The scoring system for determining water quality status can be seen in Table 3 and the air quality classification based on US-EPA can be seen in Table 4.

Table 2. Water quality parameters.

No	Parameter	Unit	Testing tool/Metodh	Measurement frequency
1.	Temperature	°C	SCT meter	Once a day
2.	pH	-	SCT meter	Once a day
3.	Salinity	ppt	SCT meter	Once a day
4.	Conductivity		SCT meter	Once a day
5.	Total dissolved solid (TDS)	mg/ L	SCT meter	Once a day
6.	Turbidity	NTU	Turbidimetry	Once every two weeks
7.	Clarity	cm	Secchi disk	Once every two weeks
8.	Dissolved Oxygen (DO)	mg/L	SNI 066989.72:2009	Once every two weeks
9.	Biological Oxygen Demand (BOD)	mg/L	SNI 066989.72:2009	Once every two weeks
10.	Chemical Oxygen Demand (COD)	mg/L	Spectrophotometry	Once every two weeks
11.	Ammonia	mg/L	Spectrophotometry	Once every two weeks
12.	Total plankton	Cell/mL	Microscope	Once every two weeks
13.	Total vibrio count (TVC)	CFU/mL	Total Plate Count	Once every two weeks

Table 3. Determination of the scoring system for water quality status.

Number of Sample[a]	Score	Parameter		
		Physic	Chemistry	Biology
<10	Maximum	-1	-2	-3
	Minimum	-1	-2	-3
	Average	-3	-6	-9
≥10	Maximum	-2	-4	-6
	Minimum	-2	-4	-6
	Average	-6	-12	-18

Source: Canter 1977; [a]The number of data points from each parameter used to determine water quality status.

CCME WQI index analysis

The CCME WQI applies a target value (guideline or objective) for each water quality parameter that should not be exceeded, and three key factors are used to estimate a single unitless score representing overall water quality. The calculation steps according to CCME (2017) are as follows:
F1 (Scope), represents the percentage of variables that deviate from the established quality standards:

$$F1\ (\%) = \frac{\text{Number of variables}}{\text{Total number of variables}} \times 100\%$$

F2 (Frequency), represents the percentage of tests for each parameter that do not meet quality standards:

$$F2\ (\%) = \frac{\text{Number of test that deviate}}{\text{Total number of of test}} \times 100\%$$

F3 (Amplitude), represents the magnitude of deviation:

$$F3 = \left[\frac{\text{nse}}{0.01\ \text{nse} + 0.01} \right]$$

Note = nse is the total deviation score for each test

$$\text{nse} = \frac{\sum_{i=1}^{n} \text{Total excursion value}}{\text{Total number of tests}}$$

CCME WQI, Once the factor values have been calculated, the CCME WQI can be determined using the following formula:

$$\text{CCME WQI} = 100 - \frac{\sqrt{F1^2 + F2^2 + F3^2}}{1.732}$$

Water quality characteristic spatial variation

Spatial analysis of water quality characteristics between observation stations uses a multivariate statistical analysis approach, specifically principal component analysis (PCA) (Bengen, 2000). PCA is used in parameter selection to identify the strength and direction of variation among the collected water quality parameters (Koçer & Sevgili, 2014).

RESULT AND DISCUSSION

Result

Chemical and physical parameters of Belawan waters

The water quality conditions of Belawan Waters were observed at 15 different sampling points. The analyzed parameters included chemical, physical, and biological parameters (Table 5). The chemical and physical parameters that did not meet the water quality standards for fish farming in floating net cages, based on Prema (2013) and Government Regulation (PP) 2021, were COD and turbidity.

Biological parameters

Amount of plankton

The observations related to plankton data in Belawan Waters showed the presence of only phytoplankton species (Table 6). The phytoplankton species found were from the classes Cyanophyceae, Chlorophyceae, Bacillariophyceae, and Dinophyceae. During the study, species such as *Oscillatoria sp.*, *Synedra sp.*, *Microcystis sp.* from the class Cyanophyceae were found. The class Chlorophyceae consisted of *Dunaliella sp.*, while the class Bacillariophyceae included species such as *Nitzschia sp.*, *Bacillaria sp.*, *Chaetoceros sp.*, *Skeletonema sp.*, *Rhizoselenia sp.*, and *Coscinodiscus sp.* The class Dinophyceae included *Ceratocorys sp.*, *Pyrocystis sp.*, *Prorocentrum sp.*, *Ceratium sp.*, and *Noctiluca sp.*

Total vibrio count (TVC)

TVC observations were conducted on five individual fish, with each organ of the seabass (gills, liver, kidneys) and all water sampling points in Belawan Waters (Figure 2). The TVC

Table 4. Klasifikasi mutu air berdasarkan indeks STORET.

Class	Criteria	Score	Water quality status
A	Excellent	0	Meets quality standard
B	Good	-1 s/d -10	Lightly polluted
C	Moderate	-11 s/d -30	Moderately polluted
D	Poor	≥31	Heavily polluted

Source: Kepmen (2003) [Value system from the United States-Environmental Protection Agency (US-EPA)].

results showed that in all water samples, the count was Log10[5] CFU/mL, and in the seabass organs (gills, liver, kidneys), the count ranged from Log 10[4]-10[5] CFU/g.

Observation parameter

Clinical symptoms of asian seabass (Lates calcarifer)

The clinical symptoms observed in the seabass during the study can be seen in Figure 3. During the observation, only clinical symptoms such as pale body color and the beginning of scale peeling were noted.

Histological observation of asian seabass (Lates calcarifer)

The histopathological results of the white seabass organs (gills, liver, kidney) are presented in Figure 4. The condition of the gill, liver, and kidney tissues shows evidence of changes and damage. The gill organ indicates partial fusion of several lamellae, the liver shows signs of necrosis in hepatocyte cells, and the kidney indicates degenerative swelling.

Growth performance of asian seabass (Lates calcarifer)

The growth performance of white seabass during the study can be seen in Table 7. The water

Table 5. Chemical and physical parameter data of Belawan Waters.

Sampling point	Parameters									
	DO (mg/L)	BOD (mg/L)	COD (mg/L)	Ammonia (mg/L)	pH	EC (µs/cm)	TDS (mg/L)	Salinity (ppt)	Temperature (°C)	Turbidity (NTU)
St 1	7.10 ± 0.61	1.93 ± 0.75	9.05 ± 0.58	0.03 ± 0.03	7.20 ± 0.0	14625 ± 95.74	9691.5 ± 37.5	30 ± 0.00	27.975 ± 0.13	21.6 ± 0.6
St 2	6.97 ± 0.77	1.90 ± 0.57	9.03 ± 0.47	0.03 ± 0.04	7.15 ± 0.3	14623.75 ± 92.41	9389.5 ± 511.4	29.75 ± 0.50	27.975 ± 0.05	23.7 ± 2.3
St 3	7.10 ± 0.51	1.98 ± 0.85	9.25 ± 0.41	0.04 ± 0.06	7.18 ± 0.5	14629.25 ± 47.65	9472 ± 529.0	29.75 ± 0.50	28.075 ± 0.15	32.4 ± 4.3
St 4	7.18 ± 0.30	1.80 ± 0.62	9.25 ± 0.26	0.03±0.02	7.20 ± 0.8	14601.75 ± 82.50	9132.25 ± 5699	29.5 ± 0.58	27.75 ± 0.50	23.3 ± 3.2
St 5	6.99 ± 0.43	1.75 ± 0.60	9.08 ± 0.46	0.02±0.01	7.30 ± 0.8	14648 ± 58.38	9291 ± 618.4	29.75 ± 0.50	27.95 ± 0.41	27.375 ± 54
St 6	7.18 ± 0.33	1.73 ± 0.60	9.03 ± 0.63	0.03 ± 0.04	7.15 ± 0.3	14652 ± 55.48	9435.25 ± 4711	29.75 ± 0.50	28.175 ± 0.35	27.5 ± 5.4
St 7	7.38 ± 0.29	1.60 ± 0.54	8.65 ± 0.38	0.01 ± 0.00	7.31 ± 0.8	14576 ± 95.05	8936 ± 486.3	30 ± 0.00	28.1 ± 0.20	24.85 ± 3.1
St 8	6.76 ± 0.66	2.03 ± 1.00	9.30 ± 0.37	0.03 ± 0.04	7.35 ± 0.3	14576 ± 94.00	8928.75 ± 4681	30 ± 0.00	28,125 ± 0.25	26.075 ± 26
St 9	7.34 ± 0.16	1.73 ± 0.57	8.90 ± 0.29	0.02 ± 0.01	7,16 ± 0.1	14590.25 ± 84.50	8915.25 ± 4829	30 ± 0.00	28.075 ± 0.15	23.05 ± 3.3
St10	6.93 ± 0.62	1.83 ± 0.53	9.25 ± 0.33	0.02 ± 0.01	7.23 ± 0.5	14648.5 ± 59.74	9109.5 ± 485.	29.75 ± 0.50	27.75 ± 0.50	26.4 ± 5.6
St11	7.20 ± 0.24	1.85 ± 0.73	8.90 ± 0.12	0.02 ± 0.02	7.18 ± 0.5	14650 ± 59.88	9334.25 ± 5121	29.75 ± 0.50	28 ± 0.00	27.2 ± 5.7
St12	7.24 ± 0.48	1.80 ± 0.62	8.90 ± 0.27	0.03 ± 0.03	7.19 ± 0.4	14651.25 ± 55.77	9453 ± 406.4	29.75 ± 0.50	28.1 ± 0.12	24.05 ± 2.8
St13	7.07 ± 0.70	1.73 ± 0.46	8.93 ± 0.46	0.01 ± 0.00	7.23 ± 0.1	14505.75 ± 323.89	8944.75 ± 5659	30 ± 0.00	27.75 ± 0.50	25.125 ± 66
St14	7.23 ± 0.20	1.75 ± 0.58	9.05 ± 0.40	0.01 ± 0.00	7.25 ± 0.3	14496.25 ± 225.18	8867.75 ± 4723	29.5 ± 0.58	27.65 ± 0.93	26 ± 5.9
St15	7.22 ± 0.29	1.83 ± 0.70	9.03 ± 0.25	0.01 ± 0.00	7.21 ± 0.6	14650.75 ± 56.88	9204.5 ± 672.0	29.75 ± 0.50	27.975 ± 0.05	27.5 ± 5.4

Table 6. Phytoplankton diversity in Belawan Waters during the study.

Phytoplankton	Testing				Total Phytoplankton (Cell/mL)
	Week-1	**Week-2**	**Week-3**	**Week-4**	
Cyanophyceae					
Oscillatoria sp.	2	0	0	0	5.0×10^3
Synedra sp.	0	0	1	0	2.5×10^3
Mycrocystis sp.	0	0	0	1	2.5×10^3
Chlorophyceae					
Dunaliella sp.	1	0	0	0	2.5×10^3
Bacillariophyceae					
Nitzschia sp.	1	1	0	1	7.5×10^3
Bacillaria sp.	0	1	1	0	5.0×10^3
Chaetoceros sp.	1	0	1	0	5.0×10^3
Skeletonema sp.	0	0	0	2	5.0×10^3
Rhizoselenia sp.	0	1	0	1	5.0×10^3
Coscinodiscus sp.	0	0	0	1	2.5×10^3
Dinophyceae					
Ceratocorys sp.	1	0	0	0	2.5×10^3
Pyrocystis sp.	0	0	1	0	2.5×10^3
Prorocentrum sp.	0	0	1	1	5.0×10^3
Ceratium sp.	0	1	0	0	2.5×10^3
Noctiluca sp.	0	0	1	0	2.5×10^3

Source: Laboratory analysis results from LPPMHP, Dumai City.

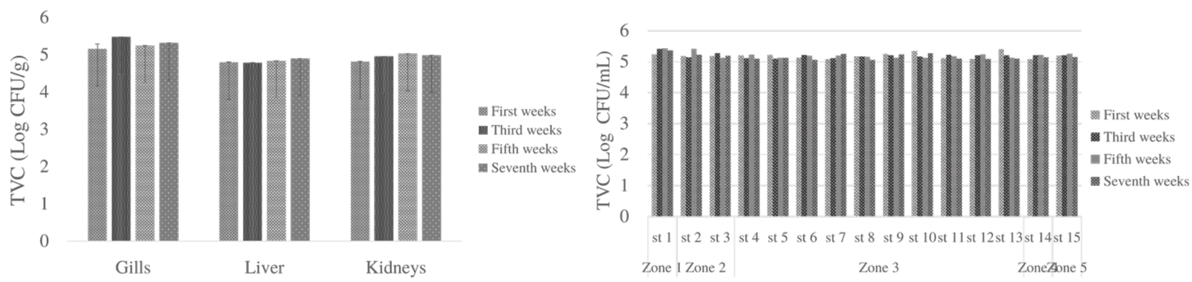

Figure 2. (A) TVC observation results on white snapper organs; (B) TVC observation results on water samples in Belawan Waters.

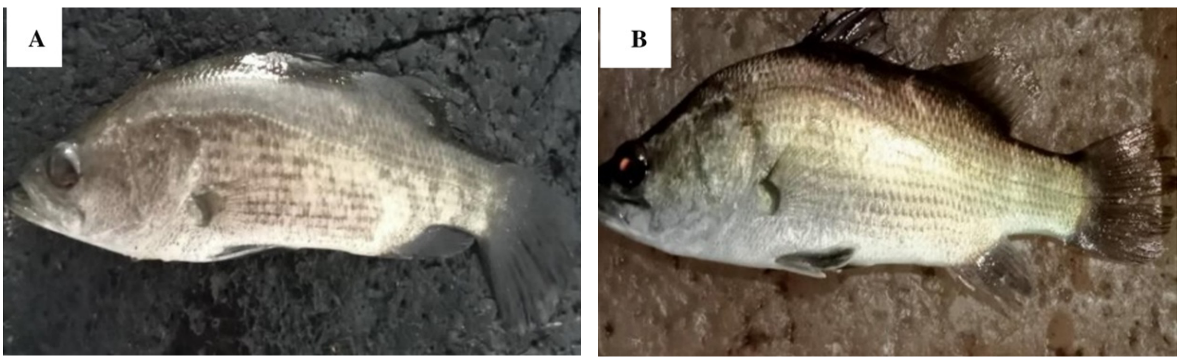

Figure 3. (A) Morphological condition of snapper showing a decline in health; (B) Morphological condition of healthy snapper.

quality of Belawan for the aquaculture activities of white seabass in floating net cages has an impact on the growth performance data.

Determination of the water quality status of Belawan Waters

STORET and CCME WQI index

The water quality status of Belawan is determined based on the STORET index and CCME WQI. According to the STORET index, the water quality status in August (the first and third weeks) and September (the fifth and seventh weeks) indicates that the condition of Belawan waters is moderately polluted. The average water quality index (WQI) value using the CCME method in Belawan waters is 64.32, which categorizes the water quality condition as marginal (Figure 5). For further clarification, please refer to the figure below:

PCA (principal component analysis) of water quality

Based on Table 8, the PC1 value has an eigenvalue of 5.8446 with a cumulative value of 58.4%. PC2 has an eigenvalue of 2.2013 and a cumulative value of 80.5%, while PC3 has an eigenvalue of 1.6681 and a cumulative value of 97.1%. The scree plot also shows that the slope flattens out at the third dimension with an eigenvalue greater than one.

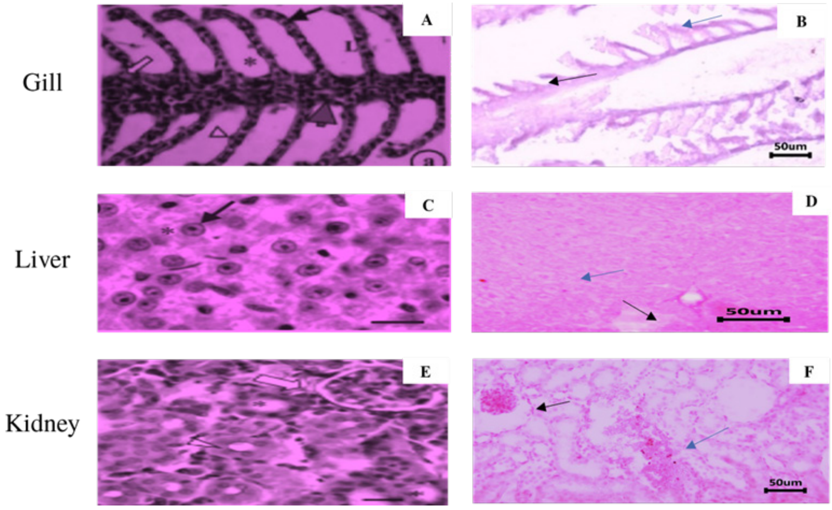

Figure 4. (A) Normal gill aspect, showing filaments (gray arrow), lamella (L), water channel (*), pillar cells (black arrow), and epithelial cells (pointer); (B) Lamella with widened marginal channel (blue arrow), partial fusion of several lamellae (black arrow); t(C) Normal liver tissue, showing hepatocytes with granular cytoplasm (*) and central round nucleus (arrow); (D) Hepatocytes with irregularly shaped nucleus (blue arrow), liver tissue showing focal necrosis (black arrow); (E) Normal kidney blood cells showing well-defined glomerulus and Bowman's space (arrow), proximal tubule (*), distal tubule (arrow); (F) Tubules initiating the regeneration process (black arrow), cloudy swelling degeneration (blue arrow).

Table 7. Initial biomass (W0), final biomass (Wt), initial fish length (L0), final fish length (Lt), absolute weight gain (PB), average daily growth (ADG), absolute length growth (PL), survival rate (SR).

Test parameters	Value
W_0 (g)	17.46 ± 6.79
W_t (g)	81.74 ± 5.56
L_0 (cm)	10.76 ± 1.60
L_t (cm)	18.50 ± 0.50
PB (g)	64.28
ADG (g/hari)	1.07
PL (cm)	7.74
SR (%)	79.20

According to Table 9, the eigenvector values based on the PCA computation results indicate that the first principal component has a strong positive relationship with BOD (0.4), ammonia (0.394), and TDS (0.382), and a negative relationship with DO (-0.374) and pH (-0.377). The second principal component has a strong positive relationship with COD (0.476) and a negative relationship with EC (-0.432), salinity (-0.379), and temperature (-0.57). The third principal component has a positive relationship with turbidity (0.732).

Discussion

The COD values during the observations ranged from 8.85 to 9.45 mg/L, indicating that the water quality is not good. This is assessed based on the quality standards (Prema, 2013), where the preferred COD level for mariculture is <1 mg/L. Higher COD values were observed in coastal areas during the rainy season compared to the dry season (Chen *et al*., 2016; Lao *et al*., 2021; Nguyen *et al*., 2022). The high concentration of COD is associated with the presence of domestic waste, industrial wastewater, food outlet waste, market waste, and agricultural activities (Maulud *et al*., 2021).

Turbidity is an important parameter for environmental monitoring because it can be used as an indicator of water body pollution or as an indirect measure of total suspended solids in water (Tomperi *et al*., 2020). During the study, the clarity ranged from <1 m and turbidity ranged from 21 to 34.8 NTU, indicating that the turbidity

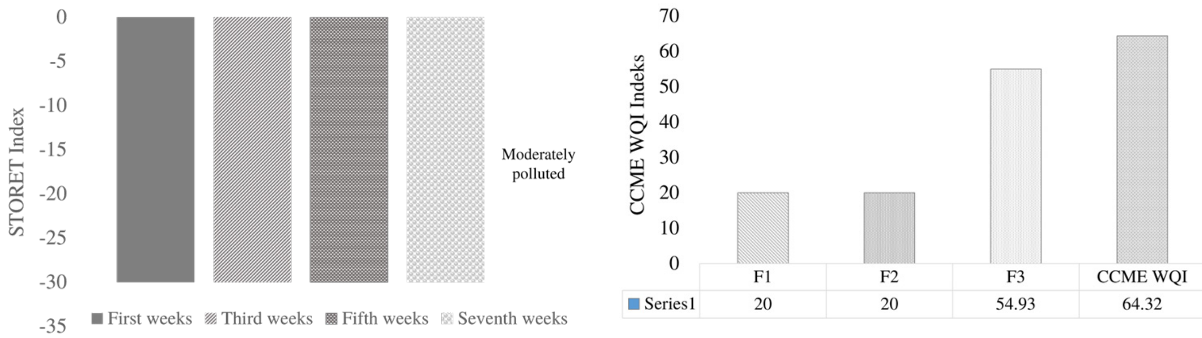

Figure 5. (A) STORET index values; (B) CCME WQI index values in Belawan Waters.

Table 8. Eigenvalue analysis and cumulative percentage of PCA computation results.

	Main component		
	PC1	**PC2**	**PC3**
Eigenvalue	5.8446	2.2013	1.6681
Proportion	0.584	0.22	0.167
Cumulative	0.584	0.805	0.971

Table 9. Eigenvector analysis of water quality parameters at all research locations.

Variable	PC1	PC2	PC3
DO	-0.374	-0.192	0.035
BOD	0.4	0.033	0.02
COD	0.249	0.476	0.265
Amnonia	0.394	0.179	-0.074
pH	-0.377	-0.03	-0.309
EC	0.286	-0.432	0.245
TDS	0.382	-0.155	-0.195
Salinity	0.32	-0.379	-0.194
Temperature	-0.054	-0.57	0.395
Turbidity	-0.083	0.151	0.732

values do not comply with the quality standards of PP 2021. According to Sallam and Elsayed (2018), high turbidity levels can alter the diversity of aquatic systems and shade aquatic plants and other fauna. Furthermore, high turbidity levels can endanger fish and other aquatic life by reducing the supply of natural food, damaging spawning grounds, and affecting gill function (Matta *et al.*, 2015). Turbidity levels are generally higher during the rainy season compared to the dry season due to the mixing of rainwater and river water (Trang *et al.*, 2020).

The characteristics of plankton and the physicochemical environment are significantly influenced by anthropogenic activities such as industrial, agricultural, and fisheries activities (Nguyen & Huynh, 2023). The plankton found during the study consisted of phytoplankton. The phytoplankton identified in the waters of Belawan comprised 15 species, belonging to four classes: Cyanophyceae, Chlorophyceae, Bacillariophyceae/Diatom, and Dynophyceae. Some harmful diatom, dinoflagellate, and cyanobacteria species can degrade habitat and water quality (Carstensen *et al.*, 2015). *Skeletonema* sp., *Chaetoceros* sp., and *Rhizosolenia* sp. were among the species identified during the study.

Sidabutar *et al.* (2016) noted that *Skeletonema* sp. and *Chaetoceros* sp. can cause fish mortality, while *Rhizosolenia* sp. does not pose a significant danger but can lead to color changes. *Ceratocorys* sp., *Pyrocystis* sp., *Prorocentrum* sp., *Noctiluca* sp., and *Ceratium* sp., which belong to the class Dynophyceae, were also found. According to Sidabutar *et al.* (2016) and Apriadi *et al.* (2021), some dinoflagellates are known to cause red tides, which are highly detrimental to aquatic ecosystems. Among various *Vibrio* species, *V. harveyi*, *V. vulnificus*, *V. alginolyticus*, and *V. parahaemolyticus* are commonly encountered fish pathogens associated with significant economic losses in the aquaculture industry (Mohamad *et al.*, 2019; Deng *et al.*, 2020).

Vibriosis leads to symptoms of septicemia, characterized by lesions on the skin and necrosis in the liver, kidneys, and other tissues (Wang & Leung, 2000). In the liver, visible histopathological changes include hemorrhage, lymphocytic infiltration, mild to severe hepatocellular degeneration, and necrosis of hepatocytes, which appear as cell lysis with numerous melanomacrophage centers (Manchanayake *et al.*, 2023). Changes during histopathological examination are particularly noted in the secondary lamellae of the gill organs, as secondary lamellae are very delicate structures continuously exposed to the aquatic environment. Mahardika *et al.* (2020) classified the population of *Vibrio* sp. into four groups: low (<10^2 CFU/g), moderate (10^2-10^3 CFU/g), high (10^4-10^6 CFU/g), and very high (10^7-10^9 CFU/g). This population grouping is based on the standards of the BBRBLPP (Balai Besar Riset Budidaya Laut dan Penyuluhan Perikanan) Pathology Laboratory, Gondol, Bali, which is accredited (ISO/IEC 17025:2017).

The STORET (Storage and Retrieval of Water Quality Data System) method is used to assess the overall level of pollution. This analysis employs the STORET method as a common determination of water quality in accordance with Kepmen (2003). According to CCME (2017), target values (guidelines or objectives) are established for each water quality parameter that should not be exceeded, along with three key factors to estimate a unitless number representing overall water quality. These three factors are the scope or number of variables in the dataset that do not meet water quality criteria, frequency or how often the targets are not achieved, and amplitude or the extent to which the targets are unmet.

A score of 0 indicates the worst water quality, while a score of 100 represents the best. Acceptable water quality criteria are combined into a single number ranging from 0 to 100, with 100 indicating “very good” quality, as defined by the Canadian Council of Ministers of the Environment (CCME, 2017). The advantages of using this technique include improved data visualization, reduced data complexity, and increased computational efficiency, where new variables called principal components exhibit low multicollinearity (Hasan & Abdulazeez, 2021). PCA produces principal components (PCs) from the original dataset to identify parameters indicating variable variation and to identify potential pollution sources (Zeinalzadeh & Rezaei, 2017). An eigenvector value of at least 0.3 can be utilized (Lesmana & Roychansyah, 2021).

CONCLUSION

The results of the study conclude that there are no differences in pollution levels between zones in the Belawan waters, as assessed by the STORET index (moderately polluted) and the CCME WQI index (poor/marginal), with limiting factors being COD and turbidity. The Belawan waters are in a less suitable condition from August to September for the cultivation of snapper in floating net cages (KJA), as indicated by low values of SR and ADG.

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