Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 29(2): 31 – 50 (2025)
www.ejabf.journals.ekb.eg

The Impact of Shrimp Farming Waste in Pangandaran Coastal Park, Indonesia (Case Study: Sea Turtle Landing Habitat)

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ARTICLE INFO

Article History:
Received: Dec. 19, 2024
Accepted: Jan. 21, 2025
Online: March 4, 2025

Keywords:
Shrimp farm waste,
Water quality,
Zoning,
Sea turtles,
Sediment

ABSTRACT

Fish farming is a crucial and profitable sector in fisheries industry, especially for vannamei shrimp (*Litopenaeus vannamei*, Boone 1931) commodities. Pangandaran Regency is a major producer of vannamei shrimp in Indonesia, and its coastal areas have been designated as conservation zones, especially for sea turtle species. However, the conservation location in Pangandaran Coastal Park Conservation Area is now affected by vannamei shrimp farming activities. Thus, this research aimed to analyze the impact of waste generated from vannamei shrimp (*L. vannamei*) aquaculture on the coastal ecosystem, particularly on sea turtle landing and nesting activities in the Pangandaran Coastal Park Conservation Area. The research method that was used is survey method, with purposive sampling used to determine the sampling stations. Data collection was conducted at five stations, with water samples taken from both shrimp farm outlets and the nearby seawater. Sampling was conducted in 4 repetitions during shrimp farm effluent discharge or harvest. The shrimp farm waste discharged into the environment, with parameters such as TSS, NH_3, NO_3, and PO_4, has not met the established quality standards, as it exceeds the allowable thresholds. This condition has contributed to the decline in sea turtle landing and nesting activities, primarily due to the poor management of shrimp farm waste.

INTRODUCTION

Fish farming is a crucial sector in the Indonesian fisheries industry, contributing significantly to the country's aquaculture development and economy. According to **Arifin *et al.* (2012)**, Indonesia has approximately 344,759 hectares of shrimp ponds, representing about 39.78% of the available land potential 866,759 hectares, spread throughout Indonesia.

Indonesia's leading aquaculture export commodity is shrimp. There are two main shrimp export commodities, namely the vannamei shrimp (*Litopenaeus vannamei*, Boone 1931) and the giant tiger shrimp (*Penaeus monodon*). The vannamei shrimp (*L. vannamei*) is the largest shrimp commodity and has a high export value. The vannamei shrimp commodity was officially introduced to aquaculture farmers through the Decree of the Minister of Marine Affairs and Fisheries of the Republic of Indonesia No. 41/2001 on July 12, 2001, as a superior commodity for cultivation in Indonesia. Shrimp farming activities are classified under the KBLI code 03254, which covers brackish water crustacean farming (Government Regulation No. 5 of 2021, Appendix 1, Marine and Fisheries Sector).

Year after year, the vannamei shrimp production has increased. According to data from the **DJPB (2015)**, the vannamei shrimp production between 2010-2014 experienced an average annual increase of 20.49%. Furthermore, **DJPB (2021)** data report that the vannamei shrimp production in 2021 reached 884,939 tons. Based on data from the Ministry of Marine Affairs and Fisheries, the total value of Indonesian shrimp exports until October 2015 was 162,580 tons. The total value represented an 8.19% increase from 2014, when the volume was 145,092 tons annually **(Aulia 2018)**.

In Pangandaran, brackish water aquaculture exclusively cultivates the vannamei shrimp, with a production value of 6 billion rupiah in 2015, as reported by the **BAPPEDA West Java Province (2016)**. Additionally, the amount of brackish water fish cultivation production in Pangandaran Regency between 2018-2019 increased by around 18.76 tons. In 2018, the amount of the vannamei shrimp production reached 72.07 tons, with a production value of IDR 5,025,068,000, making the vannamei shrimp as the commodity with the highest production value among other commodities **(BPK, 2020)**. The coastal area of Pangandaran Regency is designated as part of a conservation zoning areas. Conservation area zoning is a form of spatial utilization engineering within conservation areas, carried out through the establishment of functional boundaries in accordance with the resource potential, carrying capacity, and ecological processes taking place as part of a unified ecosystem **(DKP West Java Provincial, 2020)**.

The spatial boundaries of the Pangandaran Coastal Park Conservation Area are based on the spatial allocation map of the Coastal Zone and Small Islands Zoning Plan (RZWP3K) of West Java Province, covering the areas of Legok Jawa Village and Batu Hiu, with a total area of 38,856.12 hectares. The function of this area is to maintain and enhance the quality of biodiversity also as habitat for nesting of sea turtle along Legok Jawa Beach.

According to the results of the data series analysis by the **DKP West Java Provincial (2020)**, during the period of 2015-2018, the types of sea turtle that were known to land for a long time were the olive ridley sea turtles (*Lepidochelys olivacea*) and the green sea turtle (*Chelonia mydas*). However, among these two species, the green sea turtle (*C. mydas*) was more frequently observed landing in the waters of Legok Jawa Beach. From 2014 to 2015, on Legok Jawa Beach, the average number of turtle landings and nesting was only four to five per month. However, in 2016, no nesting activity was recorded, and recent observations reported only 1–2 turtles landing annually. On September 19, 2017, 11 adult sea turtles, including the green, olive ridley, and loggerhead species, were found dead along the Legok Jawa coastline. These findings highlight a sharp decline in nesting activity and increased mortality, raising significant conservation concerns.

Another issue in the Pangandaran Conservation Area, particularly the Legok Jawa Beach area within the Pangandaran Coastal Park Conservation Area, is the presence of the vannamei shrimp farms near the coastal area and directly on the border with the core conservation zone. According to data from the **DKPKP (2024)**, the vannamei shrimp farming activities in the Pangandaran Coastal Park Conservation Area generally follow a semi-intensive farming pattern, with an average stocking density applied ranging from 30-80 shrimp/m^2. This aligns with the finding of **Aulia (2018)**, who noted that the stocking density for the vannamei shrimp farming using the semi-intensive system is between 30-60 shrimp/m^2.

The shrimp farming activities, along with the disposal of waste through outlets into the sea, can affect water quality and the coastal habitat quality in Legok Jawa and its surrounding areas. Furthermore, numerous shrimp ponds do not meet the required standards because they lack proper Wastewater Treatment Plants (WWTP) in accordance with regulations. This situation could have negative impacts on the survival of the sea turtles nesting in the area, as sea turtles are highly sensitive to changes in their habitat **(Afandy *et al.*, 2017)**. The aim of this research was to analyze the impact of waste generated from the vannamei shrimp (*L. vannamei*) aquaculture on the coastal ecosystem, particularly on sea turtle landing and nesting activities in the Pangandaran Coastal Park Conservation Area.

MATERIALS AND METHODS

1. Research location

This research was conducted in Pangandaran Regency, West Java. Data collection for this study took place from May to July 2024. The sampling stations for water and sediment collection totaled five stations, which were selected based on the zoning areas established by the Decree of the Minister of Marine Affairs and Fisheries of the Republic of Indonesia Number 1 of 2022 concerning Conservation Areas in the Waters of Pangandaran, West Java Province (2022). These stations included two stations in the core conservation zone in Legok Jawa Village, with one station in the limited utilization zone in Kertamukti Village and the other in Madasari Village. Additionally, a control station was situated at Karapyak Beach, Bagolo Village. This setup was designed to compare the water quality affected and unaffected by shrimp farm waste.

The research was conducted at 5 stations with 2 stations at Legok Jawa Beach which is the location of the core conservation zone, 1 station at Kertamukti Village and 1 station at Madasari Village which are included in the limited utilization zone, also 1 station located at Karapyak Beach, Bagolo Village which is a control station.

Sampling of seawater (input and output), pond water, and sediment was carried out in the conservation area which includes both core and limited utilization zones with five stations, as follows:

Station 1: Semi-intensive shrimp pond in Kertamukti Village, located at coordinates 7°48'46.23"S, 108°23'1.60"E.

Station 2: Semi-intensive shrimp pond in Legok Jawa Village, Cimerak District, located at coordinates 7°49'08.00"S, 108°25'14.20"E.

Station 3: Intensive shrimp pond in Legok Jawa Village, Cimerak District, located at coordinates 7°49'8.50"S, 108°26'05.90"E.

Station 4: Intensive shrimp pond in Madasari Village, Cimerak District, located at coordinates 7°48'19.15"S, 108°28'22.98"E.

Station 5 (Control): Coastal waters of Karapyak Beach in Bagolo Village, Kalipucang District, located at coordinates 7°41'1.851"S, 108°44'14.00"E, as presented in Fig. (1).

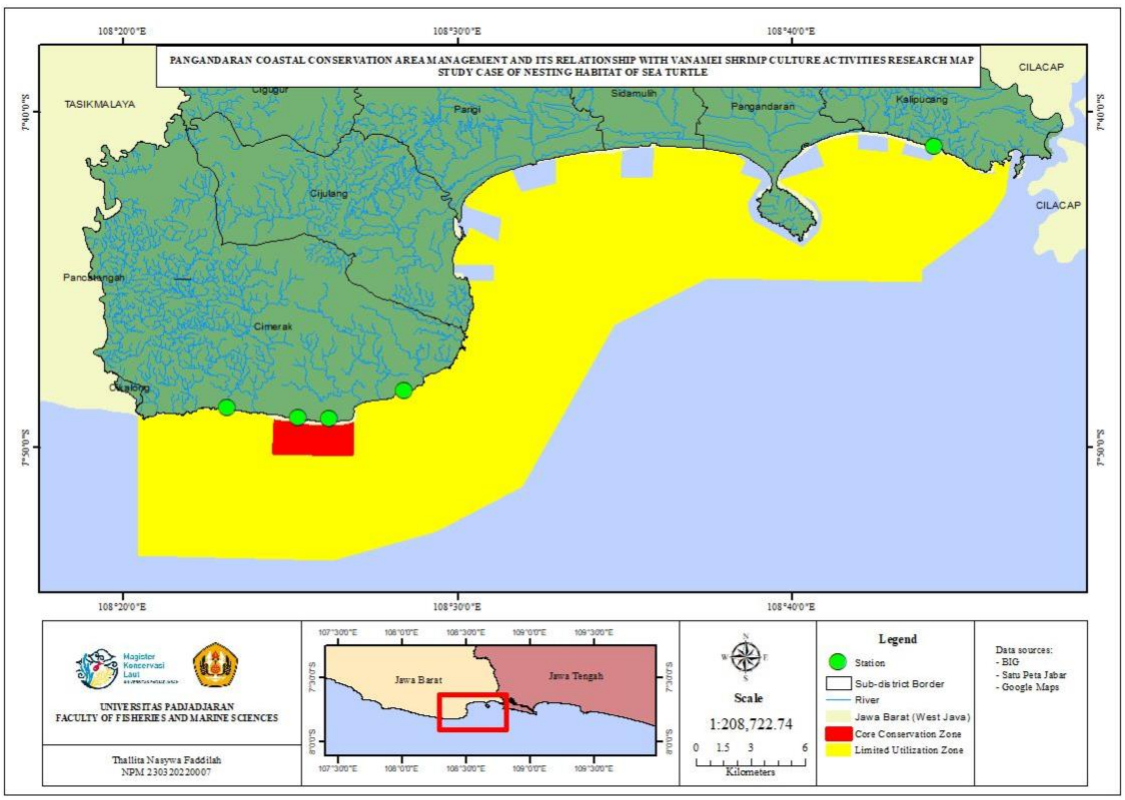

Fig. 1. Research map station

The selection of research locations was based on the presence or absence of shrimp farming activities along the coastal area. Stations 1, 2, 3, and 4 represent coastal areas where the vannamei shrimp farming ponds are present, while Station 5 serves as a control station with no shrimp farming activities (Fig. 1). The procedures for seawater and outlet water sampling were conducted in accordance with the methods described by **APHA (1998)**, while sediment sampling followed the guidelines outlined by **Tanah (2005)**.

2. Tools and materials

The tools and materials used in this study include those for sampling, *in situ* measurements, and *ex situ* measurements. The tools used include a Garmin GPS model Etrex 10 for determining sampling coordinates and creating research maps, a Lutron DO meter model DO-5510 with an accuracy of $0.1 mgL^{-1}$ for measuring dissolved oxygen levels, and a Lutron pH meter model PH-207 with an accuracy of 0.1 for measuring water pH. A refractometer model ATAGO was used to measure water salinity, while HDPE sample bottles (1000 and 100ml) were used for storing water samples. Sediment samples were stored in ziplock plastic bags. Cool boxes and Styrofoam containers were used to store and cool the samples during transport from the research stations to the laboratory, with label paper for sample identification. A scoop or water dipper was utilized for collecting water and sediment samples.

The materials used in this study include aquadest (distilled water) for diluting and rinsing instruments during sample measurements, outlet water samples from shrimp farms as research objects, seawater samples, and sediment samples (300 grams per station) from outlets. Ice and coarse salt were also used to preserve water samples through cooling during transport.

3. Data collection techniques

3.1 Primary water quality parameters

Sampling for water quality assessment was conducted *ex-situ* at the outlet of the pond and the sea at each research station. Sample preservation was carried out by cooling with ice and storing in a cool box during transportation to the laboratory. The water quality parameter analysis was conducted in two separate laboratories. Total suspended solids (TSS) was analyzed at the Central Laboratory of Universitas Padjadjaran, while biochemical oxygen demand (BOD), ammonia, nitrate, and phosphate parameters were analyzed at the Water Quality Laboratory of the Faculty of Civil and Environmental Engineering, Institute Teknologi Bandung.

Table 1. Research parameters and main parameter measurement methods

Parameter	Unit	Methods	Analysis tool	Location
BOD	mg/L	APHA-5210-B	Spectrophotometer	*Ex situ*
TSS	mg/L	SNI 6989.3-2019	-	*Ex situ*

Ammonia (NH_3)	mg/L	APHA-4500-NH_3-F	Spectrophotometer	*Ex situ*
Nitrate (NO_3)	mg/L	APHA-4500-NO_3-E	Spectrophotometer	*Ex situ*
Phosphate (PO_4)	mg/L	APHA-4500-D	Spectrophotometer	*Ex situ*

3.2 Secondary water quality parameters

In-situ water quality sampling was conducted directly at the pond outlet and the sea at each research station. Meanwhile, *ex-situ* water quality sampling was also conducted at the pond outlet and the sea at each research station. Sample preservation was carried out by cooling with ice and storing in a cool box during transportation to the laboratory. *Ex-situ* water quality parameter analysis was conducted in two laboratories. Total dissolved solids (TDS) were analyzed in the Central Laboratory of Universitas Padjadjaran, while Turbidity was analyzed in the Water Quality Laboratory of the Faculty of Civil and Environmental Engineering, Institut Teknologi Bandung.

Table 2. Research parameters and secondary parameter measurement methods

Parameters	Unit	Method	Analysis Tool	Location
Temperature	^{0}C	Potensiometric	Thermometer	*In situ*
Degree of acidity (pH)	-	Potensiometric	pH meter	*In situ*
Salinity	‰	Refraktrometric	Refractometer	*In situ*
Turbidity	NTU	APHA-2130-B	Turbidimeter	*Ex situ*
Dissolved oxygen (DO)	mg/L	Potensiometric	DO meter	*In situ*
Total dissolved solid (TDS)	mg/L	SNI 6989.27-2019	TDS Meter	*Ex situ*

3.3. Sediment organic (N-total)

Measurement of sediment organic matter content (N-total) was conducted at the Soil Fertility and Soil Nutrition Laboratory (KTNT) of Universitas Padjadjaran. The results of sediment measurements were compared with the criteria for sediment analysis results according to **Tanah (2005)** which can be seen in Table (3).

Table 3. Sediment analysis results assessment criteria **(Tanah, 2005)**

Parameter of Sediment	Percentage				
	Very Low	Low	Medium	High	Very high
N-Total (%)	<0.1	0.1-0.2	0.21-0.5	0.51-0.75	>0.75

4. Data analysis

Data analysis was conducted using a mixed methods approach. Mixed methods research, also commonly referred to as a combined methods approach, integrates both qualitative and quantitative approaches within a single study. According to **Shorten and Smith (2017)**, mixed methods research leverages the potential strengths of both qualitative and quantitative approaches, allowing researchers to explore perspectives more broadly and in greater depth, as well as uncover relationships among the various research questions posed. Furthermore, as stated by **Masrizal (2012)**, mixed methods were employed when researchers seek to examine both the outcomes and processes within a study, utilizing qualitative and quantitative methods to comprehensively address the research questions

4.1 Water quality data analysis

Quantitative descriptive data were obtained through observations of the physical and chemical parameters of the water, and these results were subsequently compared with secondary data from previous studies and water quality standards. The standards referenced include those specified in the Minister of Marine Affairs and Fisheries Decree No. 28 of 2004 on General Guidelines for Shrimp Farming in Ponds (2004) for outlet water, and the Water Quality Standards in Government Regulation of the Republic of Indonesia No. 22 of 2021 for seawater quality.

To compare the water quality analysis results across each station and the control station, a two-way ANOVA test was applied. According to **Hendri (2022)**, ANOVA was used to compare unpaired means across more than two groups on a normally distributed continuous variable. Following ANOVA, a Duncan's multiple range test (DMRT) was conducted as a post-hoc analysis **(Bewick *et al.*, 2004)**. DMRT is a statistical method used to compare means across more than two groups and to identify which groups exhibit significant differences following the ANOVA test.

RESULTS

1. Vannamei shrimp cultivation waste (*L. vannamei*)

This research conducted *in situ* and *ex situ* water quality tests, comparing the outlet water quality to the Minister of Maritime Affairs and Fisheries Regulation No. 28 of 2004 on General Guidelines for Shrimp Farming and the sea water quality to the Water Quality Standards outlined in the Government Regulation of the Republic of Indonesia No. 22 of 2021 on the Implementation of Environmental Protection and Management, with the seawater quality standards specified in Appendix VI. Furthermore, the results of the water quality tests were analyzed using two-way ANOVA and subsequent Duncan's post-hoc test. The results of water quality measurements are shown in Table (4).

Table 4. Average readings and standard deviations of water quality parameters at 5 stations in the Pangandaran Coastal Area at significant level of 0.05

No.	Parameter	Unit	Location	Station					Quality
				1	2	3	4	5	Standard
1.	BOD	mg/L	Outlet	1.50±0.78^{ab}	9.51± 2.81^{ab}	38.88± 30.28^{b}	34.10± 23.14^{ab}	-	<45 [1]
		mg/L	Seawater	5.72±0.40^{c}	4.70±0.70^{bc}	4.84±0.57^{bc}	3.49±0.63 ^{a}	4.47 ±0.98^{ab}	20 [2]
2.	TSS	mg/L	Outlet	254±68^{b}	133±7^{a}	144±12^{a}	280±81 ^{b}	-	≤ 200 [1]
		mg/L	Seawater	107±32^{a}	185±48^{b}	195±37^{b}	136±6^{ab}	121±12^{a}	20 [2]
3.	NH_3	mg/L	Outlet	2.69±0.10 ^{b}	0.92±0.56 ^{a}	0.77±0.08 ^{a}	2.77±1.78 ^{b}	-	< 2.5 [1]
		mg/L	Seawater	0.52±0.02 ^{b}	0.30±0.23 ^{a}	1.14±0.16 ^{c}	0.10±0.11 ^{a}	0.06±0.01 ^{a}	70.3 [2]
4.	NO_3	mg/L	Outlet	0.74±0.23 ^{a}	0.83±0.56 ^{a}	3.03±1.99 ^{b}	0.64±0.07 ^{a}	-	< 0.1 [1]
		mg/L	Seawater	0.78±0.43 ^{a}	0.92±0.45 ^{a}	0.44±0.18 ^{a}	0.55±0.42 ^{a}	0.69±0.55 ^{a}	0.06 [2]
5.	PO_4	mg/L	Outlet	0.38±0.02 ^{b}	0.16±0.02 ^{a}	0.52±0.37 ^{a}	0.73±0.33 ^{a}	-	< 0.1[1]
		mg/L	Seawater	0.27±0.02 ^{b}	0.04±0.02 ^{a}	0.07±0.02 ^{a}	0.10±0.10 ^{a}	0.05±0.01 ^{a}	0.015 [2]
6.	Temperature	^{o}C	Outlet	28.90±1.24 ^{a}	30.08±0.89 ^{ab}	31.13±1.92^{b}	30.30±0.79^{ab}	-	-
		^{o}C	Seawater	30.03±0.78 ^{a}	31.48±1.54 ^{ab}	31.95±1.14^{b}	31.78±0.65^{ab}	29.43±0.58^{ab}	28-30 [2]
7.	pH	-	Outlet	6.72±0.21^{a}	6.71±0.14^{a}	6.63±0.29^{a}	6.77 ±0.19^{a}	-	6-9 [1]
		-	Seawater	7.60±0.25 ^{b}	7.40±0.35 ^{b}	7.44±0.34 ^{b}	6.60±0.22 ^{a}	7.44±0.11 ^{b}	7 - 8.5[2]
8.	Salinity	‰	Outlet	27.0±0.71^{b}	31.80±2.33 ^{c}	22.25±0.83^{a}	31.50±4.39^{c}	-	-
		‰	Seawater	37.0±2.55 ^{a}	32.75±1.48 ^{a}	36.25±1.48^{a}	32.75±0.83^{a}	35.75±0.83^{b}	33-34 [2]
9.	Turbidity	NTU	Outlet	39.50±1.52 ^{c}	21.12±1.88^{b}	22.26 ±0.96^{a}	6.96±5.36 ^{c}	-	≤ 50 [1]
		NTU	Seawater	28.3±1.66 ^{b}	5.46±2.51 ^{a}	8.85±0.69 ^{a}	7.57±0.66 ^{a}	4.73±1.67 ^{a}	5 [2]
10.	DO	mg/L	Outlet	7.01±0.53^{a}	7.50±0.16 ^{a}	7.32±0.36 ^{a}	8.440.17^{b}	-	-
		mg/L	Seawater	7.65±0.47^{a}	7.44±0.46 ^{a}	7.58±0.33 ^{a}	7.72±0.15 ^{a}	7.49±0.28^{a}	>5 [2]
11.	TDS	mg/L	Outlet	6,043±464 ^{a}	8,699±106 ^{b}	8,508±494 ^{b}	8,250 ±1427^{b}	-	-
		mg/L	Seawater	7,578±332 ^{a}	8,078±64^{ab}	8,234±183^{b}	9,103±504^{c}	8,871±210^{c}	-

[1] Decree of the Minister of Maritime Affairs and Fisheries Number 28 of 2004

[2] Government Regulation of the Republic of Indonesia Number 22 of 2021

($P<0.05$); a, b, c means with different letters (superscripts) in the same row are significantly different ($P<0.05$).

1.1 Primary parameters

Biochemical oxygen demand (BOD)

Based on the results of the measurements conducted at each research station, the average biochemical oxygen demand (BOD) values at the outlets of the four shrimp farms ranged from 9.51 to 38.88mg/ L. According to Table (1), the lowest outlet BOD value was recorded at station 2 (9.51 ± 2.81mg/ L), while the highest was at station 4 (34.10mg/ L). The BOD concentrations at outlet station 3 (38.88mg/ L) and station 4 (34.10mg/ L) were higher compared to station 1 (1.50mg/ L) and station 2 (9.51mg/ L), but the differences were not statistically significant (ANOVA, $P > 0.05$). The BOD value measured at each research station remained within the permissible effluent quality standard from Minister of Marine Affairs and Fisheries Regulation No. 28 of 2004, which is set at less than 45mg/ L.

Based on the results in Table (4), the lowest BOD in the seawater was recorded at station 4, with a value of 3.49 ± 0.63mg/ L, while the highest BOD in the seawater was found at station 2, measuring 5.72 ± 0.40mg/ L. Moreover, the BOD levels at seawater station 1 (5.72mg/ L) and station 3 (4.84mg/ L) were significantly higher compared to station 4 (3.49mg/ L) and station 5 (4.47mg/ L), showed significant spatial variation across the sampling stations at seawater (ANOVA, $P < 0.05$). The BOD concentrations across the five research stations are classified as normal or below the water quality standards for marine biota by the Government Regulation of the Republic of Indonesia No. 22 of 2021, with a maximum permissible value of 20mg/ L.

Total suspended solid (TSS)

Based on the results of measurements conducted *in situ* at each research station, the average TSS value at the outlet of the 4 pond stations has an interval of 133 - 280mg/ L. Furthermore, the average TSS value at sea from the 5 stations has an interval of 107 - 195mg/ L. The average TSS value at the pond outlet and sea can be seen in Table (1). The TSS concentrations at outlet station 4 (280.25mg/ L) and station 1 (254mg/ L) were significantly higher compared to station 2 (133mg/ L), and station 3 (144mg/ L), showed significant spatial variation across the sampling stations (ANOVA, $P < 0.05$). According to the Minister of Marine Affairs and Fisheries Regulation No. 28 of 2004 regarding the General Guidelines for Shrimp Cultivation in Ponds, the average TSS for shrimp pond waste (effluents) should be ≤ 200mg/ L. Only stations 2 and 3 met the quality standards, while stations 1 and 4 were on the threshold limit for shrimp farm effluents.

According to the results presented in Table (4), the lowest TSS in seawater was recorded at station 5 (control) at 121 ± 12mg/ L, while the highest TSS in seawater was observed at station 4 at 195 ± 37mg/ L. The TSS concentration at seawater station 3 (195 mg/L) and station 2 (185mg/ L) were significantly higher compared to station 4 (136mg/ L), station 5 (121mg/ L), and station 1 (107mg/ L), showing significant spatial variation across the sampling stations (ANOVA, $P < 0.05$). According to the Government Regulation of the Republic of Indonesia No. 22 of 2021, the water quality standards for marine life have been established, and based on these standards, the TSS valued at each station in this study did not meet the quality standards for marine biota.

Total ammonia (NH_3)

Based on the measurements conducted at each research station, the average total ammonia values at the outlets of the four shrimp farm stations ranged from 0.77 to 2.77mg/ L. The ammonia levels at station 4 (2.77mg/ L) and station 3 (2.70mg/ L) were significantly higher compared to station 2 (0.92mg/ L), station 5 (0.05mg/ L), and station 1 (0.77mg/ L), indicating significant spatial variation across the sampling stations (ANOVA, $P < 0.05$). Based on effluent standards for shrimp farms, only stations 2 and 3 were below the effluent quality threshold set by the Ministry of Marine Affairs and Fisheries Decree Number 28 of 2004, which specifies a maximum effluent ammonia concentration of <2.5mg/ L.

As shown in Table (4), the lowest average ammonia concentration in seawater was found at station 5 (control), with a total ammonia concentration of 0.06 ± 0.01mg/ L, while the highest was at station 3, with a concentration of 1.14 ± 0.16mg/ L. The ammonia concentration at seawater station 3 (1.14mg/ L) and station 1 (0.52mg/ L) were significantly higher compared to station 2 (0.30mg/ L), station 4 (0.10mg/ L), and station 5 (0.6mg/ L), indicating significant spatial variation across the sampling stations (ANOVA, $P < 0.05$). However, stations 1 and 3, with ammonia concentrations of 0.52 ± 0.02mg/ L and 1.14 ± 0.16mg/ L, respectively, exceeded the threshold stipulated by Government Regulation Number 22 of 2021, which sets the marine water quality standard for biota at 0.3mg/ L.

Nitrate (NO_3)

Based on *ex situ* measurements conducted at each research station, the average nitrate values at the outlet of the four shrimp pond stations ranged from 0.64 to 3.803mg/ L. The nitrate outlet concentration outlet at station 1 (0.74mg/ L), ST.2 (0.83mg/ L) and ST.4 (0.64mg/ L) were higher compared to and ST.3 (3.03mg/ L), showing no significant spatial variation across the sampling stations (ANOVA, $P > 0.05$). Nitrate concentrations at all four pond outlets surpassed the effluent quality standard for shrimp ponds, as outlined in the Minister of Marine Affairs and Fisheries Decree No. 28 of 2004, which established a nitrate limit of less than 0.1mg/ L. Notably, only Station 3 exhibited a significantly elevated nitrate concentration exceeding 1mg/ L, reaching 3.03mg/ L

As shown in Table (4), the lowest average nitrate concentration in the coastal waters was observed at Station 3, with a concentration of 0.44 ± 0.18mg/ L, while the highest nitrate concentration was found at Station 2, with a concentration of 0.92 ±

0.45mg/ L. The nitrate concentration seawater at stations 2 (0.92mg/ L) and 1 (0.78mg/ L) were higher compared to stations 5 (0.69mg/ L), 4 (0.55mg/ L), and 3 (0.44mg/ L), showing no significant spatial variation across the sampling stations (ANOVA, $P > 0.05$). Nitrate concentration across all five stations exceeded the permissible standard for seawater quality set by Government Regulation No. 22 of 2021 for marine biota, which stipulates a nitrate concentration limit of 0.06mg/ L.

Phosphate (PO_4)

Based on the results of measurements conducted *ex situ* at each research station, the average phosphate value at the pond outlet from the 4 pond stations has an interval of 0.16 - 0.73mg/ L. The phosphate value outlet at Station 4 (0.73mg/ L) and Station 3 (0.52mg/ L) were significantly higher compared to Station 1 (0.38mg/ L) and Station 2 (0.16mg/ L), showing significant spatial variation across the sampling stations (ANOVA, $P < 0.05$).

According to Table (4), the lowest average phosphate concentration in the seawater was found at Station 2, with a value of 0.04 ± 0.02mg/ L, while the highest concentration was observed at Station 1, measuring 0.27 ± 0.02mg/ L. The phosphate levels at Station 1 (0.27mg/ L) were significantly higher compared to Station 4 (0.10mg/ L), Station 3 (0.07mg/ L), Station 5 (0.05mg/ L), and Station 2 (0.04mg/ L), showing significant spatial variation across the sampling stations (ANOVA, $P < 0.05$). Referring to the phosphate measurements, all observed stations exceed the regulatory threshold established by Government Regulation Number 22 of 2021 on Marine Water Quality Standards for Marine Biota, which sets a maximum phosphate concentration of 0.015mg/ L.

1.2 Secondary parameters

Temperature

Based on the results of measurements conducted at each research station, the average temperature at the outlet of the 4 pond stations had an interval of 28.90 – 31.13^{o}C. The temperature levels outlet at Station 1 (28.90 ± 1.24°C) and Station 3 (31.13 ±1.92°C) were significantly higher compared to station 2 (30.08 ± 0.89°C) and station 4 (30.30 ± 0.79°C), showing significant spatial variation across the sampling stations (ANOVA, $P < 0.05$). The temperatures recorded at all four aquaculture outlet stations remain within the safe threshold for the vannamei shrimp cultivation. This is further supported by SNI 01-7246-2006, which stipulates that the optimal water quality for the vannamei shrimp rearing, with respect to temperature, is in the range of 28.5-31.5°C.

As presented in Table (4), the lowest average sea temperature was recorded at Station 5, measuring 29.43 ± 0.58°C, while the highest was at Station 3, at 31.95 ±

1.14°C. The temperature levels at Station 3 (31.95±1.14°C) and Station 4 (31.775°C) were significantly higher compared to Station 2 (31.475°C), Station 1 (30.025°C), and Station 5 (29.425°C), showing significant spatial variation across the sampling stations (ANOVA, $P < 0.05$). According to Indonesian Government Regulation No. 22 of 2021 on Water Quality Standards, Stations 1 and 5 remain within the acceptable temperature range conducive to the metabolic needs of marine biota and coastal ecosystems, such as coral reefs and seagrasses.

Degree of acidity (pH)

Based on the results of measurements conducted *in situ* at each research station, the average pH value at the outlet of the 4 pond stations has an interval of 6.63 - 6.77. The pH concentration at outlet Station 1 (6.71), Station 2 (6.72), Station 3 (6.63), and Station 4 (6.77) were not significantly different across the sampling stations (ANOVA, $P > 0.05$). The average pH values recorded at each observation station remain within the regulatory limits set by the Indonesian Minister of Marine Affairs and Fisheries Decree No. 28 of 2004, which specifies a pH range of 6–9 for shrimp pond effluent. This indicates that the discharged effluent was within safe limits for release into the environment.

According to the results in Table (4), the lowest pH level in seawater was recorded at Station 4, with a pH of 6.60 ± 0.22, while the highest pH level was observed at Station 5 (control), at 7.60 ± 0.25. The pH concentration at Station 4 (6.5975), Station 2 (7.3975), Station 1 (7.4350), Station 3 (7.4425), and Station 5 (7.5950) did not show significant spatial variation across the sampling stations (ANOVA, $P > 0.05$). Among the five research stations, only Station 4 exceeds the seawater quality standards for marine biota, as stipulated in Government Regulation No. 22 of 2021, which requires a pH range of 7–8.5; Station 4's pH of 6.60 is below this threshold.

Salinity

Based on the results of measurements conducted at each research station, the average salinity at the outlet of the 4 pond stations has an interval of 27.0 - 31.80‰. The salinity levels at the outlet of Station 1 (27.00mg/ L) and Station 3 (22.25mg/ L) were significantly lower compared to Station 4 (31.50mg/ L) and Station 2 (31.80mg/ L), showed significant spatial variation across the sampling stations (ANOVA, $P < 0.05$).

Referring to Table (4), the lowest average salinity measurement in seawater was recorded at Station 2 (32.75 ± 1.48‰) and Station 4 (32.75 ± 0.83‰), while the highest average salinity was observed at Station 1, with a range of 37.0 ± 2.55‰. The salinity levels at Station 1 (37.00mg/ L) and Station 3 (36.25mg/ L) were significantly higher compared to Station 5 (35.75mg/ L), Station 2 (32.75mg/ L), and Station 4 (32.75mg/ L), showing significant spatial variation across the sampling stations (ANOVA, $P < 0.05$).

According to the Indonesian Government Regulation No. 22 of 2021 on Water Quality Standards, stations 2 and 4 fall within normal limits and are conducive to the metabolic needs of marine organisms and coastal ecosystems, such as coral reefs and seagrass. Measurements at stations 1, 3, and 5 (control) are also within normal limits for marine metabolism requirements.

Turbidity

Based on the results of the analysis at each research station, the average turbidity at the outlet of the 4 pond stations had an interval of 6.96–39.50 NTU. Based on the turbidity valued obtained from each shrimp farming station, the turbidity concentration at all four stations still meet the quality standards set forth in the Minister of Marine Affairs and Fisheries Decree No. 28 of 2004, which specifies a turbidity limit of ≤ 50 NTU. The turbidity levels at the outlet of the vannamei shrimp ponds exhibited significant spatial variations among the sampling station. Station 1 (21.12 NTU) and Station 2 (39.50 NTU) demonstrated significantly higher turbidity levels compared to Station 3 (22.26 NTU) and station 4 (6.96 NTU), indicating differences in sediment dispersion across the stations (ANOVA, $P< 0.05$).

Based on the results presented in Table (4), the lowest turbidity was recorded at Station 5 (control), measured 4.73 ± 1.67 NTU, while the highest turbidity was observed at Station 1, measuring 28.33 ± 1.66 NTU. For the surrounding seawater, turbidity concentration varied significantly across all sampling stations. Station 2 (5.46 NTU) and Station 5 (8.85 NTU) exhibited the lowest values, while Station 3 (8.85 NTU) and Station 1 (28.33 NTU) showed an elevated turbidity concentration; Station 4 recorded the highest turbidity valued (7.57 NTU), highlighting notable differences among the stations (ANOVA, $P< 0.05$). The results indicate that only Station 5 (control) has the lowest turbidity value, which complies with the quality standards outlined in Government Regulation No. 22 of 2021, specifying a turbidity limit of below 5 NTU for marine biota.

Dissolved oxygen (DO)

Based on the results presented in Table (4), the lowest dissolved oxygen (DO) value at the outlet was recorded at Station 1, with a DO valued of 7.01 ± 0.53mg/ L, while the highest DO value was found at Station 4, measuring 8.44 ± 0.17mg/ L. The DO levels at Station 1 (7.01mg/ L), Station 3 (7.32mg/ L), and Station 4 (8.44mg/ L) showed significant spatial variation across the sampling stations (ANOVA, $P < 0.05$). There were no specific quality standards for the effluent from shrimp ponds regarding the DO parameter.

According to the results presented in Table (4), the lowest DO value in the seawater was recorded at Station 2, measuring 7.44 ± 0.46mg/ L, while the highest DO value was observed at Station 4, at 7.72 ± 0.15mg/ L. The DO concentration at Station 2 (7.4350mg/ L), Station 5 (7.49mg/ L), Station 3 (7.49mg/ L), Station 1 (7.65mg/ L), and

Station 4 (7.72mg/ L) did not show significant spatial variation across the sampling stations (ANOVA, $P > 0.05$). The DO valued at all stations met the quality standards outlined in Government Regulation Number 22 of 2021, which states that the standard for dissolved oxygen in seawater for marine biota must exceed 5mg/ L.

Total dissolved solid (TDS)

Based on the results of measurements at each research station, the average TDS value at the outlet of the 4 pond stations has an interval of 6043 - 8699mg/ L. Based on the results presented in Table (4), the lowest total dissolved solids (TDS) at the outlet were recorded at Station 1, with a value of 6,043 ± 464mg/ L, while the highest TDS was observed at Station 2, with a value of 8,699 ± 106mg/ L. The TDS levels at the outlet of the vannamei shrimp ponds showed significant spatial variations among the sampling stations. Station 1 (6,042mg/ L) had the lowest TDS levels, while Station 3 (8,520mg/ L) and Station 4 (8,250mg/ L) exhibited higher values. The TDS values at Station 2 (8,699mg/ L) and Station 3 remained comparable, indicating differences in spatial patterns across the stations (ANOVA, $P < 0.05$).

Referring to the results presented in Table (4), the lowest TDS in seawater was found at Station 1, measuring 7,578 ± 332 NTU, while the highest TDS was recorded at Station 4, with a value of 9,103 ± 504 NTU. Station 5 (control) had a TDS value of 8,871 ± 210 NTU, which is higher than those at stations 1, 2, and 3. The TDS value at Station 5 (control) is considerably elevated compared to the other stations with shrimp farms. For the surrounding seawater, TDS levels were significantly different among all sampling stations. Station 1 (7,578mg/ L) and Station 3 (8,234mg/ L) demonstrated higher TDS valued compared to Station 4 (8,250mg/ L) and Station 2 (8,078mg/ L). However, Station 5 exhibited the highest levels (8,871mg/ L), showed a notable increase relative to other stations (ANOVA, $P < 0.05$).

2. Sediment organic matter analysis (N-total)

The results of the analysis of total nitrogen content that has been carried out at the station that has the highest total nitrogen content is at Station 1 at 1.68% and the lowest nitrogen content is at Station 3 at 0.04%. The results of the measurement of the analysis of total organic nitrogen content can be seen in Table (5).

Table 5. Average readings and standard deviations of water quality parameters at 5 stations in the Pangandaran Coastal Area at significant level 0.05

Station	Result (%)	Criteria*
1	1,68	Very high
2	0,07	Low
3	0,04	Low
4	1,36	Very high
5 (control)	0,05	Low

* **Tanah (2005)**

3. The Impact of waste on turtle landing and nesting

The results of waste analysis show that in the main parameters, several stations exceed the established quality standard threshold. The excess nutrients can have an impact on turtle landings and nesting. The results of waste measurements that exceed quality standards and have the potential to affect sea turtle landing and nesting activities can be seen in Table (6).

Table 6. Waste measurement results exceeding quality standards

No.	Parameters	Unit	Station					Previous research		Quality standards
			1	2	3	4	5	(Nursyam 2017)	(Kurnia 2023)	PP No. 22 Tahun 2021
Primary Parameter										
1.	BOD	mg/L	✓	✓	✓	✓	✓	2.76	-	20
2.	TSS	mg/L	x	✓	✓	x	✓	-	-	20
3.	NH_3	mg/L	x	✓	x	✓	✓	0.18	-	0.30
4.	NO_3	mg/L	x	x	x	x	x	0.001	-	0.06
5.	PO_4	mg/L	x	x	x	x	x	0.362	-	0.015
Secondary Parameter										
1.	Temperature	ºC	x	x	x	x	x	26.2	28	28-30
2.	pH	-	✓	✓	✓	x	✓	6.5	7.0	7-8.5
3.	Salinity	‰	x	✓	x	✓	x	26.17	34	33-34
4.	Turbidity	NTU	x	x	✓	✓	x	-	12.45	5
5.	DO	mg/L	✓	✓	✓	✓	✓	3.22	5.2	>5
6.	TDS	mg/L	✓	✓	✓	✓	✓	-	-	20

Description: x= exceeds the quality standard threshold
✓= below the standard quality threshold/does not exceed

The following is data on sea turtle deaths at Legok Jawa Beach from Cinta Bahari Group, Legok Jawa (Table 7).

Table 7. Total amount of dead sea turtle at the Legok Jawa Beach

No	Landing date	Sea turtle species	Total
1.	24 June 2024	Green Sea Turtle	1
2.	2 July 2024	Leatherback Sea Turtle	1
3.	July 2024	Green Sea Turtle	1
4.	July 2024	Green Sea Turtle	1
5.	August 2024	Green Sea Turtle	1
6.	September 2024	Green Sea Turtle	1

Source: Cinta Bahari Group, Legok Jawa

Based on the data obtained from the Cinta Bahari group, as shown in Table (7), six sea turtles were found deceased along the Legok Jawa coast. The decline in the number of sea turtle landings was suspected to be due to the influx of shrimp farm waste entering the waters. The species of sea turtles that were found dead at Legok Jawa include the green sea turtle and the leatherback sea turtle.

DISCUSSION

Research on the impact of shrimp farm waste on sea turtle landing and nesting habitats serves as supporting data that can be utilized by various stakeholders to improve aquaculture systems, particularly those located within conservation areas, to ensure that economic activities align with conservation efforts. According to **Vanto (2016)**, shrimp pond waste contains nitrogen (N) and phosphate (P) compounds originating from feed which will be discharged into the aquatic environment.

The high nitrogen content observed at stations 1 and 4 is likely due to untreated waste from aquaculture ponds. At Station 1, the unmanaged outlet channel accumulates feed residues and feces, forming sediment at the channel bed. Similarly, intensive aquaculture at Station 4 increases feed input, contributing to feed and fecal residues at the pond outlet. These residues from the vannamei shrimp feed and waste accumulate as sediment at the base of the wastewater outlet channel (IPAL). These findings align with **Chávez-Mejía *et al.* (2019)**, who noted that accumulated feed and fecal residues contribute to sediment formation, impacting sedimentation and increasing the concentration of organic matter in water.

The primary parameters that exceed the quality standards include total suspended solids (TSS), ammonia (NH_3), nitrate (NO_3), and phosphate (PO_4), especially at Station 1. Stations 2 and 3, which were designated as the core sea turtle conservation zones, exhibit elevated levels in several key parameters, specifically ammonia, nitrate, and phosphate. High ammonia levels can adversely affect sea turtle mortality rates. This finding aligns with **Laras (2016)** and **Xiao *et al.* (2019)**, who stated that NH_3 originates from the decomposition of proteins from leftover feed or dead plankton. If it accumulates without proper circulation, it can lead to increased mortality rates.

In a study conducted by **Nursyam (2017)**, at both the landing and release sites of adult sea turtles, the obtained values were as follows: biochemical oxygen demand (BOD) of 2.76mg/ L, ammonia at 0.18mg/ L, nitrate at 0.001mg/ L, and phosphate at 0.362mg/ L. In this case, the ammonia and nitrate levels fell within the acceptable quality standards, whereas phosphate levels exceeded the established limits.

Secondary parameters such as temperature, salinity, and turbidity in this study were found to exceed the quality thresholds set forth. According to research by **Kurnia (2023)**, measurements of water quality at Batu Hiu Beach during sea turtle landings indicated that the parameters of temperature, salinity, pH, and dissolved oxygen (DO) met the necessary conditions for turtle landings. However, the turbidity parameter did not comply with the quality standards established in Government Regulation No. 22 of 2021.

The impact of shrimp farming activities is the environmental pollution caused by unmanaged waste. This waste affects coastal habitats as well as aquatic ecosystems, such as coral reef ecosystems. Coral reefs serve as habitats for various reef fish and other biota, including lobsters **(Sadili *et al.*, 2015)**. Lobster (homarid) habitats are typically found in coastal waters that contain rocks and coral reefs. In addition to acting as a barrier against waves, coral reefs provide feeding grounds and shelter from predators **(Verianta *et al.*, 2016)**.

CONCLUSION

The shrimp farm waste discharged into the environment, with parameters such as TSS, NH_3, NO_3, and PO_4, has not met the established quality standards, as it exceeds the allowable thresholds. This condition has contributed to the decline in turtle landing and nesting activities, primarily due to the poor management of shrimp farm waste.

ACKNOWLEDGMENT

This research was supported by Universitas Padjadjaran (Padjadjaran University Lecturer Competency Research) Funded Research Project 2024. Thanks are extended to all stakeholders such as government agencies, shrimp farmers, NGOs especially Raksa Bintana Foundation and Cinta Bahari group, fishermen, on the coast of Pangandaran who have provided the opportunity to take water and sediment for sampling, as well as to researchers for their cooperation in the field and in the laboratory.

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