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Threats of Industrial Estates and Anthropogenic Activities on Seagrass Ecosystems in Lima Island, Serang, Banten

Wezia Berkademi [a] , Kosuke Mizuno [a,b,*], TEB Soesilo [a]

[a] School of Environmental Science, University of Indonesia, Salemba, 10430 Jakarta, Indonesia
[b] Kyoto Universities, Sakyo-ku, Kyoto 606-8501, Japan
Corresponding author: [*]kosuke.mizuno@ui.ac.id

Abstract—**Bojonegara District, having a strategic location in the coastal area of Banten Bay, is undergoing rapid industrial development. The economic activities in coastal areas simultaneously increase the ecological pressure on ecosystems and coastal resources. Ecosystem stress, directly and indirectly, disrupts organisms' life on land and in waters, causing physical, chemical, and biological changes in coastal areas of Bojonegoro District to Lima Island, causing a potential impact on socio-anthropogenic activities. This research uses a mixed qualitative and quantitative approach through observational data and literature review to estimate the economic loss that occurs if one element in the coastal area is disturbed, impacting the whole system. The water sample was collected at fifteen spots, including industrial, port, and monitoring stations along the coastal areas of Bojonegoro District to Lima Island, to assess the severity of the impacts of industrial pollution. Total economic loss is calculated using the productivity and replacement cost approach to analyze the loss value of damage on three seagrass ecosystem functions. The total loss value due to damage is estimated to be more than IDR. 950 million per year. This study finds the high economic loss is due to the low level of public knowledge and awareness, as only ≤19% of the research respondents recognize the types of ecosystem variations in coastal areas, their existence, current conditions, and utilization. This study also finds that the industry still commits environmental violations in various cases, which the stakeholders must resolve to avoid further environmental damage.**

Keywords— **Coastal management; seagrass contamination; economic loss; pollution load.**

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I. INTRODUCTION

Vast coastal areas have great economic activity potential; one of the potentials of coastal cities is for industrial development [1], [2] one of which is Bojonegara Village which has a strategic location in the coastal area of Banten Bay [3]. Under Banten Province Regional Regulation Number 5 of 2017 concerning Amendments to Banten Province Regional Regulation Number 2 of 2011 concerning Regional Spatial Planning of Banten Province Year 2010-2030, Serang Regency is destined as the Development Work Area II, which is directed at the development of government activities, education, forestry, agriculture, industry, tourism, services, trade, and mining sectors. In the directive of the spatial pattern set in the Regional Spatial Planning of Serang Regency in 2010-2030, the Bojonegara District is particularly predestined for the Local Promotional Activity Center urban system development plan. It is intended for industrial activities, settlements, and protected areas. In line with this directive, an industrial area of 358 ha has been established along 16.62 km on the coast of Banten Bay, especially in Bojonegara Village [3]. Coastal areas have high productivity and are essential in sustaining life on the sea, coast, and land [4]. However, they are also categorized as vulnerable areas [5].

According to prior research, the Banten Bay area has high-value ecosystems such as mangroves, seagrass beds, coral reefs, and endemic birds [6]. However, the waters are relatively shallow [4], with an average depth of seven meters. Coastal areas have high biodiversity potential due to their characteristics as land-sea border areas, so they are dynamically impacted by natural processes or human activities [9]. This particular characteristic can be beneficial as it will act as a nutrient trap but can be a pollutant trap if massive pollution occurs, on the other hand [10].

Economic activities in coastal areas for various activities simultaneously increase the ecological pressure on ecosystems and coastal resources. The development of the coastal area would cause its ecosystems to receive the most severe environmental stress of all existing ecosystem types [11]. Ecosystem stress will disrupt the life of organisms on land and in waters directly and indirectly [4], [9] causing physical, chemical, and biological changes [2].

The developments of industrial and residential areas around the Bojonegara District, and the intensive development of coastal infrastructure, have led to a decline in the coastal environmental function of the coastal in the waters of Banten Bay and its surroundings, as well as the erosion of the coastline due to reclamation activities [12]. The natural characteristics of rocky and sandy beaches have been modified with reclamation works to construct port infrastructure, jetties, and other coastal structures [10]. In addition, there is evidence that several industries around the area dispose of their untreated production waste in the water body.

According to the Environmental Impact Management Agency for Banten Province, Bojonegara District is the second largest contributor to industrial waste that drains its waste into Banten Bay [13]. The volume of waste discharged into the waters is 1,759,700 m3/year. This condition is also reinforced by a study indicating that the concentrations of copper (Cu) and lead (Pb) in the waters were 0.250 mg/L and 0.184 mg/L [14]. The numbers have exceeded the natural concentration in the sea that is allowed according to the Regulation of the Minister of the Environment Number 51 of 2004 concerning Seawater Quality Standards. In addition, some research findings prove that there was an increase in the lead concentration (Pb), salinity, sedimentation, copper (Cu), and zinc (Zn) around the ship port areas [15], [16].

Copper (Cu) and Lead (Pb) accumulate in the sediment through bioconcentration and bioaccumulation by marine biota. If the concentration is excessive, it can intoxicate the plants that live in aquatic sediments, such as seagrass [17]. Seagrass is one of the adaptable plants to live in waters with high salinity, so it can be utilized as an indicator plant for water pollution. Prior studies describe that the seagrass ecosystem in the waters of Banten Bay continues to decline at a moderate damage level [18], [19], [20]. Seagrass is one of the essential ecosystems in coastal areas, as its presence is vital for fishermen who do demersal fishing to their ecosystem service as a place for fish to gather and spawn.

One of the causes of the coastal damage is that these areas are considered public goods, so all stakeholders try to utilize them optimally. Coastal areas are not public goods but common pool resources that are competitive. If one party takes advantage, another party loses the opportunity to take advantage of it (Pareto Optimum). Water pollution is a form of market failure. Environmental services such as aquatic and seagrass ecosystems have not been considered economic assets, so they are not transacted in the market and do not have a market price (non-market), even though environmental services, directly and indirectly, contribute to the economy.

The ability of coastal's natural and environmental resources to provide services for water assimilation, coastal protection, nutrient supply for fish, and carbon sinks should be evaluated as environmental services that contribute to the policy-making process. Furthermore, water pollution and reduced seagrass cover are externalities: consequences that other parties receive from production activities and are not compensated for [21]. It is due to the absence of well-quantified economic values. This economic value can be the basis for environmental protection policymaking [22].

As one of the factors contributing to water pollution and damage to seagrass in Banten Bay, industry disposes of waste containing copper and lead into waters without treatment so that it pollutes water and marine biota [23]. It is considered one of the actions to reduce production costs, even though they must be internalized as part of the company's costs [24]. The absence of compensation for the impact on other stakeholders is an externality that causes market failure [14], [25].

Another cause of environmental damage in the coastal area of Banten Bay is government failure in the sectoral planning of coastal areas [26]. The local government encouraged the expansion of residential, industrial, and transportation areas through the Serang Regency Master Plan in 2005 and neglected the environmental capacity and carrying capacity [4]. The limited land availability for industrial purposes triggered reclamation activities, especially in Puloampel and Bojonegara Districts [27].

Environmental damage continues to occur, and so far, the resolution of environmental problems, especially water pollution, has only been resolved through technical and legal aspects [25]. Environmental law studies are also limited to analyzing administrative violations and criminal acts against the environment, which tend to be repressive, while the leading cause of environmental problems is human behavior. Therefore, this study aims to see the threat of industrial growth and anthropogenic activities in the coastal area of Bojonegara District on seagrass ecosystems. The study is designed within the system framework concept, defining the coastal area as an integral unit of various biological and non-biological components that are interrelated and dependent. This study is essential to determine the economic loss that arises if one component in the coastal area is disturbed, which will impact the whole system.

II. Materials and Methods

A. Research Location

The research was conducted in Bojonegara District, one of the coastal districts in Serang Regency. This location was chosen because of the massive industrial growth in this area, even though this coastal area has a relatively high diversity of coastal natural resources [8]. Bojonegara Village (Figure 1) is the largest village in Bojonegara District, which is 4.27 km2 or 13.85% of the total area of Bojonegara District. Bojonegara Village is the capital of the Bojonegara District and one of two villages located in the district's coastal area. Referring to Law Number 1 of 2014 concerning Management of Coastal Areas and Small Islands of Waters, the sea bordering the land covers waters as far as 12 (twelve) nautical miles measured from the coastline and or waters connecting the coast and islands, estuaries, bays, shallow waters, brackish marshes, and lagoons.

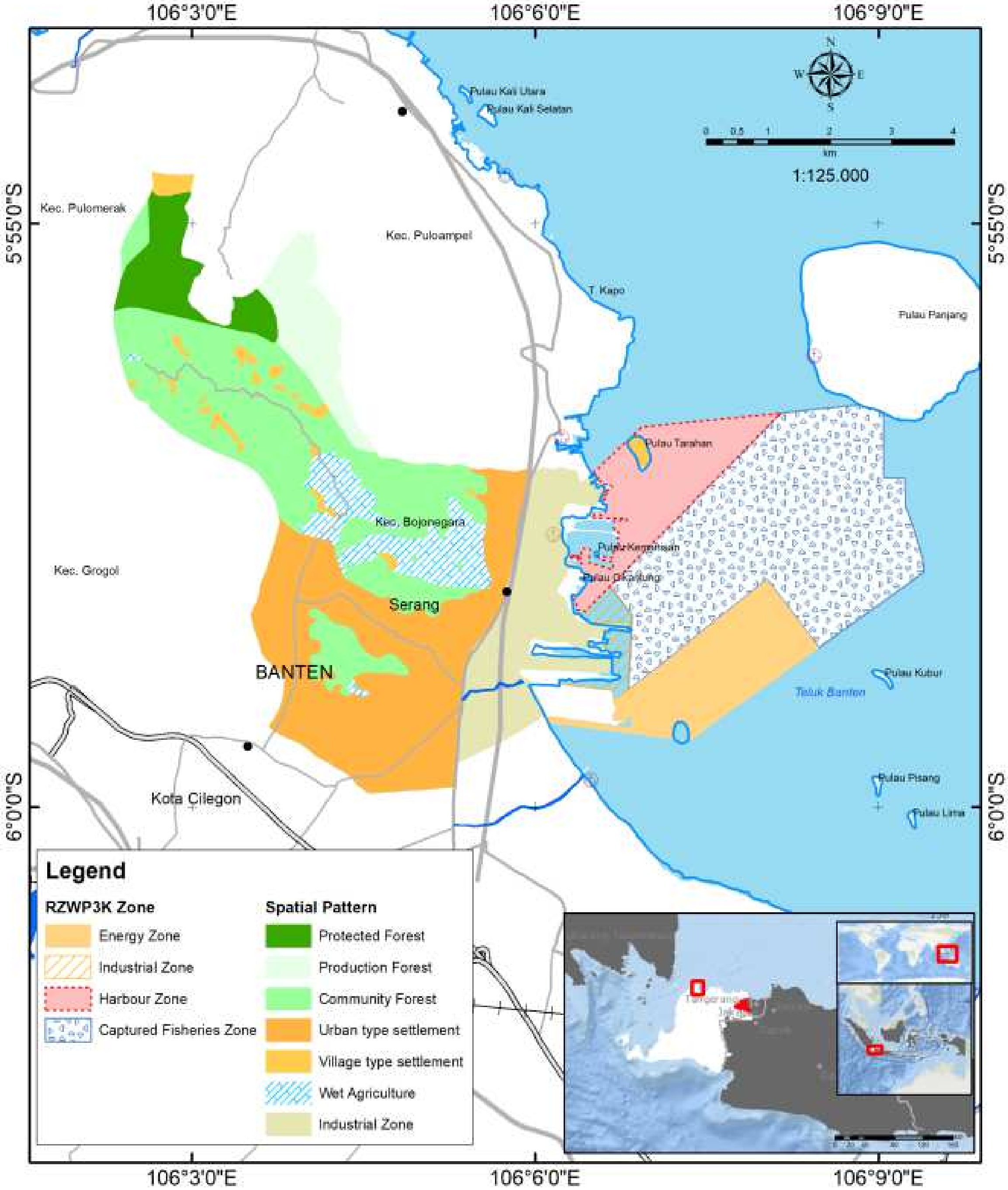

Fig. 1 Research Location

B. Research Methods

This research uses a mixed qualitative and quantitative approach to produce a conclusion from underlying theories. The facts are built from quantitative and qualitative data to test and prove the research hypothesis. The data used are observational and literature review. The research was conducted in the Coastal Area of Bojonegara District to Lima Island because, as an ecosystem unit, this area is affected by industrial activities in Bojonegara Village. Water samples were collected at fifteen industrial, port, and Lima Island monitoring stations.

Water quality analysis is carried out through laboratory tests on parameters following SNI 6964.8:2015 concerning Seawater Quality, Section 8: the method of sampling seawater tests. Seawater quality standards parameters have been determined based on their designation: port seawater, marine tourism, and marine biota in the Decree of the State Minister of the Environment Number 51 of 2004 concerning Seawater Quality Standards. There are seven parameters to determine the quality: pH, temperature, D.O., salinity, clarity, TSS, and metals, namely Copper (Cu) and Lead (Pb). Table 1 shows the tools and methods for measuring respective water quality parameters.

TABLE I
TOOLS AND METHODS TO MEASURE SEAWATER QUALITY

Parameter	Unit	Tools and Methods
Temperature	°C	Thermometer, in situ
Salinity	°/oo	Rzl17 Refractometer, in situ
Clarity	NTU	Secchi Disc, in situ
DO	ppm	Dissolve Oxygen Meter, in situ
TSS	mg/l	L/TI method
Pb	mg/l	Atomic Absorption Spectrophotometry (AAS), Laboratory analysis
Cu	mg/l	Atomic Absorption Spectrophotometry (AAS), Laboratory analysis

The analysis of the decline in the seagrass area on Lima Island from 2011 to 2021 utilizes the desk valuation method on secondary data and remote sensing results from previous studies. The data obtained from the results of laboratory tests and secondary data will be compared with the theory of ideal conditions for seagrass species to live. Furthermore, in this study, data were collected using interview techniques to calculate the value of the total economic benefits of the seagrass ecosystem. The total economic value is the sum of all economic values of the benefits of seagrass resources that have been identified and quantified. The Total Economic Value (TEV) is calculated using Equation (1) as follows:

$$TEV = DV + IV + OV + EV \quad (1)$$

TEV	Total Economic Value
DV	Direct Benefit Value
IV	Indirect Benefit Value
O.V.	Optional Benefit Value
E.V.	Existence Benefit Value

The next step is determining the economic valuation and environmental services using a productivity approach. This method describes the direct benefits of changes in fishery production due to damage to seagrass ecosystems in the waters of Bojonegara District by comparing the production value before and after the damage. The change in productivity is formulated as follows:

1) The economic value of seagrass ecosystems before the damage occurred: The economic value of the seagrass ecosystem before the damage is the direct benefit value of fishery production before the damage to the seagrass ecosystem, which is calculated using Equation (2) as follows:

$$NESK0 = [(Pi0 \times Hi) - CPi0] / L \quad (2)$$

$NESK_0$	Economic value of seagrass ecosystem before damage (IDR. /ha/year)
Pi_0	Production of commodity i before damage (Kg/year/person)
Hi	Price of commodity i (IDR. /kg)
CPi_0	Operational cost of catching commodity i before damage (IDR.)
i	Commodity type
L	Bojonegara District Coastal Area (ha)

2) The economic value of seagrass ecosystems after the damage occurred: The economic value of the seagrass ecosystem after the damage is the value of fishery production after a decline in the seagrass ecosystem which is calculated using Equation (3) as follows:

$$NESK1 = [(Pi1 \times Hi) - CPi1] / L \quad (3)$$

$NESK_1$	Economic value of seagrass ecosystem after damage (IDR. /ha/year)
Pi_1	Production of commodity i after damage (Kg/year/person)
Hi	Price of commodity i (IDR. /kg)
CPi_1	Operational cost of catching commodity i after damage (IDR.)
i	Commodity type
L	Bojonegara District Coastal Area (ha)

3) The value of seagrass ecosystem loss: The value of seagrass ecosystem loss is calculated from the comparison of the direct benefit value before and after the damage to the seagrass ecosystem, which is calculated using Equation (4) as follows:

$$KELkti = NESK0 - NESK1 \quad (4)$$

KELkti	Economic loss of seagrass ecosystems (IDR. /ha/year)
$NESK_0$	Economic value of seagrass ecosystem before damage (IDR. /ha/year)
$NESK_1$	Economic value of seagrass ecosystem after damage (IDR. /ha/year)

Furthermore, to measure indirect benefits from ecosystem damage through replacement costs is as follows:

4) The seagrass ecosystem as fish spawning grounds: The value of the seagrass ecosystem as a spawning ground for fish is calculated through a pond construction approach. The cost of making a pond reflects the value of fish spawning sites as a substitute for the function of the seagrass ecosystem. The replacement cost formulation for this approach refers to prior study [35], research as shown in Equation (5):

$$Npi = THi \times KBi \times Pbi \quad (5)$$

Npi	Economic value of seagrass ecosystem as fish spawning grounds (IDR. /ha/year)
THi	Fish survival rate (%)
KBi	Hatchling density (individual/ha)
Pbi	Price of hatchling (IDR. /individual)

5) Seagrass ecosystem as abrasion prevention: Another indirect benefit value is abrasion prevention. The replacement cost of abrasion prevention can be calculated using a bamboo sheet pile construction approach. The replacement cost formulation for this approach refers to prior study [32] esearch as shown in Equation (6):

$$Npx = (Cpi \times Pt) / DTi \quad (6)$$

Npx	Economic value of seagrass ecosystem as abrasion prevention (IDR. /year)
Cpi	Cost of bamboo sheet pile construction (IDR. /m)
Pt	Length of sheet pile to prevent abrasion (m)
DTi	Bamboo sheet pile durability (year)

The total value of economic loss from damage to seagrass ecosystems is calculated through Equation (7), which is obtained from the value of economic losses due to a decrease in fishery production and ecosystem function as a fish spawning ground and abrasion prevention, which are formulated as follows:

$$TNKEL = KELkti + Npi + Npx \tag{7}$$

TNKEL	The total value of economic loss from seagrass ecosystems damage (IDR. /year)
KELkti	The economic loss of seagrass ecosystems (IDR. /year)
Npi	The economic value of seagrass ecosystem as fish spawning grounds (IDR. /year)
Npx	The economic value of seagrass ecosystem as abrasion prevention (IDR. /year)

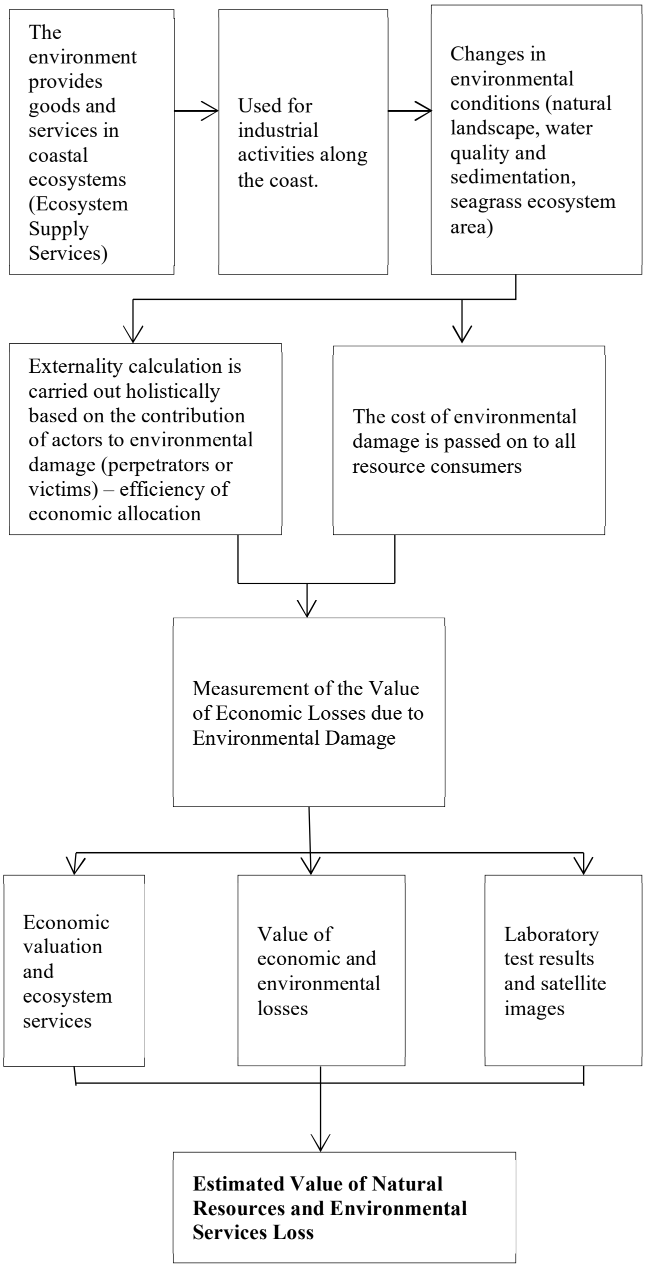

Fig. 2 Research Framework

The steps taken to obtain the value of economic losses from industrial development activities and anthropogenic activities in the coastal area of Bojonegara begin with the background of this research to identify the available natural resources and the actors of each activity, then determine the boundaries of the coastal area following applicable regulations, then determine the functions and roles resources, especially seagrass as the basis for calculating the value of economic losses. After that, it studies the literature, identifies problems that this research needs to be carried out, and prepares tools and materials. The next step is surveying water samples and distributing questionnaires. The explanation of the research flow diagram can be seen in Fig. 2.

III. Result and Discussion

A. Result

Seagrass plants, commonly called seagrass, live and grow below the surface of the shallow sea [34]. The location of the seagrass ecosystem that is closest to Bojonegara Village and has become a fishing ground for fishermen is Lima Island. The dominant seagrass species found on Lima Island are *Thalassia hemprichii* and *Enhalus acoroides* due to the nature of the sandy substrate and is ideal for both species. The types of seagrasses and their habitats on Lima Island are explained in Table 2

TABLE II
SEAGRASS SPECIES ON LIMA ISLAND

Species	Habitat	Location
Thalassia hemprichii	Often found on sandy substrates, it mainly grows with other types and can grow to a depth of 25 meters.	Coastal around Lima Island
Enhalus acoroides	Grows on muddy substrates and turbid waters, it can form a single species or even dominate the seagrass community.	

The analysis results confirmed that from 2008 to 2018, there was a significant decrease in seagrass areas in Bojonegara District's coastal area. It is known that seagrass ecosystems on the coast of Bojonegara District in 2011 were 15 ha scattered along the coast on sloping land, mud/sand plains, and close to mangrove ecosystems and coral reef ecosystems located in two villages, namely Bojonegara and Margagiri Villages. However, in 2018 the seagrass beds in Bojonegoro District were less than 1 Ha, which means a reduction of up to 14 Ha occurred in only five years. Seagrass beds in Bojonegara District are located on sloping land. The decrease in the seagrass area in detail is shown in Fig. 3.

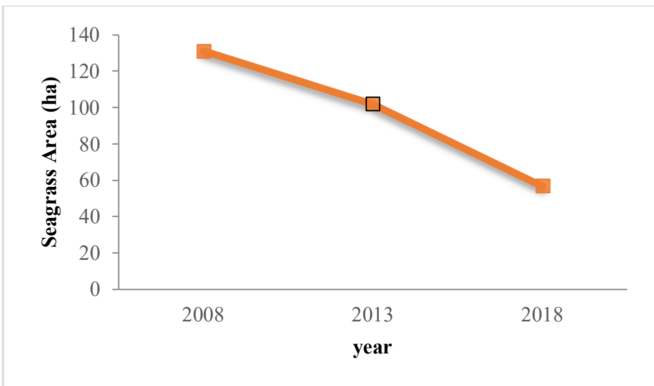

Fig. 3 Decrease in Seagrass Area in Banten Bay [7]

Furthermore, seawater sampling was also carried out to monitor the quality of the environment around the coastal area of Bojonegara Village. The results of laboratory tests at 15 sampling locations indicated that the water temperature was within normal limits, namely in the range of 27 to 290C, and did not differ from the temperature of other tropical waters. Salinity ranges from 27 to 28.2 ppm, with the clarity level in the Banten Bay waters area, especially in Bojonegara, being 1.5 NTU to 5 NTU. It is known from the laboratory test results that the copper and lead concentration in the waters is still below the quality standard set by the government, which is less than 0.0002 mg/l. In February 2021, the water quality of Banten Bay is in good condition. However, the TSS parameter at stations 1 and 8 had a TSS concentration greater than 30 m/l. It is known that these two stations are located on the coast of Lima Island. This value exceeds the optimal conditions for the seagrass ecosystem to live, measured at 20 mg/l [33]. The seawater quality monitoring results are shown in Table 3.

TABLE III
RESULT OF SEAWATER QUALITY MONITORING

Sampling Point	Clarity (NTU)	Temperature (^{0}C)	Salinity (ppm)	DO (ppm)	TSS (mg/l)	Pb (mg/l)	Cu (mg/l)
1	1.5	28.3	27.8	6.48	30	<0.003	<0.006
2	4	28.3	27.7	6.61	19	<0.003	<0.006
3	2	28.6	28.0	6.4	17	<0.003	<0.006
4	4	28.5	27.4	6.72	18	<0.003	<0.006
5	3	28.2	27.7	7.04	17	<0.003	<0.006
6	4	28.4	27.6	7.32	19	<0.003	<0.006
7	3	28.2	27.6	6.9	9	<0.003	<0.006
8	1.5	28.8	27.9	6.6	33	<0.003	<0.006
9	3	29.0	28.0	6.17	9	<0.003	<0.006
10	4	28.1	27.7	6	18	<0.003	<0.006
11	5	28.6	27.6	7.84	8	<0.003	<0.006
12	5	28.1	27.6	7.38	3	<0.003	<0.006
13	4	28.1	27.9	7.21	8	<0.003	<0.006
14	3	29.6	28.4	6.36	8	<0.003	<0.006
15	2	29.2	28.2	6.5	3	<0.003	<0.006
Quality Standards for Marine Biota	>3	28-30	33-34	>5	20	0.008	0.008

B. Discussion

The threat to changes in environmental quality in the coastal area of Bojonegara Village is mainly caused by changes in the landscape on the mainland that developed the expansion of the coastal area to land through reclamation activities. The occurrence is driven by regional planning based on the Serang Regency Regional Regulation Number 10 of 2011 concerning the Serang Regency Spatial Plan 2011-2031, which stipulates the development plan of this area as the Bojonegara Local Promotional Activity Center urban system, which is intended for industrial activities, then settlements and protected areas. This regulation encourages the industry to continue to grow. To date, the Bojonegara area is being developed as an integrated industrial area in West Serang with activities in the form of base/upstream metal industry, primary chemicals, and maritime industry. Based on the data from the [33] the number of industrial activities in the Serang Regency is shown in Table 4.

TABLE IV
DATA OF INDUSTRIES IN SERANG REGENCY

Main Business	Number of Companies	Local Workers	Foreign Workers
Industries	392	128,857	1,156

Based on these statistical data, it is known that there are 392 companies with 44 types of industries that are spread unequally in seven villages in Bojonegara Village. The number of companies in this industrial business field is 63% of the total companies in Bojonegara Village, with a total absorption of local workers of 128,857 people. The number of these industries continues to increase every year. In 2007 there was only one ample Food and Beverages industry in Bojonegara Village with 178 workers and one small industry with five workers. Along with the direction of the Serang Regency master plan, which encourages the development of industrial areas in West Serang, industrial growth is also increasing. The growth of industrial estates in Bojonegara Village is depicted in Figure 4.

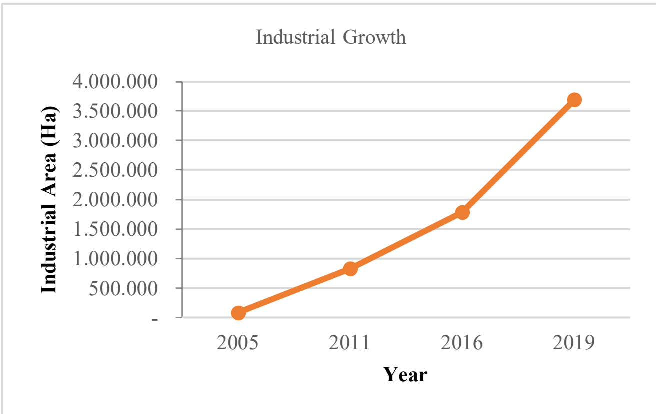

Fig. 4 The growth of industrial estates in Bojonegara Village

The growth of this industrial area is obtained from the calculation of the area using satellite imagery. From the results of the analysis, it is concluded that within a period of 14 years, from 2005 to 2019, land reclamation of 260.40 ha occurred in Serang Regency (Table 5), which is the most significant addition to the reclamation area occurred in Bojonegara Village covering an area of 83.35 ha which is wholly allocated for industrial activities. In 2010 the area of Bojonegara District was 3,017.09 ha, with two villages located in the coastal area, namely Bojonegara Village of 336.51 ha and Margagiri Village of 349.37 ha.

Settlements, agriculture, plantations, and industrial activities on the coast dominated land use in Bojonegara District in 2010. Then there was a change in the area of land in Bojonegara District, namely the expansion of land by 3.5%, 111.7 ha from the previous area. The most significant amount of land expansion is in Bojonegara Village, with a percentage of 21.1%, which is 90.5 ha from the previous area. Referring to the Regional Spatial Planning directive, the designation for industrial activities is set at 1,491.11 ha, for the protected forest at 562.08 ha, and the rest is allocated as urban areas, namely settlements and other supporting facilities. Therefore, the reclamation area built is not following the spatial planning of the coastal area.

Based on the distribution of industrial activity locations in the Bojonegara District, the coastal areas have the highest industrial activity compared to mainland areas. The high intensity of industrial activities in this coastal area causes limited land for developing industrial activities, thus triggering these industrial activities to carry out reclamation activities to meet the adequate space necessity.

TABLE V
LAND USE IN BOJONEGARA VILLAGE (HA)

Type of Land Use	2005	2010	2015	2020
Reclamation Industry	35.80	128.60	187.08	260.40
Non-Reclamation Industry	10.20	52.70	58.60	97.54

Coastal areas have high complexity. As a single coastal ecosystem, changes in the regional landscape and increasingly massive anthropogenic activities have an impact on seagrass ecosystems. Seagrasses can live optimally in waters with surface temperature conditions between 25oC-30oC, salinity between 24o/oo to 35o/oo, and TSS below 20 mg/l (38). Based on the results of laboratory measurements, it is concluded that two stations located around Lima Island, a habitat for seagrass ecosystems and one of the fishing locations, experienced an increase in TSS or sedimentation. Meanwhile, the heavy metals suspected of contaminating these waters were not found in the sample through measurements and laboratory tests. This research findings follow [3]. [4], [36], [37], where water conditions in Bojonegara can still be seen as tolerable but not in line with the findings from prior research conducted [16], [17].

This increase in sedimentation is supposed to be due to port construction activities for industrial activities. Port activities, in addition to potentially causing sedimentation, also have the potential to pollute water areas, especially seagrass. It is known that in two locations around Lima Island, the water quality has exceeded the conditions for seagrass to live. Seagrass is the only flowering plant that can survive and adapt to life in water with high salinity. Seagrass ecosystems on Lima Island provide economic benefits and environmental services for coastal communities in Bojonegara Village. The seagrass ecosystem functions as a nursery ground and spawning ground and provides economic benefits, namely as a capture fisheries area such as shrimp, grouper, tuna, mullet, and snapper main catches of fishermen. The impact of seagrass on fishermen is that the area around the seagrass ecosystem has an abundance of fish.

Fishermen in Pansoran Village use the seagrass ecosystem area on Lima Island as one of the fishing areas. Most of these coastal communities' work as fishermen and depend on their livelihoods to catch fish and look for shellfish using modern and traditional fishing gears, such as bondet, arad nets, small and large blades, rawe, and gill nets in the seagrass ecosystem area [19]. It is known that the amount of capture fisheries production in Serang Regency in 2011 reached 14% of the total production of Banten Province, which was about 8,061.5 tons and was the three largest contributors to capture fisheries production after Pandeglang Regency and Tangerang Regency. Banten Bay is one of the areas that play a role in the contribution of capture fisheries production to Serang Regency because its area is directly adjacent to the Java Sea. In 2015 the total production of capture fisheries in Serang Regency was 7,879.3 tons. Based on the data in Figure 5, from 2011-2015, it is shown that there were decreases in the number of captured fisheries productions by 182.2 tons.

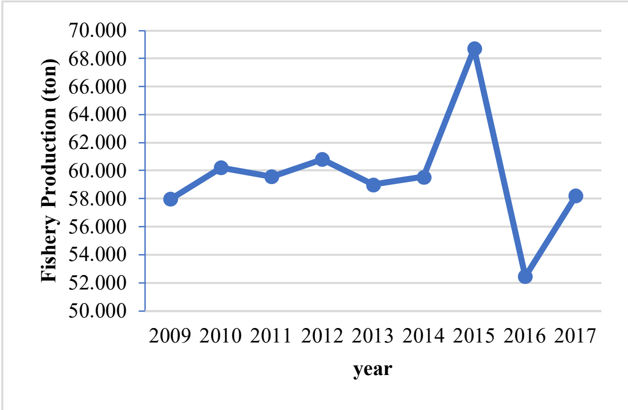

Fig .5 Total Capture of Fishery Production

Fishing is a cultural activity passed down from generation to generation in a coastal community. Along with the increase in TSS in the Banten Bay waters, the seagrass ecosystem in the Bojonegara District waters has decreased, as shown in Figure 3. This change also causes a decrease in economic benefits or utilities for coastal communities in Bojonegara District. This economic valuation calculation will use Formula 1 to calculate the total economic value of the seagrass ecosystem, both direct and indirect benefits. Assessment of direct benefits is calculated by using a fishery production approach.

In contrast, indirect benefits are calculated from the environmental services of seagrass ecosystems as fish spawning grounds and preventing abrasion. The calculation uses a replacement cost approach from constructing fishponds and bamboo sheet piles. Changes in economic benefits and environmental services from the loss of seagrass ecosystems are shown in Table 6.

This economic loss's high value occurred due to the low level of public knowledge and public awareness. It is indicated from the interviews with fishermen respondents that only 19% of fishermen recognize the types of ecosystem variations in coastal areas, their existence, current conditions, and utilization. Another 81% only know one of the three ecosystems and their locations but have never utilized and made improvements.

TABLE VI
RESULTS OF CALCULATION OF ECONOMIC VALUATION

No	Seagrass Ecosystem Functions	Analysis Methods	Loss Value due to damage Occurred (Rupiah)
1	Seagrass ecosystems as fishing grounds	Productivity approach	8,527,773
2	Seagrass ecosystems as fish spawning grounds	Replacement Cost	72,000,000
3	Seagrass ecosystem as abrasion prevention	Replacement Cost	870,000,000
Total Loss Value due to Damage			**950.527.773**

Moreover, it is known that only 27% of the respondents know the types of ecosystems on the coast of Bojonegara Village, and the remaining 73% do not know. The environmental awareness from the industrial sector is still inadequate. The company's CSR activities have provided physical assistance for food, clothing, and other goods and have not touched community capacity-building service. In addition, there are still violations committed by the industry with various cases, even though they have a downward trend from 2015 to 2020 (Figure 6).

The decrease in the case numbers is one of the government's monitoring efforts to prevent environmental damage in the coastal area of Bojonegara Village. Some of the cases often encountered in this location are the environmental permit had not been issued but had carried out activities ahead and the neglect of completion of primary wastewater treatment.

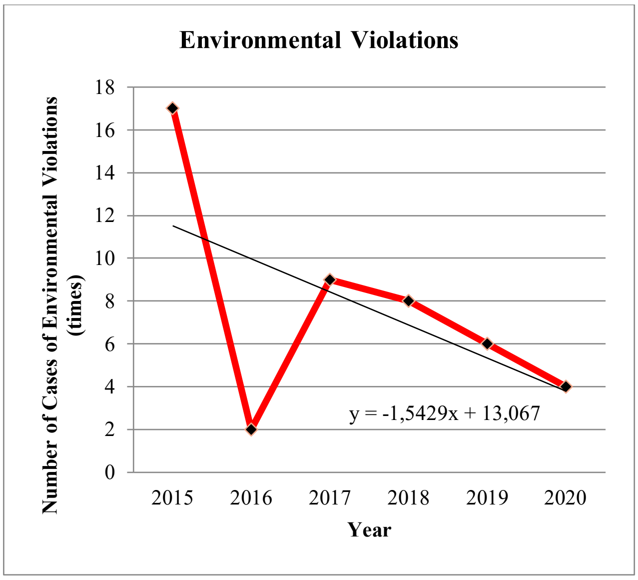

Fig. 6 Number of Cases of Environmental Violations by Industries in Bojonegara Districts

IV. Conclusion

From the study results, it can be concluded that it is true that environmental damage is occurring in coastal areas of Bojonegoro District to Lima Island. The value of Natural Resources and Environmental Services Loss can be estimated by analyzing the productivity approach on seagrass and mangrove ecosystems as fishing grounds and replacement cost on seagrass and mangrove ecosystems as fish spawning grounds and abrasion prevention. The total loss value due to damage is estimated at IDR. 950.527.773 per year. This study finds the high economic loss is due to the low level of public knowledge and awareness, as only ≤19% of the respondents recognize the types of ecosystem variations in coastal areas, their existence, current conditions, and utilization.

Based on the results of laboratory measurements, it was discovered that two stations located around Lima Island, a habitat for seagrass ecosystems and one of the fishing locations, experienced an increase in TSS or sedimentation. Meanwhile, the heavy metals suspected of contaminating these waters were not found in the sample through measurements and laboratory tests. This increase in sedimentation is supposed to be due to port construction activities for industrial and port activities.

These findings prove the hypothesis that the industry still commits environmental violations, which causes water pollution in various cases. It is concluded that in two locations around Lima Island where the sample was collected, the water quality has exceeded the conditions for seagrass to live. As The seagrass serves its ecosystem function as a nursery ground and spawning ground, in the long run, the disruption of its habitat might cause a decrease in the number of capture fisheries, such as shrimp, grouper, tuna, mullet, and snapper, which are the main catches of fishermen. Therefore, it is crucial for the stakeholders, especially policymakers, to resolve these cases to avoid further environmental damage that may cause higher economic loss. To date, the positive reinforcement of the local government's settlement and monitoring efforts can be observed from the decrease in the environmental violation case numbers to prevent environmental damage in the coastal area of Bojonegara Village, which can considerably improve the future of Banten Bay management.

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