



## **An ecosystem approach to integrated coastal zone management: Case study on the Gresik Regency, East Java**

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### **ABSTRACT**

Gresik Regency is one of the industrial development areas in East Java Province due to its strategic location. This region has the opportunity to actively integrate the ecosystem into development planning. Management of integrated coastal areas is widely advocated at all levels of government as a means of delivering sustainable development in coastal areas. This study was conducted to determine the level of impact caused by each activity cumulatively on coastal and marine ecosystems in Gresik Regency. In general, this study is oriented towards collecting data of marine pollution level from various substances and sources, as well as changes over time in the status of the marine environment in Gresik Regency. The results showed that the increase in population growth accompanied by an increase in the amount of waste, as well as an increase in industry, port and agricultural activities in coastal areas of Gresik Regency require special attention in the management of the coastal and marine environment in Gresik Regency. The use of coastal and marine areas of Gresik Regency can lead to loss of biodiversity, as well as decreased stability and resilience of ecosystems in coastal and marine areas. It is necessary to take into account the pressures and impacts due to activities in coastal and marine areas and then propose the most appropriate development solutions within the framework of Integrated Coastal Zone Management in Gresik Regency.

**Keywords:** environmental pressure, environmental limit, ecosystem approach, integrated coastal zone management, Gresik Regency.

### **INTRODUCTION**

Gresik Regency is one of the industrial development areas in East Java Province due to its strategic location. In addition to the industrial sector, the development in Gresik Regency is also directed at the agriculture, trade, maritime, education and tourism sectors. Increasing industrial activities in the region have resulted in various environmental problems. Environmental pollution is beginning to emerge both air, water, and soil pollution, including pollution in river ecosystems and coastal and marine areas [1-3]. Environmental pollution has a negative impact on the community both in terms of economy and health till the emergence of conflicts in the community, such as the upheaval that occurred in the Ujung Pangkah farmers community in Gresik Regency as a result of water pollution [4]. The report of 2010 East Java Regional Environmental Status also stated that most of the mangroves in the Gresik Regency area had been reclaimed as warehousing and industrial areas.

On the other hand, the Gresik coastal area has very attractive natural potential for the development of ecotourism and the potential use of ecosystems and natural resources. Thus the Gresik Regency has the opportunity to actively integrate the ecosystem into development planning. At present ecosystem-based management is increasingly being used to build relationships between integrated coastal management processes based on the

application of regional geographical approaches [5]. The starting point for ecosystem-based integrated coastal zone management is taking into account the pressure and impacts that can occur related to planning in coastal and marine areas. Thus the next most appropriate development solution can be proposed.

Integrated coastal zone management is widely advocated at all levels of government as a means of delivering sustainable development in coastal areas. Research on the management of the Gresik coastal area has been done before by using a co-management model along with the formulation of a related ecosystem restoration model [6]. However, the study has not examined how the condition of the ecosystem and changes that might occur due to pressure from both land-based pollution and marine-based pollution. That is, studies of ecosystem and its changes are important in integrated coastal zone management that integrates sectoral dimensions, fields of science, and ecological linkages. This study was conducted to determine the level of impact caused by each activity cumulatively in coastal and marine ecosystems in Gresik Regency.

### **METHODS**

The ecosystem approach is used in dealing with the problem of managing coastal and marine areas in Gresik Regency. First, an analysis of the effects of various

activities in coastal and marine areas was carried out. This analysis is conducted to evaluate the impact as well as the pressure caused by the activities cumulatively on coastal and marine ecosystems and resources. Based on the results of the evaluation in the first phase, an analysis of ecosystem functions and environmental limits is carried out. This analysis is conducted in an effort to maintain the optimization of natural resource systems in coastal and marine areas within the framework of integrated and sustainable coastal area management.

The scope of the coastal area reviewed in this study was Sidayu, Gresik, Manyar, Bungah, Panceng and Ujungpangkah District. Sangkapura and Tambak District located on Bawean Island are not included in the scope of the study area. In general, this study is oriented towards data collection of marine pollution levels of various substances and sources. The effects of pollution on ecosystems are explored, as well as changes over time in the status of the coastal and marine environment.

## RESULTS AND DISCUSSIONS

### PRESSURES ON THE ECOSYSTEM

#### Increasing Population Density

In general, the population in the coastal area of Gresik Regency increases from year to year [7-13]. The population growth rate in the coastal area of Gresik Regency from 2010 to 2020 by a percentage of 0.66%, 2.40%, 1.21%, 1.53%, 1.55%, and 1.05% respectively in Sidayu, Panceng, Bungah, Ujungpangkah, Manyar, and Gresik District. Increasing population density in coastal areas shows that economic activity increases, along with land and infrastructure development, and is accompanied by population inflows due to growing urbanization in coastal areas which are increasing.

On the other hand, an increase in population density is closely related to the potential deterioration of environmental conditions in coastal areas, along with increasing pressure, conflicts of interest and use of space on land and in the sea which is also increasing. One of the pressures arising from the increase in population density in coastal areas is the increasing number of household waste, both liquid waste (sewage) and solid waste (garbage), which enter the marine environment.

Assuming the volume of household liquid waste produced per day (flow rates) is 200 liters/person/day [14], it can be estimated that the volume of household liquid waste produced per day that enters the marine environment and coastal area in Gresik Regency. Estimates of the volume of household wastewater produced in Gresik Regency are given in Table-1.

The Gresik Regency Cleaning, Landscaping and Fire Service noted that the entire waste generated in Gresik Regency was 900 tons/day. With the carrying capacity of 125 tons/day, thus, only 15-30% per day of waste is served [15].

#### Industrial Development in Coastal Areas

The increase in development activities is the potential for creating economic empowerment. Industrial development, as a driving force for the economy, will continue to be driven by its role because it will contribute significantly to national development. The number of industries in the coastal areas of Gresik Regency in 2017

and 2018 is shown in Table-2. It can be seen that small-scale or home industries dominate the industry in the coastal area of Gresik Regency. The problem is often found that most home industries do not have a wastewater treatment plant. Thus, the potential for pollution generated from this sector is very significant, especially considering that home industry dominates the industry in the coastal area of Gresik Regency.

However, industrial development has the potential for environmental damage including industrial waste. This industrial waste can contain highly toxic elements, in the form of acids, bases, heavy metals, and toxic organic materials [16].

Increasing industrial activities in Gresik Regency thus has the potential to increase the amount of waste produced. One of the wastes that must be considered by industrial activities is hazardous and toxic waste. This waste usually contains heavy metals including mercury (Hg), cadmium (Cd), lead (Pb), copper (Cu), zinc (Zn), and chromium (Cr). The previous research show that lead pollution has occurred in the coastal and marine waters of Gresik Regency [17]. The biggest lead pollution is in marine waters in the V Maspion Industrial Estate (0.083 mg/L). While the lowest lead pollution is in the Manyar Subdistrict (0.021 mg/L).

The biggest lead pollution was in the seawaters in Maspion V Industrial Area (0.083 mg/L), followed by the waters of the PT Petrokimia Gresik Port area (0.056 mg/L), and waters of the Manyar District (0.021 mg/L). The overall measured lead concentration in Gresik waters exceeds the seawater quality standard [18], namely 0.05 mg/L for port waters, 0.008 mg/L for marine life, and 0.005 mg/L for marine tourism.

**Table-1.** Estimated volume of household liquid waste in Gresik Regency, 2020

District	Total Population [7]	Volume of Sewage (liters/day)	Volume of Sewage (000 m <sup>3</sup> /year)
Ujungpangkah	48,955	9,791,000	3,573.72
Sidayu	43,492	8,698,400	3,174.92
Manyar	119,338	23,867,600	8,711.67
Bungah	65,298	13,059,600	4,766.75
Panceng	50,525	10,105,000	3,688.33
Gresik	76,347	15,269,400	5,573.33
Gresik Regency	1,311, 215	262,243,000	95,718.70

**Table-2.** Industries in the coastal areas of Gresik Regency 2017 & 2020 [7-13]

District	Small Industry		Medium Industry		Large Industry	
	2017	2020	2017	2020	2017	2020
Ujungpangkah	393	300	0	2	8	9
Sidayu	1252	1253	13	15	0	0
Manyar	490	514	38	37	28	35
Bungah	2685	2685	6	6	2	3
Panceng	123	123	16	16	0	0
Gresik	472	472	19	19	11	11

### Port Activity

As an industrial city, Gresik Regency has a seaport that plays a role in supporting economic development in the region. In addition to Gresik Port, there are nine ports that support the economic development of Gresik Regency, both government ports and private-owned ports. The number of special ports in Gresik Regency is expected to continue to grow given the many companies that stand in strategic locations adjacent to the sea. This will be accompanied by an increase in the number of ships along with the increase in ships that are leaning on the port. The ships carry various production goods of export companies, including fertilizers, wheat and processed food products.

Most of the trade flows in East Java through Gresik Port, which has become an important port in East Java, after the Port of Tanjung Perak. In 2013, the number of foreign trade or exports in Gresik Port reached 167 thousand t/m<sup>3</sup>; in 2014 it rose to 174 thousand t/m<sup>3</sup>; although it subsequently decreased by 111 thousand t/m<sup>3</sup> and 119 thousand t/m<sup>3</sup> in 2015 and 2016. In accordance with the development trend of "sea highway", it is expected that transportation through the sea port will also increase.

However, in this regard, the risk of accidents and marine pollution will also increase, such as oil pollution in the waters of PT Maspion in 2009 and oil spills in Ujungpangkah offshore waters in 2012 [19]. The potential for oil spills can also come from tankers that have an accident or run aground. Increasing maritime transportation also causes an increase in noise in coastal areas. Pollution from maritime transportation produces waste which, although the number is relatively small but has a clear portion of pollution in the sea [20]. The waste from maritime transportation activities originates from ship operational activities including routine cleaning of tanks as well as for docking, ballast water disposal, sewage disposal on ship gutters, including waste and waste oil from ship engines or oil transfers between ships.

### Agriculture Sector

Development of the agricultural sector strives to increase productivity and to diversify crops. This is done for food needs and environmental sustainability. Overall in Gresik Regency, rice production in 2016 amounted to 419,713 tons with a harvest area of 66,306 ha. This when compared to 2015 increased by 5.59 percent. For field rice, cassava and soybean commodities when compared to 2015 decreased. While the commodities of corn, sweet potatoes, peanuts, and green beans have increased.

The process of agricultural production in 2005 emitted 1.4 - 1.7 Gt C or about 10-12% of the total anthropogenic Greenhouse Gas (GHG) emissions, which consisted of: 0.76 Gt C is equivalent to N<sub>2</sub>O, and 0.90 Gt C is equivalent to CH<sub>4</sub> (sequentially 58% and 47% of the total anthropogenic influence) [21]. In the same year, changes in land use (deforestation for agriculture) contributed emissions of 1.5 GtC [22]. U.S. The main component of GHG emissions from agricultural activities is N<sub>2</sub>O from soil related to the application of N (38%) fertilization, enteric fermentation, and CH<sub>4</sub> and N<sub>2</sub>O from fertilizer management (38%), CH<sub>4</sub> from rice fields (11%), and CH<sub>4</sub> and N<sub>2</sub>O from burning savannahs, forests and agricultural residues (13%). These global problems can be

anticipated through agricultural development that can reduce carbon loss or low GHG emissions.

## ENVIRONMENTAL LIMITS

### Coastal Hydrodynamics

Coastal and marine areas are vulnerable to the impact of pollution due to the flow of waste from the land through rivers, channels leading to the sea (ocean outfall) or direct disposal into the sea. Physically, the condition of coastal waters and high seas is influenced by the hydrological cycle, hydrodynamics, topography of coastal and marine areas, spatial planning or zoning, and the intensity of natural resource utilization activities, as well as the technology used in these activities. This condition affects the nature of the pattern and intensity of pollution that may occur due to socio-economic activities in coastal and marine areas [23].

When pollutants enter the marine environment, currents and sea turbulence cause the transportation process and pollutant dilution. These processes, on the one hand, can reduce the concentration of pollutants as well as the level of their effect, on the other hand, they can also transport pollutants to a place where they were not previously found. Thus, the interaction of pollutants with physical components and living organisms affects the extent of the impact of pollutants on the coastal and marine environment.

The existence of Bawean and Madura Islands, which are located close to the coastal and marine areas of Gresik Regency, will affect the condition and characteristics of marine oceanography in the waters of Gresik Regency. Land and processes that occur on land (for example, the flow of the Manyar river with substances or particles that are carried towards the sea) will affect salinity, turbidity, fertility, and the brightness of coastal waters. Local climate such as rainfall will affect salinity and strong winds will cause the development of ocean currents and waves. The effects of these local factors will cause the oceanographic characteristics of the coastal and marine areas of Gresik Regency to become more complex.

### Coastal Water Quality

Marine pollution is characterized by changes in the quality of seawater that occur as a result of the entry of pollutants or waste into the marine environment. When changes occur in ecosystem components, these changes will affect the system as a whole, both in terms of functional structure and in terms of balance. Furthermore, the continuity of an ecosystem function greatly determines the preservation of natural resources.

Since 1999 the productivity of ponds in the coastal areas of Gresik Regency has decreased due to marine pollution by the accumulation of industrial waste and waste from aquaculture activities [24]. Other research states that Gresik waters have been contaminated with heavy metal lead [17]. Sources of heavy metal pollution can come from vehicle fumes, agriculture using pesticides, workshops, industrial activities and disposal of household waste. Heavy metals are dangerous pollutants because they are toxic in large quantities.

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activities and disposal of household waste. Heavy metals are dangerous pollutants because they are toxic in large quantities.

Research on lead pollution in the coastal waters of Gresik has also been conducted [25]. Unlike the previous research, in this study which published in 2014, all lead measurement stations are located in the waters of the Manyar River Estuary. In addition, measurements were not only carried out on seawater samples, but also on sediment samples at the study location. The results of research by [25] showed that the heavy metal content of lead in seawater ranged from 0.31 to 0.57 mg/L. The measured lead content in seawater in Gresik waters is higher than the quality standards [18], namely 0.008 mg/L for marine biota and 0.005 mg/L for marine tourism. The lead content in the bottom sediments ranges from 2.7757 - 3.3724 mg/Kg.

Apart from heavy metals, oil pollution also has the potential to occur in the coastal and marine waters of Gresik Regency. This oil pollution can come from port activities and sea transportation. Mangroves are ecosystems that are ecologically highly sensitive and have very high sensitivity and are chronic to oil spills [26]. The characteristics of the mangrove community in the coastal area of Gresik Regency in general have a very sensitive level of oil pollution. This can be a direction for coastal management policies to as much as possible prevent oil pollution from entering the mangrove area. Prevention is important because if oil contamination enters mangroves it will damage important ecological functions in coastal areas, complicate handling of oil spills, and will result in expensive oil spill control costs.

Apart from industrial waste and oil pollution, this research also examines radioactive contamination in the coastal areas of Gresik Regency. Radioactive pollution is one of the marine pollution in Gresik waters that has not received much attention and has not been widely studied. In fact, the coastal waters of Gresik are a dumping ground for waste from several industries such as the fertilizer industry and phosphoric acid, which are thought to release a number of natural radionuclides. Disposal of waste containing natural radionuclides into the sea will potentially pollute the coastal environment and increase the levels of natural radionuclides in aquatic biota including fish. The results of research by [3] found natural radionuclides  $^{238}\text{U}$ ,  $^{232}\text{Th}$  and  $^{226}\text{Ra}$  and  $^{40}\text{K}$  in all marine fish species analyzed from the coastal waters of Gresik.

### Ecological Footprint

The environmental carrying capacity of Gresik Regency has an imbalance in accommodating any increased activities due to population growth and increasingly intensive land use changes. This is indicated by an imbalance between the supply of environmental carrying capacity and the consumption of natural resources where land use changes in Gresik Regency have resulted in ecological damage such as decreased land productivity, water crisis, flood disasters, and environmental pollution [24].

The carrying capacity component of land use optimization in Gresik Regency can be identified through the ecological footprint approach. In this ecological footprint approach, the level of consumption of natural resources and the ability of land to provide these

consumption needs can be measured in global land units of hectares (gha). The ecological footprint describes the need for goods and services needed by humans from nature which is reflected in the net consumption of categorized products such as agricultural products, livestock products, forestry products, fishery products, space and land needs, and energy consumption.

The results of the research by [24] show that the biocapacity of Gresik Regency reaches 319,179.6 gha, which is widely spread in periurban areas. The highest percentage of biocapacity is in agricultural land types of 53.92%. However, this biocapacity is not comparable to the consumption of ecological footprint which reaches 1.63 million gha, especially in urban areas due to high population and activity activities. This reinforces the imbalance of environmental carrying capacity in Gresik Regency, which is already experiencing an ecological deficit of 1.04 gha/capita. All land types experience a deficit and only livestock land types experience a surplus of 0.05 gha/capita.

In the coastal area of Gresik Regency, Gresik District has a biocapacity of 225.37 gha to meet the needs of ecological footprint consumption. This value is the smallest biocapacity of all sub-districts in Gresik Regency. When compared as a whole, the districts with the highest biocapacity are those with large agricultural land. This is because in this study the ecological footprint approach considers agricultural land to have the highest level of sustainability as the main food land. Thus, coastal sub-districts such as Manyar and Ujungpangkah Districts tend to have lower biocapacity compared to other sub-districts in the Gresik Regency area because they have large fishing grounds.

Furthermore, the calculation of ecological footprint is calculated based on food consumption, energy,  $\text{CO}_2$  emission levels, and wood consumption. Coastal districts such as Gresik District and Manyar District have higher consumption of ecological footprints compared to other coastal areas. This is inseparable from the high population intensity in the region.

In terms of ecological balance, Gresik District has the highest deficit, which ranges from 0.5-0.9 gha/capita. This is inseparable from the absence of agricultural land in Gresik District. Other coastal areas, such as Panceng District, where there is a lot of livestock land, have a surplus of 0.21 gha/capita. A surplus condition is a condition where the biocapacity is greater than the ecological footprint. Meanwhile, Manyar District experienced a surplus of 0.01 gha/capita.

In terms of the ecological surplus of fisheries land, Sidayu and Bungah Subdistricts experienced an ecological surplus of fisheries land of 0.003 and 0.001 gha/capita, respectively. This is because the area and productivity of fishery land in each of these districts are relatively higher than in other districts.

### CONCLUSIONS

The increase in population growth accompanied by an increase in the amount of waste, as well as an increase in industry, port and agricultural activities in coastal areas of Gresik Regency is a form of increasing utilization of coastal and marine areas that require special attention in the management of the coastal and marine environment. This is because the use of coastal and marine

areas can lead to loss of biodiversity, as well as decreased stability and resilience of ecosystems in coastal and marine areas. Furthermore, this can also reduce the quality of human life in coastal areas.

It is necessary to take into account the pressures and impacts that may be caused to coastal and marine ecosystems due to activities in coastal and marine areas and then propose the most appropriate development solutions within the framework of Integrated Coastal Zone Management. Thus, further steps can be formulated to reduce pressure from land and sea activities that affect marine ecosystems.

This study is oriented towards collecting data on the level of marine pollution from various substances and their sources. Thus, the effects of pollution on the marine environment and organisms can be explored, and changes in the status of the marine environment over time can be investigated. Furthermore, strategies for environmental improvement and synchronization of programs for the use and management of coastal and marine areas can be formulated. In addition, the involvement of various stakeholders in the process of preparing programs for sustainable development in coastal and marine areas is also very important.

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