

Time Series Ecological Coastal Resilience in Ende City, Indonesia

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Abstract. Ende city is a coastal area that is one of cities in East Nusa Tenggara province. There are risk that threatens the city and coastal area originating from natural disasters and human activity. It is necessary to assess and monitor coastal resilience of this city since abrupt change of city landscape has impact on ecosystem resilience. Therefore, the aim of this research is to measure and analyze ecological coastal resilience from 2016 to 2021. Coastal resilience can be assessed from ecosystem-ecology approach so that sustainability of coastal community can be strengthening. Landscape parameter of typology was used to measure ecological resilience in coastal ecosystem of Ende City. One of widely used approach to measure ecological resilience is applying a variety of different indicator or metric of resilience. Parameter of resilience is scored and classified for each typology in coastal area of Ende City. Research method includes field survey, in depth interview and focus group discussions. One of method to determine coastal resilience classification is from resilience index. Based on result, coastal resilience is mostly moderate class in Ende City. The lowest class of resilience index is in volcanic coast typology.

1 Introduction

Coastal ecosystems are greatly very essential for humans since they provide a wide range of services for human well-being and they provide the greatest support for industry and economic activities. Coastal regions have developed and have become populous areas where anthropogenic stresses can cause damage to coastal ecosystems in preserving resilience. The coastal region is also facing a high risk of natural disasters and is highly susceptible to the impact of climate change [1]. The resilience of coastal areas in a natural disaster and a changing climate is necessary to protect coastal habitats and to maintain critical ecological function [2].

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Resilience encompasses various varieties of concepts. The concept of resilience is the capacity of the ecological system to support the ecosystem in facing stress and/or disturbances. The ability of an ecosystem to recover after disturbances is the fundamental concept to understand the resilience of coastal ecosystems [3]. The key to having a resilient ecosystem is the ability to absorb shocks, bounce back, learn, and adapt [4]. The definition of resilience was first stated by [5] as a measure of a system's resilience and its ability to absorb changes and disturbances while maintaining relationships between populations or between changes in the same or stable conditions. Ecological resilience is a measure of the amount of disturbance that can be accepted by a system before changes occur to a new condition (stability) that is different in controlling its structure and function [6]. Analysis of the ecosystem from an ecological perspective is applicable and optimal choice since the ecosystem is an entity observed externally and that it can be analyzed as such [7]. Natural habitats are also crucial for coastal resilience since they can act as recovery driver for coastal functionality loss [8]. Therefore, ecological resilience can highlight the ability of an ecosystem to absorb perturbations without tipping toward another attractor in a long-term perspective [9].

Ecological resilience focuses on persistence, change, and an unpredictability, emphasizing conditions that drive system dynamics away from any equilibrium steady state, including dynamical instabilities that can flip a system into another regime of behavior [10]. The ecological resilience approach can facilitate a better understanding of how persistent multiple stressors threaten the resilience and long-term use of natural ecosystems [11]. Maintaining the ability of ecological systems to resist and recovery from disturbances is the key of conversation [12].

One of widely used approach to measure ecological resilience is applying a variety of different indicators or metrics of resilience. These indicators or metrics are used to define, quantify, compare, and predict resilience across different ecological systems, species, and subdisciplines [12]. Landscape is ecosystem that can be used to measure ecological resilience with different indicator and metric. Landscapes are able to assess the relation between human and natural resources from the notion of land use. Landscapes also the key to understand the conceptual framework of resilience in the systems in long term [9]. Ecosystem status is determined by the natural landscape. Changes in landscape cause changes in coastal ecosystems [13]. Geomorphological processes that work continuously on landscape will result in changes to the landscape and affect the ecosystem above them [14]. Landscape approach through coastal typology can determine the characteristics of coastal area.

Coastal typology is the classification of coastal types based on genesis of coastal formation and the processes that take place in them (Shepard, 1972 in [15]). Classification of coastal typology is necessary to identify the characteristics and dynamics of coastal area since coastal resilience depends on characteristics and dynamic condition of coastal area. Coastal typology can be classified based on genesis that is primary coast and secondary coast. Primary coast is from terrestrial process, while secondary coast is from marine process, including the activities of organisms in the sea [15]. Primary coast consists of land erosion coast, sub aerial deposition coast, structurally shaped coast, and volcanic coast. Secondary coast consist of marine deposition coast, wave erosion coast, and coast built by organism.

Ende is a city in the province of Nusa Tenggara. There is a risk that threatens this city. It is necessary to assess and monitor coastal resilience of this city since abrupt change of city landscape has impact on ecosystem resilience. Therefore, the aims of this research is to measure and analyze ecological coastal resilience from 2016 to 2021. This research provides input for the Ende district government in sustainable management of the coastal and marine environment.

1.1 Study Area

Ende City is located in East Nusa Tenggara Province between 8°39' -8°54' N and 121°37' - 121°42' W. Ende City is the capital city of Ende Regency. The coastal area is approximately 28,907,386 m² that consists of 10 sub districts (kelurahan) such as Kota Raja, Kota Ratu, Mbongawani, Rukun Lima, Paupanda, Tanjung, Tetandara, Mautapaga, Nanganesa dan Manulando. It is a city where center of government and industry offices lying on. Ende City is a city in Nusa Tenggara Timur (South East Nusa Tenggara) that most part of the area is a coastal area. Ende City is an open sea area with Sawu Sea and Indian Ocean, therefore, high tide and high wave activities influence this city. West monsoon and south east monsoon can lead high tide into multi-risk disaster to this coastal city. Study area location is shown in Figure 1.

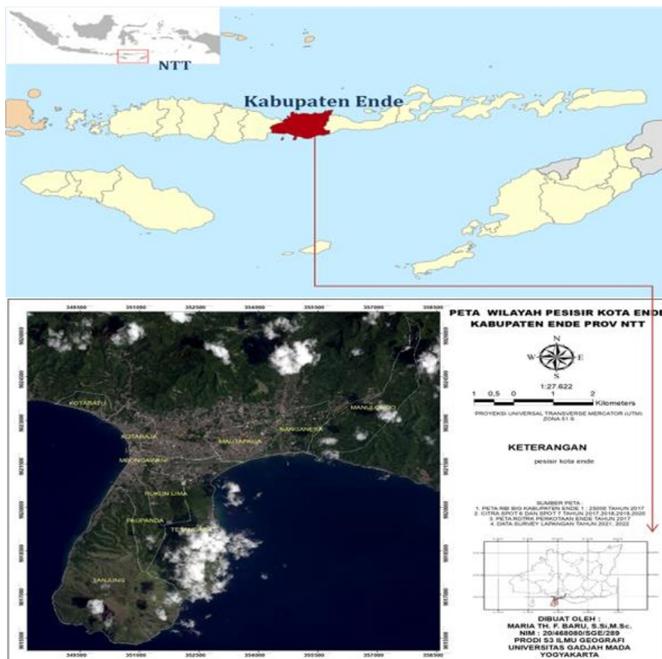


Figure 1. Study Area Location

There are five coastal typologies in Ende City, i.e. are marine deposition coast, antropogenic coast, wave erosion coast, sub aerial deposition coast, and volcanic coast (Figure 2). Most of the southern part is volcanic coast. Volcanic coast has the largest area occupied in this city compared to others coastal typology. The second position is marine deposition coast that has large area occupied in this city. The area of wave erosion coast and antropogenic coast are almost comparable existing in this coastal city. Marine deposition coast is found in Ndao coastal area (Kota Ratu sub district). Marine deposition coast-antropogenic coasts are found in Ende coastal area (Kota Raja sub district), Ippi coastal area (Tetandara sub district) and Bitu beach coastal area. Tanjung coastal area if formed from marine deposition coast-antropogenic coast-volcanic coast typology. Combination of marine deposition coast, antropogenic coast, and wave erosion coast are found in Arubara coastal area (Tetandara sub district), while Mbu'u coastal area is found as mix typology of marine deposition coast-sub aerial deposition coast-wave erosion coast. Coastal typology of Ende City is shown in figure 2.

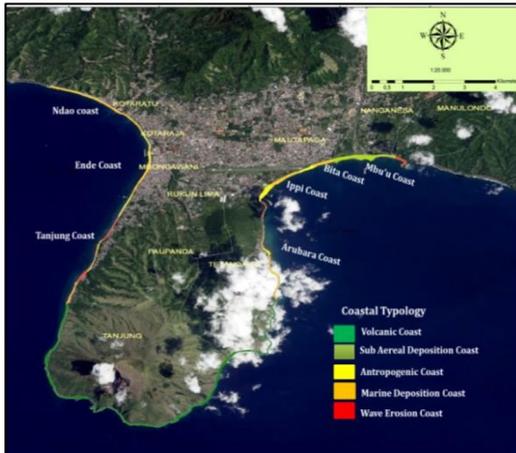


Figure 2. Coastal Typology of Ende City.

2 Method

The method used is descriptive qualitative. This research analyzes primary data and secondary data and describes field conditions at the time the research took place. Analysis of primary data and secondary data to produce an ecological resilience index for coastal ecosystem.

2.1 Primary Data Collection and Analysis.

2.1.1 Interview and Focus Group Discussion

Interview is guided by questionnaire. Interview complete data that is not available from secondary data. Through series of interview with resident of Ende City, representative government of Ende City, and practitioner, and field observation this paper employ a qualitative approach to investigate the understanding of coastal resilience. Research method included in depth interview and focus group discussion. A respondent for in depth interview is selected applying purposive sampling. A total of 100 interviews for focus group discussion were conducted. Information gathered interview set the context of understandings percentage of coral reef coverage, water contamination index, employment status, educational background, potency of conflict, awareness of ecosystem function, dependency of community to ecosystem, and management of coastal resources. Focus group discussions to explore ideas from coastal communities in more depth and detail to complement the exploration of ideas obtained during in depth interview and field survey.

2.1.2 Field Survey.

Field survey provide additional information on the topic being researched by creating documentation such as notes, recordings, photos, sketches[16]. Information obtained from field survey regarding coastal dynamics in each segment of coastal typology, characteristic of coastal ecosystem (biotic and cultural), coastal land cover, suitability of land use, density of terrestrial vegetation, diversity/biodiversity of terrestrial vegetation and types of fauna.

Field survey of vegetation and fauna diversity are carried out by determining counting points/observation points to record fauna and vegetation types. Each type of vegetation was

recorded. Every type of fauna that can be seen and heard is recorded. Number and type of vegetation and fauna are documented. The points are determined randomly. The points are scattered in a straight line along the coast. The analysis to measure vegetation diversity (Diversity Index) is by calculating diversity (Diversity Index) using the Shannon-Wiener Diversity Index (\hat{H}) was performed using as (1).

$$\hat{H} = -\sum p_i \ln p_i \quad (1) \quad [17].$$

Where p_i is number of individual species i , N is number of individual of all species and H is species diversity index.

2.1.3 Sea Water Quality Analysis

Sea waters quality analysis to determine level of ecological resilience of aquatic biota. Sea water quality analysis is done because the coastal area is the final location for waste disposal. Physical and chemical parameter measurements are done in the field and in the laboratory. Parameters measured in the field are temperature, pH, DO, TDS, salinity, DHL, turbidity and brightness. Parameters analyzed in laboratory are TSS, Nitrate, Nitrite, Ammonia and Total Coliform. Sea water quality indicator is measured based on regulation of Decree of Ministry Environment (Keputusan Menteri Lingkungan Hidup) Number 51 year 2004 [18].

2.1.4 Secondary Data Collection and Analysis.

Secondary data is also collected to support this research. Secondary data consists of fish productivity, fish type, education background, and employment status, coastal typology, vegetation density, land cover, percentage of coral reef cover. Coastal typology is analyzed from SPOT 7 scale 1:50,000 and topographical map scale 1:25,000 from Bureau of Geography Information year 1998, Planning Map for Ende City year 2017 (locally called RTRW map). Time series SPOT from 2016 to 2021 are used to define land cover, coral reef coverage, vegetation density, and land suitability to make detail map of coastal typology. Literature study and fieldwork survey are also conducted to define coastal typology map. Fieldwork is done on September to December 2021. Coastal typology is classified following Shepard, 1976 in [15] based on coastal ecosystem characteristics, land cover, land suitability, vegetation cover, fauna diversity, biodiversity terrestrial vegetation, coastal ecosystem condition.

Vegetation density, land cover and coral reef area from the field survey were compared with the results of image processing. Land cover map and vegetation density are generated from SPOT 7, topographical map, planning map, Landsat 8 year 2021. Land cover is classified with unsupervised classification with ArcGIS. Band composite that is used to classify the Landsat is 432. This composite can differentiate land cover. Vegetation density is using NDVI formula that is $(\text{Near Infrared} - \text{Red}) / (\text{Near infrared} + \text{Red})$, while coral reef cover percentage using band combination of 532. Figure 3 shows vegetation density map in 2021 and land cover map in 2021.

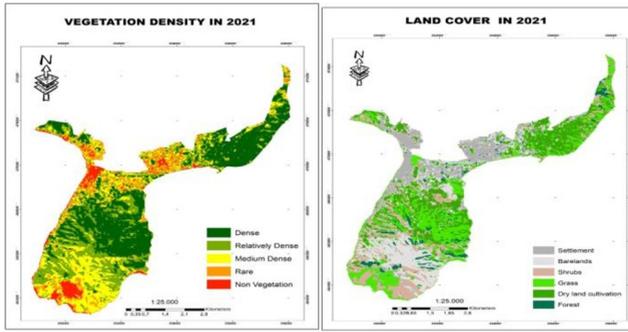


Figure 3. Vegetation Density Map in 2021 Land Cover Map in 2021

2.2 Ecological Resilience Metric

Landscape parameter of typology was used to measure ecological resilience in coastal ecosystem of Ende City. Parameter of resilience is scored and classified for each typology in coastal area of Ende City. Time series of ecological resilience index is measured from 2016 to 2021. Physical environment condition is also required to be added as parameter resilience such as land cover, land suitability, density of terrestrial vegetation, biodiversity, fauna, and percentage of coral reef coverage. Field survey, spatial analysis, depth interview are used to aid resilience scoring system. Parameter used as indicator to assess resilience ecology is modified from [19], [20], [21] as shown Table 1.

Table 1. Parameter and Indicator Used to Measure Resilience of Ecological System in Coastal City of Ende.

No	Parameter of Resilience	Resilience score			Resilience classification	Method
		score	Good	Bad		
1	Land cover	1 - 4	4	1	>80%(4), 51-80 (3), 21-50 (2), <20 (1)	Image satellite, survey
2	Land suitability	1 - 2	2	1	Non suitable (1), suitable (2)	Image satellite, survey
3	Density of terrestrial vegetation	1 - 3	3	1	rare (1), medium (2), dense (3)	Image satellite, survey
4	biodiversity	1 - 3	3	1	low(1), medium (2), high (3)	Image satellite, survey
5	Fauna	1 - 3	3	1	low (1),medium (2), high (3)	Image satellite, survey
6	Percentage of Coral reef coverage	1 - 3	3	1	0-45%(1), >45-70% (2), >70-100%(3)	In depth interview, FGD and land sat
7	Water contamination index	1 - 4	4	1	0-1%(4), 1,1-5,0(3), 5,1-10(2), IP>10,1(1)	In depth interview, FGD and water quality analysis
8	Employment status	1 - 2	2	1	diverse (1), not diverse (2)	BPS, interview

9	Education background	1 - 3	3	1	>75% SD low(1), 50-75% SD+SMP medium (2), >50%SD+SMP high (3)	BPS, interview
10	Conflict potency	1 - 2	2	1	no (2), yes (1)	Interview
11	Awareness of ecosystem function	1 - 2	2	1	No (1), yes (2)	Interview
12	Community dependency to ecosystem	1 - 2	2	1	yes (1), no (2)	Interview
13	Management of coastal resources	1 - 2	2	1	irrational (1), rational (2)	Interview

Source: Analysis of Research Result, 2022

Analysis of resilience scoring based on ecology system was performed using Eq. (2), while the classification of resilience ecology is shown in Table 2 as below.

$$RE = \frac{\sum ecology}{\sum max} \tag{2} [22]$$

where RE is the level of resilience ecology, $\sum ecology$ is the score of resilience ecology, and $\sum max$ is the resilience maximum score. Low resilience score is 0 and high resilience score is 1.

Table 2. Classification of Resilience-Ecology System Based

No	Resilience index	Resilience class
1	0.0 – 0.2	Not resilience
2	>0.2 - 0.4	Low resilience
3	>0.4 – 0.6	Moderate
4	>0.6 – 0.8	Resilience
5	>0.8 – 1.0	High resilience

Source : [21]

3 Result and Discussion

Time series coastal resilience index is necessary to monitor coastal resilience from time to time. Mostly, resilience index of ecology system increase for all typologies in Ende City. The ecological system resilience index for all coastal typologies was averaged to obtain the coastal resilience of Ende City (Table 3). It indicate coastal ecosystem is not resilience enough. It is necessary to apply some management to fix some weakness in the ecosystem such as vegetation density, fauna diversity, coral reef cover area, level of water pollution, land cover and land suitability. Resilience index of marine deposition coasts increase from 2016 to 2021, although it is stable for three years from 2019 to 2021. Resilience index of wave erosion coasts typology gradually increase from 2016 to 2021. Index of resilience for sub aerial deposition coasts, anthropogenic coasts, and volcanic coast also increase in the end, although for some years it relatively has similar values of resilience index. Ecology parameter that give high contribution to increase resilience index from 2016 to 2021 is

vegetation density, diversity of employment status, absence of conflict potency between coastal communities, awareness of ecosystem function and rational use of coastal ecosystem. Volcanic coasts typology has no resilience capability because it has the lowest resilience index especially on 2016 to 2020. Parameters that have a high resilience value in the typology of volcanic coast are the suitability of land type and the marine pollution index. Overall, Ende City has moderate level of coastal resilience ranging from 0.50 to 0.56 index value.

Table 3. Time series resilience index of coastal Ende City for each typology from 2016 to 2021

Typology	Year				
	Resilience Index				
	2016	2017	2019	2020	2021
Marine deposition coasts	0.6	0.62	0.64	0.64	0.64
Wave erosion coasts	0.55	0.59	0.6	0.63	0.65
Antropogenic coasts	0.59	0.59	0.61	0.61	0.63
Sub Aereal Deposition Coasts	0.56	0.56	0.6	0.62	0.62
Volcanic coasts	0.23	0.23	0.23	0.23	0.34
Coastal typology	0.506	0.522	0.537	0.529	0.566

Source: Analysis of Research Result, 2022

Human ecological parameters influence level of coastal ecological resilience. Resilience of coastal communities is usually reflected in their behavior and adaptation patterns to the dynamics of coastal areas. Communities with a high level of resilience will experience a smaller impact on negative natural changes. Communities will respond better to ecosystem changes. Ecosystem damage will be controlled. The diverse types of work of coastal communities have resulted in continued use of coastal ecosystems reasonable. Employment status not only utilizing coastal and marine resources but also working in other service sector. Understanding of the benefit or function of ecosystem influences people's behavior in maintaining their ecosystems well. Ecosystem conditions that are maintained sustainably by society lead to high resilience of the ecological system.

The potential for conflict in the use of natural resources is not found on the coastal of Ende City. The highest level of public education in the coastal typology of marine deposition coast, anthropogenic coast, wave erosion coast and sub area deposition coast is elementary school and junior high school graduates. Level of education provides an illustration of how people understand coastal ecosystem. Understanding the ecosystem influences strategies for taking action to maintain the sustainability of coastal ecosystems. society understands the importance of each element of the ecosystem for humans. According to the community, the causes of damage to ecosystems are caused by nature and humans. Community maintains and replant coastal vegetation such as *Hibiscus tiliaceus* and *Pandanus tectorius* to protect their settlements from abrasion and tidal waves.

Coastal land cover in the marine deposition coast and anthropogenic coast typology area is dominated by settlement, infrastructure, public facilities, social facilities, health facilities, government facilities, sports facilities, culinary and natural tourism facilities, trade facilities and vegetation. Coastal land cover in sub aerial deposition coast typology is dominated by rivers and lakes, settlement, hotels, agricultural and livestock, vegetation. Coastal land cover in the wave erosion coast typology is dominated by coastal forest vegetation. There is pressure on land use in the coastal typology of marine deposition coast, anthropogenic coast and sub-area deposition coast, where coastal green open space is

dominated by settlement and infrastructure. This affects the level of resilience of coastal vegetation.

The waters in coastal areas are lightly polluted. The level of water pollution is determined based on community activities in coastal typologies that produce waste. The water pollution index in marine deposition coast typology is lightly polluted condition with an index value of 1.8. The water pollution index in marine deposition coast typology is lightly polluted condition with an index value of 1.2. The water pollution index in sub aerial deposition coast typology is lightly polluted condition with an index value of 2.28. The water in the volcanic coast typology is not polluted because no community activity was found in this typology. Organic and inorganic waste, domestic waste, livestock waste, public facility waste, industry waste are one of the factors causing water environmental pollution by total coliforms and nitrates. The presence of Coliform bacteria in water can be a pathogen for the biota in that water. Coliform bacteria and nitrates become pathogens for the biota in this water. TSS (Total Suspended Solid) parameter in the sub aerial deposition coast typology is 34 mg/L, exceeding the quality standards set for sea water biota. TSS or suspended solids occurs due to process of erosion of soil or rocks carried by water, resulting in a sedimentation process which causes turbidity in water bodies. These solid particles will interfere with the photosynthesis process in water due to the obstruction of light entering the water body. The condition of lightly polluted waters is affecting the level of aquatic biota resilience.

Vegetation density in the coastal areas of Ende City from 2016 to 2021 is in the moderate resilient category. Vegetation density increased from sparse density to medium density. The high density of vegetation is bush and grass vegetation in the volcanic coast typology. Coastal materials consist of the result of volcanic and marine processes. Changes in vegetation density in each coastal typology in the coastal area of Ende City can be seen in table 4.

Table 4. Vegetation Density in Coastal Typology
from 2016 to 2021

Year	Coastal Typology Vegetation Density				
	Marine Deposition Coast	Wave Erosion Coast	Antropogenic Coast	Sub Aerial Deposition Coast	Volcanic Coast
2016	41.11	10.81	21.28	24.66	24.24
2017	37.80	28.39	25.67	22.40	94.88
2020	42.34	19.53	28.65	23.45	97.82
2021	44.67	11.13	19.95	22.15	81.84

Source: Analysis of Research Result, 2022.

Vegetation diversity in each typology in the coastal area of Ende City is in a condition of moderate resilience. Vegetation density in the anthropogenic coast typology is low due to high infrastructure land use. Vegetation density in the marine deposition coast typologi and wave erosion coast typology is medium to high. Vegetation density in the wave typology is medium to high. Vegetation density fluctuates due to waves causing abrasion on the coast. Vegetation density in the sub area deposition coast typology is low to moderate because land use consists of water, social facilities, education, tourism and residential. Fauna diversity in each coastal typology is in a condition of low resilience. Vegetation diversity and vegetation density need to be increased because increasing the diversity and density of vegetation species will increase the resilience of the ecological system.

Coral reef population are decreasing and are in a damaged condition. This condition causes the coral reef population to be in a condition of low resilience. Coral reef is only found on the marine deposition coast and anthropogenic coast typologies of the Arubara coast. Damage to coral reefs is caused by waves and as material for building houses. Damage to coral reef populations causes loss of habitat for fish populations. Fishing area for fishermen are becoming farther from coastal. This creates new problem. Simple fishing equipment and small boats result in small fish population and high fuel cost. The area of coral reef in the marine deposition coast and anthropogenic coast typology areas in 2016, 2017 and 2021 can be seen in table 5.

Table 5. Coral Reef Area in 2016-2021

No	Year	Area (m ²)
1	2016	37,6
2	2017	20,6
3	2021	12,4

Source : Analisis of Research Result, 2022.

Rehabilitation and conservation of coastal terrestrial vegetation needs to be carried out to increase the density and diversity of coastal vegetation. Ecosystem resilience is related to biodiversity. High diversity indicates the ecosystem is more resistant to disturbance. Ecosystem function is disrupted in ecosystems with high species diversity if one group cannot carry out its function. The positive impact of diversity in ecological functions is when there is a decrease in species diversity due to a disturbance without a subsequent decrease in ecosystem [23].

High vegetation density prevents a high risk of disasters. Vegetation can reduce coastal disasters such as abrasion and tidal waves. The absence of coastal vegetation (mangrove) which serves as a damper of wave energy and the characteristics of the beach which is dominated by sand, increasingly adds to the abrasion rate of the coast in the coastal area of Tamalate sub-district and coastal areas of Makasar City [24], [25]

Coral reef conservation increases the diversity and abundance of fish species. If the abundance and diversity of fish species is maintained, coastal communities will be resilient to their living condition. Utilization of coral fish resources is the main livelihood of the people of the Pulo Pasi Gusung Regional Marine Conservation Area, Selayar, South Sulawesi. Covering coral reefs in healthy conditions increases fish diversity and biomass. The potential for resilience or recovery of coral reefs tends to increase in line with decreasing fish density and biomass due to fishing by fishermen in the area [26]. The high dependence of society on coastal ecosystems causes a low level of resilience in the ecological system. Low ecological system resilience causes changes to the ecosystem. Ecosystem change is characterized by damage or degradation of the ecosystem. This is the main focus of human ecology as a parameter analyzed in measuring the resilience of coastal ecological system. According to [27], human intervention in the physical and biotic environment causing drastic and evolutionary changes in the form and function of ecosystems.

Efforts to increase resilience are not only carried out on ecological system parameter but also on human ecological parameter. Human ecological parameters are related to coastal community activities in the ecosystem. Increasing resilience in human ecological parameters aims to increase community capacity to anticipate and plan for the future to preserve natural resources. Each coastal area with a different typology will influence different coastal area management policies. The physical characteristics of coastal areas are used as a reference in planning, management, monitoring and evaluation of coastal area development. Management of coastal areas in the city of Ende according to landform

characteristics in the form of coastal typology has sustainable value for the ecosystem and physical coastal land, so that it is maintained.

4 Conclusion

Based on the resilience index analysis of ecological system parameter, ecological system of the coastal city of Ende generally has moderate resilience. Efforts to improve and increase the parameters of the ecological system in the coastal area of Ende city can maintain the resilience of the ecological system of the ecosystem. This moderate resilience class is mostly because of terrestrial vegetation density. Human ecological parameter increase the resilience of coastal ecosystem. Terrestrial vegetation density is mostly not dense. Although the suitability of land use is not suitable, vegetation and fauna diversity is low but it can be covered by dense of vegetation cover since it has high score criteria defining resilience index. Land cover and coastal materials in each typology influence the resilience of coastal ecosystem. Index resilience increases gradually from 2016 to 2021. Marine deposition coasts and wave erosion coasts have larger resilience index compared to other typologies in Ende City. Since the index of resilience generally increases from years to years, it is recommended to find out the reason that makes the coastal resilience ecology-based increase gradually.

5 Recommendation.

Efforts to make the ecological system in the coastal area of Ende city resilient are:

1. Ecosystem restoration or ecological restoration through vegetative land conservation. Ecosystem restoration or ecological restoration through vegetative land conservation. This effort was made to increase the density, diversity of vegetation and reduce the high risk of disaster. Vegetation in accordance with the characteristic of sandy beaches, namely Waru (*Hibiscus tiliaceus*), Pandan Pantai (*Pandanus tectoris*), Pine Shrimp (*Casuarina equisetifolia L*) and Ketapang (*Terminalia cattapa*).
2. Conservation of coral reef. Conservation of coral reefs to increase fish diversity.
3. Implementation of regional regulations regarding coastal borders that there is no development of new residential areas. Coastal border line is managed for green open space program and beach protection from coastal disasters.
4. Reduce pollution by adding and distributing trash can facilities according to the distribution of community activities. Construction of waste water treatment plant.
5. Education to the public about the impact of pollution on coastal tourist areas and the environment. Training for coastal communities to improve the community's economy and create a diversity of types of jobs. This activity reduces degradation of coastal ecosystems

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References

1. R.S. Oktari, Syamsidik, R. Idroes, H. Sofyan, K. Munadi, City Resilience towards Coastal Hazards: An Integrated Bottom-Up and Top-Down Assessment, *Water* **12**, 10 (2020)
2. T.S. Viehman, B.G. Reguero, H.S. Lenihan, J.H. Rosman, C.D. Storlazzi, E.A. Goergen, Coral Restoration for coastal Resilience: Integrating Ecology, Hydrodynamics, and Engineering at Multiple Scales, *Ecosphere* **14**, 5 (2023)
3. D.D. Battisti, The resilience of Coastal Ecosystems: A functional Trait-Based Perspective, *Journal of Ecology* **109**, 9 (2021)
4. A.M. Ágústsdóttir, Ecosystem Approach for Natural Hazard Mitigation of Volcanic Tephra in Iceland: Building Resilience and Sustainability, *Natural Hazards* **78**, 3 (2015)
5. C.S. Holling, Resilience and Stability of Ecological Systems, *Annual Review of Ecology and Systematics* **4** (1973)
6. C. Folke, S.R. Carpenter, B. Walker, M. Scheffer, T. Chapin, J. Rock-strom, Resilience thinking: Integrating Resilience, Adaptability and Transformability, *Ecology and Society* **15**, 4 (2010)
7. I. Kelman, J.C. Gaillard, J. Lewis, J. Mercer, Learning from The History of Disaster Vulnerability and Resilience Research and Practice for Climate Change, *Nat Hazards*, **82** (2016).
8. M. Sajjad, Y. Li, Z. Tang, L. Cao, X. Liu, Assessing Hazard Vulnerability, Habitat Conservation, and Restoration for the Enhancement of inland China's Coastal Resilience, *Earth's Future*, **6** (2018)
9. S. Robert, The Conceptual Framework of Ecological Resilience: A Long-term Approach. *Resilience: Persistence and Change in Landscape Forms* (John Wiley & Sons, Hoboken, 2021)
10. G. Masselink, E.D. Lazarus, Defining Coastal Resilience, *Water* **11** (2019)
11. S.F. Thrush, J.E. Hewitt, A.M. Lohrer, Interaction Networks in Coastal Soft-Sediments Highlight The Potential for Change in Ecological Resilience, *Ecological Applications* **22**, 4 (2022)
12. P. Capdevila, I. Stott, I.O. Menor, D.B. Stouffer, R.L.G. Raimundo, H. White, Reconciling Resilience Across Ecological Systems, Species and Subdisciplines, *Journal of Ecology* **109** (2021)
13. T.R. Suprobowati, Ekologi Bentang Lahan, *Laboratorium Ekologi dan Biosistemika, BIOMA* **13**, 2 (2011)
14. J. Sartohadi, Terapan Geomorfologi dalam Pengelolaan Sumberdaya Air, *Alami* **12**, 1 (2007)
15. T. Gunawan, L.W. Santosa, L. Muta'ali, S.H.M.B. Santosa, *Pedoman Survei Cepat Terintegrasi Wilayah Kepesisiran* (Badan Penerbit Dan Percetakan Fakultas Geografi, Yogyakarta, 2005)
16. H.S. Yunus, *Metodologi Penelitian Wilayah Kontemporer* (Pustaka Pelajar, Yogyakarta, 2017)
17. Odum, *Dasar-Dasar Ekologi: Edisi Ketiga* (Gadjah Mada University Press.F, Yogyakarta, 1998)
18. Keputusan Menteri Lingkungan Hidup Nomor 51 Tahun 2004 tentang Baku Mutu Air Laut., 2004, *KEPMEN LH RI*, Jakarta, (2004)

19. S.R. Carpenter, B.H. Walker, J.M. Anderies, N. Abel, From Metaphorto Measurement: Resilience of What to What?, *Ecosystems* **4** (2001)
20. A.T. Charles, *Sustainable fishery System* (Blackwell Science, Oxford, 2021)
21. M. Nystrom, C. Folke, Spatial Resilience of Coral Reefs, *Ecosystems* **4** (2021)
22. Muliani, L. Adrianto, S. Hariyadi, Rahman, A. Mukti, Resiliensi Sistem Sosial Ekologi Kawasan Desa Pesisir Kabupaten Subang, *Journal Grouper* **11**, 2 (2020)
23. D.S. Srivastava, M. Vellend, Biodiversity-Ecosystem Function Research: Is It Relevant to Conservation, *Annu. Rev. Ecol. Evol. Syst* **36** (2005)
24. I.G. Tejakusuma, Pengkajian Kerentanan Fisik untuk Pengembangan Pesisir Wilayah Kota Makassar, *J. Sains dan Teknologi Indonesia* **13** (2011)
25. Jasmani, A. Faizal, M. Lanuru, *The Threat of Extreme Wave Disasters and Coastal Abrasion in The Coastal Areas of Makassar City*, in *Proceeding of the IOP Conf. Series: Earth and Environmental Science* **235** (2019)
26. S. Kusumo, L. Adrianto, M. Boer, Suharsono, Indeks Resiliensi Terumbu Karang Dengan Pendekatan Sistem Sosial- Ekologi: Studi Kasus Kkpd Pulo Pasi Gusung, Selayar, *Journal of Fisheries and Marine Research* **3**, 2 (2019)
27. S. Ritohardoyo, *Bahan Ajar Ekologi Manusia (Program Studi Ilmu Lingkungan, Sekolah Pasca Sarjana Universitas Gadjah Mada, Yogyakarta, 2006)*