PAPER NAME

Ecological risk of coastal ecosystem.pdf

AUTHOR

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WORD COUNT

6586 Words

CHARACTER COUNT

33768 Characters

PAGE COUNT

16 Pages

FILE SIZE

1.3MB

SUBMISSION DATE

Apr 25, 2024 3:00 PM GMT+7

REPORT DATE

Apr 25, 2024 3:00 PM GMT+7

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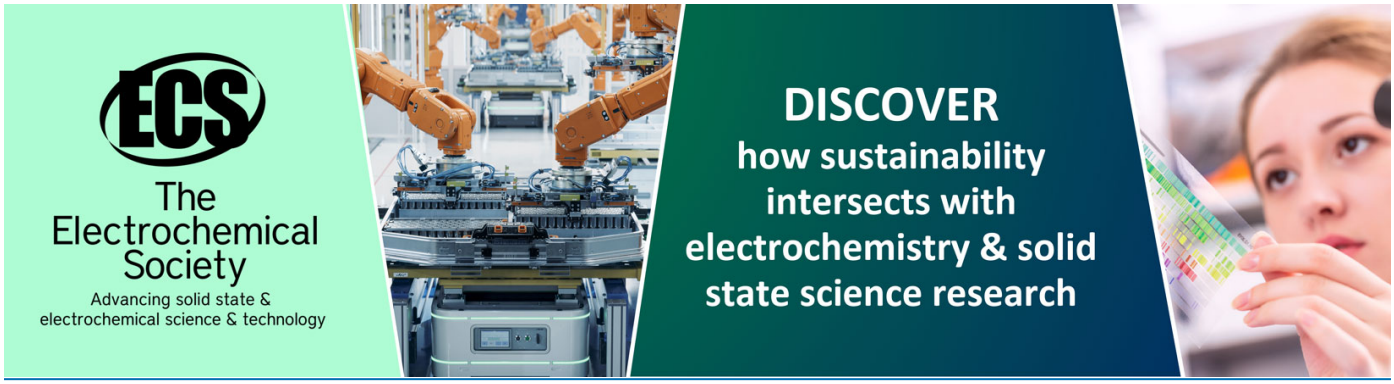

Ecological risk of coastal ecosystem: A perspective of mangrove ecological sensitivity in small islands, case in Anambas Archipelago District at Natuna Sea

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Abstract. The ecosystem sensitivity in the coastal and small islands is dependent on the vulnerability and resilience level of that ecosystem. Mangroves are one of the primary ecosystems in coastal areas, also high vulnerability and sensitivity due to natural factors such as waves, pollution, and due to the impact of human activities. Based on this reason, the study of vulnerability and sensitivity was needed for mitigation plans and other actions in reducing the risk due to the pressure by a coastal manager. This study was carried out around small islands in Anambas District, especially in Matak Island. The results showed that the level of mangrove vulnerability was relatively high at all locations; the condition of the ecological status was classified as moderate. The status of the social and economic index was classified as medium to high vulnerably. The assessment of the sensitivity level, known as the condition of mangrove ecosystems, is moderate to very sensitive. The areas with the highest sensitivity level are Peninting and Ayerbadong. The high sensitivity in both locations is due to the influence of the economic index, which indicates that the region is economically sensitive and potentially vulnerable.

1. Introduction

Matak Island and surrounding areas are groups of small tropical islands characterized by small embayments, estuaries, sandy and rocky beaches, mangroves, and coral reefs and considered biodiversity highly in terms of ecosystems and habitats. The Matak Island area is also in the middle of a massive economic development, which makes this area economically sensitive. Then also position in the Natuna Sea and Archipelagic Sea Lanes I potential to increase the impact of vulnerability and sensitivity in the coastal area.

The Environmental Sensitivity Index (ESI) study is an important program which can be further used as input for environmental management. Any activity on coastal and offshore of Matak Island, potential to increase the hazard, vulnerability, sensitivity, and risk to mangrove ecosystem. Overall, at the long time potential to reduce the carrying capacity of the coastal area.

Sensitivity determined as the potential impact on a system from perturbations, including shocks and stress [1]. The issue of sensitivity usually close relation to the topic of sustainable development. The sensitivity concept is one of the sustainability constraints together with, for example, the concept of

minimum safety standards, quality standards, carrying capacity, eco-capacity, maximum sustainable yield, critical loads, environmental utilization space, etc. [2]. All such concepts may be useful for policy analysis and operations planning.

The sustainability ecosystem express at least from four attributes [3] such as: (1) it is expressed in one or more measurable parameters; (2) these parameters are linked to sustainability targets; (3) the parameters have proper geographical scale; and (4) these parameters also have a relevant time dimension. It is also stated that ideally, these parameters should be mapped out as quantitative factors, but in reality, it is often confronted with qualitative, fuzzy and incomplete information [2]. In this context, therefore, a better understanding of the habitats and ecosystems and their sensitivity of the Matak Supply Base and surrounding areas in the western and northern parts of the Matak Island environment can be derived through the development of the Environmental Sensitivity Index (ESI).
The objectives of the study are to identify the sensitivity level of changes in both ecological and social conditions of coastal ecosystems, particularly mangrove ecosystem and human impact that cause the sensitivity area.

2. Materials and Method

2.1. Research area

The research area is in Matak Island, Anambas District, at the Natuna Sea (see figure 2). The sampling sites were selected by the team, along with the coastal areas that are inhabited by mangrove ecosystems. The survey activities cover four main divisions, i.e.: (i) Matak Jetty; (ii) Matak Strait; (iii) Peninting Strait; (iv) Ayerbandong and Mandilang Strait. The field survey and data collection were conducted on June 19th – 26th in 2014 ago. The kind of data that was collected at that location as follows: 1) Identification of the mangrove species in the study areas and its geographical position; 2) Estimation of density and other ecological function; 3) Sensitivity area map of the mangrove ecosystem. The type of data was collected in the location shown in the Table below.

Table 1. Types of Mangrove Data

No	Type of Data	Collection procedures	Equipment
1	Mangrove species	In-situ identification	Reference
2	Number of species	Direct counting	Counter
3	Diameter of tree	In-situ measurement	Roll meter
4	Coverage	Coverage estimation	-
5	Type of substrate	Visual Survey	-

Data collection was conducted in each habitat of mangrove found in the study area. On each site, the transect grid applied for species identification and density counting. Type of sediment, substrate, and associated fauna living in the mangrove was observed as well directly while sampling process.

2.2. Data analyses

2.2.1. Vulnerability index (VI)

The vulnerability value of the mangrove ecosystem is high because it grows in sensitive habitats that are vulnerable to pollution and the influence of rivers and oceans. Mangrove ecosystem was also known as a habitat for fish, crocodiles, migratory birds, fish nursery, and other resources. We have any sensitive ecosystem such as mangroves, brackish swamps, tidal areas, floodplain areas that classified as very high vulnerability areas by [5]. Therefore, the vulnerability index (VI) criteria of the mangrove ecosystem have a score value at 5 (very high).

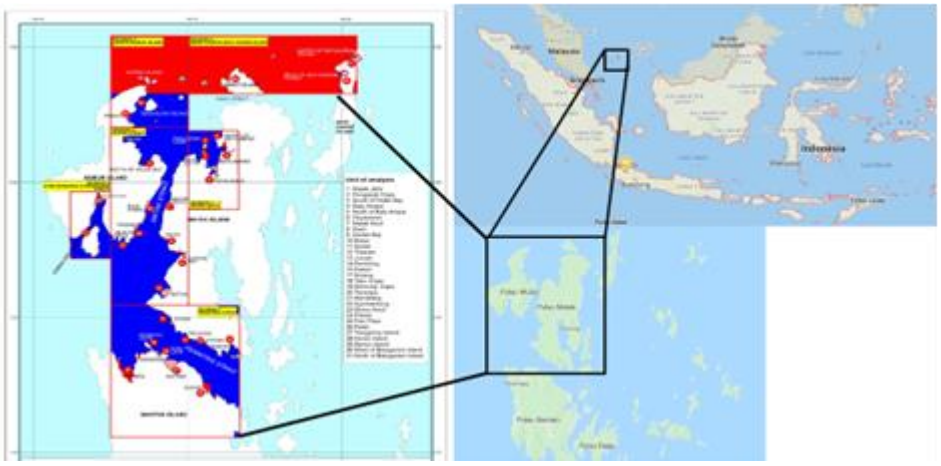

Figure 1. Site sampling in four divisions in Anambas Island [4]

Vulnerability score also refers to the sensitivity level of each species is according to its response against pollution, debris, or other pollutants on the mangrove area. Crude oils and sea waves can pool onto sediment surfaces and are highly persistent. These heavy oils and emulsified oil can be trapped in thickets of aerial roots (pneumatophores) by mangrove, especially on species *Avicennia* sp. While in a location, we found a susceptible species (*Avicennia* sp), can state as a highly vulnerable site. Based on the ability to recover from oil spill pollution, mangrove species can be divided onto five-level sensitivity such as Table 2.

Table 2. Sensitivity level and score based on species of mangrove [6]

Score	Sensitivity Level	Genus
1	Not sensitive	*Bruguiera*
2	Less Sensitive	*Lumnitzera, Xylocarpus, Scyphiphora*
3	Moderate	*Rhizophora, Ceriops*
4	Sensitive	*Sonneratia, Excoeceria*
5	Very sensitive	*Avicennia*

2.2.2. Mangrove ecology index (EI)
The first activity of analysis mangrove ecology is identified of mangrove species, through in-situ observation according to the book of mangrove identification [7,8]. Data analysis of mangrove ecology consists of species diversity, density, the status of protection, wildlife habitat, and tidal exposure to mangrove habitat.

2.2.3. Mangrove Species Diversity
Species diversity was calculated on each site of mangrove area based on occurrence mangrove species in each habitat mangrove. The higher number of species found, also increasing mangrove diversity. Value and score of mangrove diversity shown in Table 3.

2.2.4. Mangrove Species Density (Di)
The species density (Di) is the number of a mangrove tree in a specific area:

$$D_i = \frac{n_i}{A} \quad \text{.....(1)}$$

Where, D_i is species density of species-i; ni is the total number of the tree of species-i, and A is a sample area where data collected.

2.2.5. Protected of Mangrove area

Protected area mangrove means showing the status of the mangrove area, whether as a protected area or not. If it is a protected area, the area level was classified as a regional or national protected area.

2.2.6. Wildlife habitat

Wildlife habitat means whether the mangrove area is a habitat for wild biota or not, and have functioned as preservation endanger species. Therefor information or recording about wildlife in mangrove forests needed to set a protection program. The increasing number of endanger or endemic species in the mangrove ecosystem show that an increase of sensitivity. The higher number of wildlife criteria shows a critical habitat and sensitivity score value higher too.

2.2.7. Tidal exposure

Tidal exposure defined as the potential impact from the tidal process to coastal or mangrove are and also wave and sea current. While in an extreme wave, the mangrove area potential has an abrasion or rob flood in the terrestrial area. The important thing mangrove function is as coastal protection from wave, rob, and tidal dynamic. The higher tidal frequency or extreme wave on the mangrove area means increasing sensitivity on the mangrove ecosystem and score value high.

The next step environmental sensitivity index (ESI) is scoring parameters in each criterion above. The score value range from 1-5 (low-grade to high-grade). [5] Categorized the vulnerability value for mangrove into five scoring criteria. The scoring criteria for the ecological indicator on mangrove parameter as described above shown in Table 3 and 4.

Table 3. Score and Criteria of Each Variable in Ecological Value (*Ev*) for Mangrove

Score	Diversity (Number of Species)*	Mangrove Density (and/ha)*	Protected**)	Wild Life Habitat (NoS)**)	Tidal exposure ***
1	1	< 500	Not protected	Not Exist	Low exposure
2	-		-	1-2	-
3	< 3	501-1000	Locally Conserved	3	Medium exposure
4	-		-	-	-
5	> 3	> 1000	Nationally Conserved	> 3	High exposure

Sources: *) Developed from [9,10]; **) Developed from [11]; ***) Developed from [11,12]

The criteria for ecological values of mangrove ecosystem is presented in Table 4. The range of value in each description score determined based on the potential record of data and any judgment related to mangrove research. The traceability score in each criterion, there are also remark or a reference by the researcher to expand.

Table 4. Criteria for Ecological Values of Mangrove Ecosystem.

Criteria	Weight	Score	Description	Remark
Diversity*)	0,3	1	One mangrove species was recorded	The number of species found in the study area ranges from 1 to 5 species
		< 3	Two mangrove species were recorded	
		> 3	More than three mangrove species were recorded	
Mangrove*) Density	0,15	< 500	Less than 500 trees/ha	Mangrove density in the study area ranges between 300-1400 trees/ha (offshore) and between 1000-1500 trees/ha (onshore)
		501-1000	Between 500 to 1000 trees/ha	
		> 1000	More than 1000 trees/ha	
Designated Protected Area**)	0,1	Not protected	The mangrove area was not categorized as a protected area	Part of mangrove ecosystems in the River Division 4 (onshore barging) area is nationally protected by law
		LC (Locally Conserved)	The mangrove area is locally protected (green belt area)	
		NC (Nationally Conserved)	The mangrove area is nationally protected (national park)	
Wildlife Habitat**)	0,25	NE (Not Exist)	The protected wildlife is not found	The protected species were commonly found in Division 4 (onshore barging)
		1-2	1 -2 protected wildlife species found	
		3	Three protected wildlife species found	
		>3	More than three protected wildlife species found	
Tidal Exposure***)	0,2	Low Exposure	Not influenced by the tide	Whole mangrove area in the offshore and onshore (Division 4) are commonly highly influenced by the tidal
		Medium Exposure	Moderately influenced by the tide	
		High Exposure	Highly influenced by the tide	

Sources: *) Developed from [9], [10]; : **) Developed from [11]; : ***) Developed from [11], [12]

2.2.8. Socio-economic index

Socio economy data that relate to mangrove are cover demographic structure and its parameters, sensitive area (in the perspective of socio-economy), and mapping. Socio economy data analyses are comprised of, i.e., age structure, population income and expenditure, socio-economic valuation, and development of environmental sensitivity index of the local communities socio-economic at the Matak Supply Base and surrounding areas in the western and northern parts of Matak Island. As mentioned, socio-economic value is similar to the Social Values Index (SI), which comprises the economic value index (ESV) and the social value of resource uses (SV). The formula of the Social Values Index (SI) as follows [13].

$$SI = \sum(SV, EcV) \quad (2)$$

Where, SI is the social value index; SV is the social value of the resources component, and ESV = economic value component of the resources.

2.2.9. Social value

Social value for the mangrove ecosystem is calculated based on criteria such as (i) tourism development potential area, (ii) fishing ground, and (iii) other mangrove utilization such as for construction/housing materials.

Table 5. Criteria for Social Values of Mangrove Ecosystem

No.	Description	Criteria
1	Potential tourism development area	Very potential = 5; Potential = 4 Moderate = 3; Less Potential = 2 Not potential = 1
2	Fishing ground	Very intensive = 5; Intensive = 4 Moderate = 3; Rare = 2 None = 1
3	Other utilisation	Highly Utilized = 5; Utilized = 4 Moderate = 3; Less utilized = 2 None = 1

Source: Adopted and modified from [14]

The social value is calculated through a geometrical average as described in the following formula:

$$SV_j = \sqrt[3]{\left(S_{j1} * S_{j2} * S_{j3}\right)}, \quad (3)$$

Where; SV*j* is the social value of *j* site; S*ji* is score value criteria of i-social value at *j*- site.

2.2.10. Economic value

The economic value of mangrove resource is calculated based on the geometrical average of social value and ecological value multiplied by the standardized economic value of mangrove resource /ha/year issued by (Ministry of Environment KLH 1999) , i.e. USD 15,877.42/ha/year. This value was taken from similar research in Barelang and Bintan Island, which is an assumption to be identical to the recent study [13].

$$EcV_j = \sqrt[4]{\left(S_{j1} * S_{j2} * S_{j3} * Ev\right)} * 15{,}877.42, \quad (4)$$

Where, S*ji* is score value criteria of i-economic value at *j*- site; it was then justified to result in the weighted score through the following formula [13]:

$$EcV_i = \frac{EcV_{ij}}{EcV_{i-\max}} * 5, \quad (5)$$

EcVi is the economic value of mangrove resource at i-site; EcV*ji is* shown the economic value of mangrove of 1....n; EcV*ji-max* is the maximum economic value of mangrove resource observed.

2.2.11. Social Economic Index (SI)

The economic value of mangrove resource calculated through the following formula [13]:

$$SI_j = \sqrt[2]{(SV_j * EcV_j)}, \quad (6)$$

Where, SI*j* = socio-economic value of j-site, SV = social value, and EcV = economic value.

2.2.12. Environmental sensitivity index analysis (ESI)

An Environmental Sensitivity Index (ESI) value describes the relative environmental sensitivity of each area was calculated and displayed on the spatial profile. The area to be outlined on the sensitivity maps represents an integration of three main components of the ESI, namely Vulnerability Index (VI), Ecological Index (EI), and Social Index (SI). The integration of these values can be represented in a composite equation, as described in Equation [5].

$$CESI_i = VI * EI * SI \quad (7)$$

Where, $CESI_i$ is the composite ESI of $area_{1...i}$; VI is the vulnerability index; EI is the ecological index; and SI is social values index (SI), which comprises economic value index (EcV) and social value of resources use (SV) with formulas as below.

$$VI_i = (\sum_{j=1}^{n} VCj)^{-n} \quad (8)$$

$$EI = (\sum_{j=1}^{n} ECj)^{-n} \quad (9)$$

$$SI = (\sum_{j=1}^{n} SCj)^{-n} \quad (10)$$

Where, VC is vulnerability components (shoreline values); EC is ecological components (ecosystem value and species value), and SC is social components (economic values and social-uses values). Each component, i.e., vulnerability, ecological and social, has a value between 1 (minimum = the least sensitive) to 5 (maximum = the most sensitive). Since the composite ESI (CESI) is a multiplication among these components, hence the CESI values range from 1 (the least sensitive) to 125 (the most sensitive). This formula is developed by [15] which is inspired by ESI guidelines [11]. Therefore, the composite environmental sensitivity index (CESI) has a value between 1 – 125 and is categorized as follows (Table 6).

Table 6. Level of Sensitivity Based on CESI Values [15]

CESI Value	Sensitivity Level
1	Not Sensitive
2 – 8	Less Sensitive
9 – 27	Moderate
28 – 64	Sensitive
65 – 125	Very Sensitive

3. Results and Discussion

The reduction of mangrove coverage is a common cause of human settlements or other conversions such as at Antang and Butun. However, the mangrove ecosystem in Payalaman relatively stable, and no significant changes was observed, while Mangrove in Batu Ampar and Mandilang naturally grow and slightly expand in height and width of the tree.

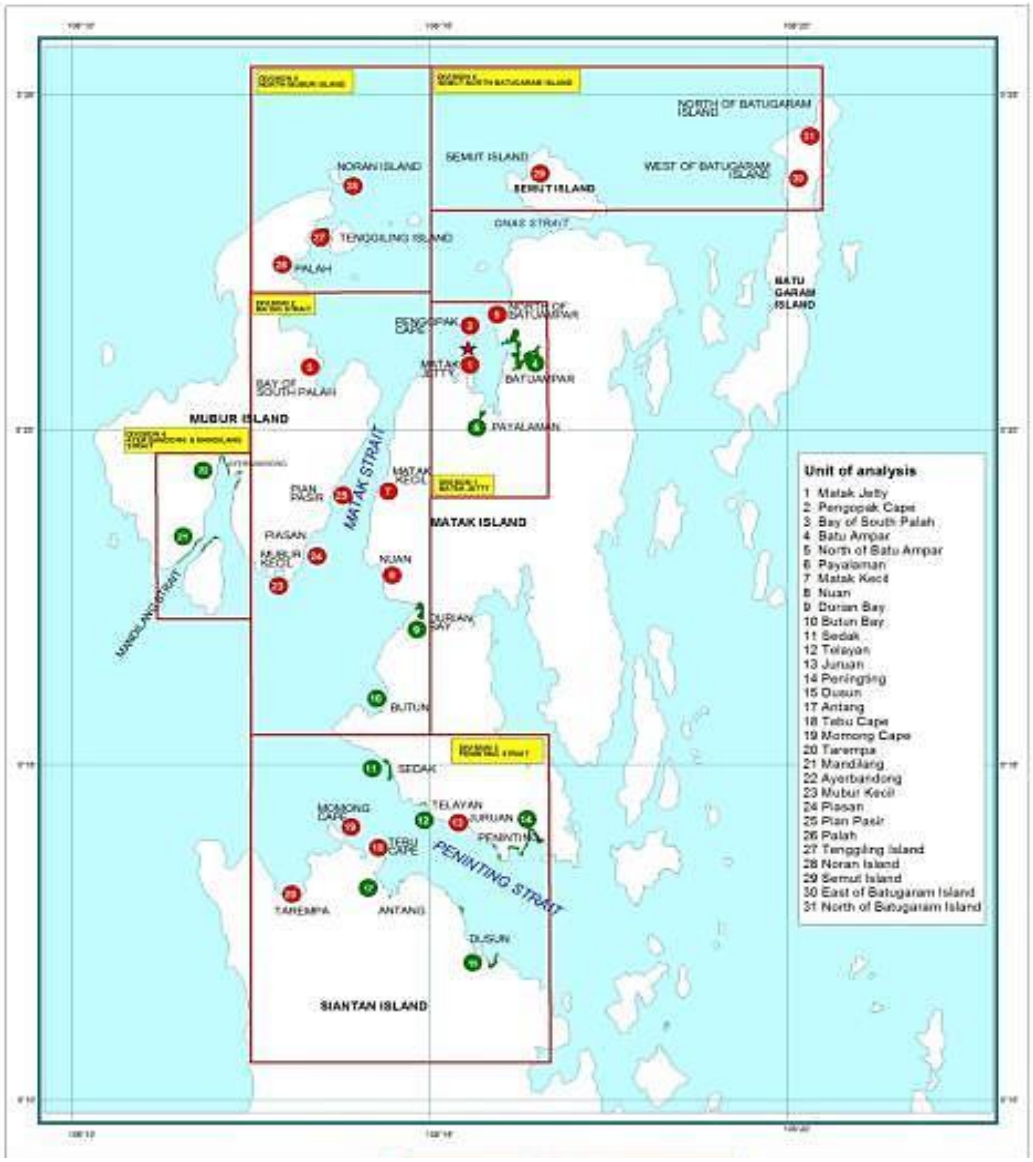

Figure 2. Map of Mangrove Distribution in Matak Island

Mangrove ecosystems in the western and northern part of Matak Island and the surroundings have a significant ecological function, environment and socio-economic functions which include: 1) to Maintain coastal water quality; 2) to reduce the severity of impact from the coastal storm, wave, and flood damage; 3) as Nursery areas and feeding grounds for commercial fisheries; and 4) as important habitat and feeding grounds for benthic and birds. The mangrove ecosystem found in the study area has unique characteristics since it is located on rocky islands with a minimum supply of freshwater, indicated by a lack of major estuary. A similar condition is also observed in the western and northern coastline of Matak Island and other surrounding small islands.

3.1. Vulnerability and ecological index

The ESI value of the mangrove ecosystem is calculated based on vulnerability value, ecological value, and social value. Based on CESI criteria, the vulnerability index of mangrove towards oil spills is the highest (the most vulnerable) while it was located in the intertidal area with a muddy substrate.

Table 7. Ecological Variable Status of Mangrove Ecosystems

No Unit Analysis	Unit Analysis	Criteria				
		Diversity	Density	Protected/ Unprotected	Wildlife	Tidal Exposure
Division 1. Matak Jetty						
4A	Batu Ampar A	3	600	Unprotected	Not Exist	Full Exposure
4B	Batu Ampar B	2	800	Unprotected	Not Exist	Full Exposure
6A	Payalaman A	2	800	Unprotected	Not Exist	Full Exposure
Division 2. Matak Strait						
9A	Durian A	4	1000	Unprotected	Not Exist	Full Exposure
10B	Butun B	3	400	Unprotected	Not Exist	Full Exposure
Division 3. Peninting Strait						
11A	Sedak A	2	400	Unprotected	Not Exist	Full Exposure
11B	Sedak B	3	500	Unprotected	Not Exist	Full Exposure
12	Telayan	1	100	Unprotected	Not Exist	Full Exposure
14A	Peninting A	2	700	Unprotected	Not Exist	Full Exposure
15A	Dusun A	3	700	Unprotected	Not Exist	Full Exposure
15D	Dusun B	3	700	Unprotected	Not Exist	Full Exposure
17A	Antang A	1	100	Unprotected	Not Exist	Full Exposure
17B	Antang B	3	500	Unprotected	Not Exist	Full Exposure
Division 4. Ayerbandong – Mandilang						
21A	Mandilang A	3	600	Unprotected	Not Exist	Full Exposure
21B	Mandilang B	3	700	Unprotected	Not Exist	Full Exposure
21C	Mandilang C	3	700	Unprotected	Not Exist	Full Exposure
22A	Ayerbandong A	3	900	Unprotected	Not Exist	Full Exposure
22B	Ayerbandong B	4	800	Unprotected	Not Exist	Full Exposure

Remarks: NoS = Number of Species

It means that the mangrove ecosystem is easily exposed to the oil spill and absorbs oil at the event of an oil spill. Mangrove is vulnerable since this plant is biologically sensitive to oil exposure considering its habitat for many aquatic biotas such as fish, crustaceans, echinoderms, mollusks, benthic animals, plankton and terrestrial wildlife. Besides, the mangrove ecosystem also plays a significant role in supporting local fisheries, as they are functioned as a nursery ground, feeding ground, and spawning ground [16]. Mangrove ecosystem as the most sensitive area to oil spill since this ecosystem has a complicated physical configuration and muddy substrate, which is difficult to clean up while spilling event [11].

The maximum number of mangrove species that have been observing in the study area are 4 (four) species, with density ranges from 200 – 1,000 ind/ha. Mangrove areas were not explicitly categorized as a protected area (i.e., Nature Reserve and Nature Conservation Areas). However, based on Indonesian law, mangrove is categorized as a protected area as stipulated in Presidential Decree No. 32/1990 regarding Protected Area Management. As a small island ecosystem, the most of mangrove ecosystems in the study area were exposed to tidal wave except at Dusun Sedak. The mangrove ecosystem in Dusun Sedak relatively protects by rubble and stone. This research also found some changes in mangrove coverage were observed and mostly causes by conversion into human uses mainly as settlements. However, it is also found increasing of mangrove width and tree height at Ayerbandong. An ecological variable of mangrove ecosystem in the study area is described in Table 7. In addition, the ecological value for the 2014 survey in each component then determined by the above data and presented in Table 8.

Table 8. Ecological Score of Mangrove Ecosystem

No Unit Analysis	Unit Analysis	Score				
		Diversity	Density	Protected	Wildlife	Tidal Exposure
Division 1. Matak Jetty						
4A	Batu Ampar A	3	3	1	1	5
4B	Batu Ampar B	3	3	1	1	5
6A	Payalaman A	3	3	1	1	5
Division 2. Matak Strait						
9A	Durian Bay A	5	3	1	1	5
10B	Butun B	3	1	1	1	5
Division 3. Peninting Strait						
11A	Sedak A	3	1	1	1	5
11B	Sedak B	3	3	1	1	5
12	Telayan	1	1	1	1	5
14	Peninting A	3	3	1	1	5
15A	Dusun A	3	3	1	1	5
15B	Dusun B	3	3	1	1	5
17A	Antang A	1	1	1	1	5
17B	Antang B	3	3	1	1	5
Division 4. Ayerbandong – Mandilang						
21A	Mandilang A	3	3	1	1	5
21B	Mandilang B	3	3	1	1	5
21C	Mandilang C	3	3	1	1	5
22A	Ayerbandong A	3	3	1	1	5
22B	Ayerbandong B	5	3	1	1	5

Each criterion of each mangrove site is then weighted to know its ecological index, as shown in the Table 9.

Table 9. Ecological Index of Mangrove Ecosystem

No Unit Analysis	Unit Analysis	Score					
		Diversity	Density	Protected	Wildlife	Tidal Exposure	EI
Division 1. Matak Jetty							
4A	Batu Ampar A	0.9	0.45	0.1	0.25	1	2.7
4B	Batu Ampar B	0.6	0.45	0.1	0.25	1	2.7
6	Payalaman A	0.9	0.45	0.1	0.25	1	2.7
Division 2. Matak Strait							
9A	Durian Bay A	1.5	0.45	0.1	0.25	1	3.3
10B	Butun B	0.9	0.15	0.1	0.25	1	2.4
Division 3. Peninting Strait							
11A	Sedak A	0.6	0.15	0.1	0.25	1	2.4
11B	Sedak B	0.9	0.45	0.1	0.25	1	2.7
12	Telayan	0.3	0.15	0.1	0.25	1	1.8
14	Peninting A	0.9	0.45	0.1	0.25	1	2.7
15A	Dusun A	0.9	0.45	0.1	0.25	1	2.7
15B	Dusun D	0.9	0.45	0.1	0.25	1	2.7
17A	Antang A	0.3	0.15	0.1	0.25	1	1.8
17B	Antang B	0.9	0.45	0.1	0.25	1	2.7
Division 4. Ayerbandong – Mandilang							
21A	Mandilang A	0.9	0.45	0.1	0.25	1	2.7
21B	Mandilang B	0.9	0.45	0.1	0.25	1	2.7
21C	Mandilang C	0.9	0.45	0.1	0.25	1	2.7
22A	Ayerbandong A	0.9	0.45	0.1	0.25	1	2.7
22B	Ayerbandong B	1.5	0.45	0.1	0.25	1	3.3

3.2. Socio-economic index

The economic value of a mangrove ecosystem is defined by the function of a mangrove ecosystem in supporting economic activities and the daily life of the local people living nearby. The social benefits of the mangrove ecosystem can be classified as direct and indirect benefits. The direct benefit is defined by the use of mangrove trees for firewood (Tancang or *Rhizophora* sp.), traditional rooftop or thatching (*Nypa fruticans*), and construction materials (*Sonneratia* sp. and *Rhizophora* sp.). The indirect benefit defined as protection and conservation function of mangrove area as well as a nursery ground for larvae and juveniles of fishes and crustaceans and feeding ground for some marine biota. Mangrove functions also as a spawning ground for some marine biota. The Social Index of Mangrove in the study area ranges from 1.82 to 4.15. The highest index was found in the north of Peninting, and the lowest index at the estuary of Antang river. The detail of the socio-economic parameters was shown in **Error! Not a valid bookmark self-reference.**10.

3.3. ESI for mangrove ecosystem

ESI for mangrove was defined as a composite calculation by vulnerability index, ecological index, and social-economic index. The multiplication of those indexes is a composite ESI, as listed in. The ESI classes were varied from moderate to very sensitive. Mangrove ecosystem at West of Batu Ampar A, and Peninting A are classified as very sensitive, while Mangrove in Antang and Mandilang B are

categories as moderate, and other areas categorized as sensitive. Based on survey ESI class from moderate to very sensitive. The moderate areas are Telayang and Antang Cape, and the very sensitive area is Ayerbandong A and Ayerbandong B.

Table 10. Social-economic Index for Mangrove Ecosystem

No.	Unit of Analysis	Tourism potential	Fishing activities	Other use of mangrove	SV	Biomass	Quality (%)	Resource economic value (USD ha/year)	EcV	SI
Division 1. Matak Jetty										
4A	Batu Ampar A	4	4	4	4	1,312.82	49.58	31,488.48	3.00	3.46
4B	Batu Ampar B	4	4	4	4	1,956.98	73.91	46,938.90	4.00	4.00
6A	Payalaman A	3	3	4	3.3	1,905.50	71.96	34,278.10	3.00	3.15
Division 2. Matak Strait										
9A	Durian Bay A	3	3	4	3.3	2,647.85	100.00	47,632.26	4.00	3.63
10B	Butun B	3	3	4	3.3	1,779.10	67.19	32,004.29	3.00	3.15
Division 3. Peninting Strait										
11A	Sedak A	4	4	4	4	984.04	37.16	23,602.57	2.00	2.83
11B	Sedak B	4	4	4	4	769.32	29.05	18,452.43	2.00	2.83
12	Telayan	5	3	4	3.91	429.44	16.22	10,859.49	1.00	1.98
14A	Peninting A	4	5	5	4.64	2,397.52	90.55	61,945.84	5.00	4.82
15A	Dusun A	4	5	4	4.31	2,030.66	76.69	52,467.10	5.00	4.64
15B	Dusun D	4	5	4	4.31	1,753.36	66.22	45,302.38	4.00	4.15
17A	Antang A	3	3	4	3.3	984.04	37.16	17,701.93	2.00	2.57
17B	Antang B	3	4	3	3.3	492.02	18.58	9,741.75	1.00	1.82
Division 4. Ayerbandong – Mandilang										
21A	Mandilang A	3	4	4	3.63	1,753.36	66.22	34,715.64	3.00	3.30
21B	Mandilang B	3	4	4	3.63	1,476.06	55.75	29,225.24	3.00	3.30
21C	Mandilang C	4	4	4	4	1,764.39	66.63	42,319.56	4.00	4.00
22A	Ayerbandong A	4	4	5	4.31	1,590.12	60.05	38,139.63	4.00	4.15
22B	Ayerbandong B	4	4	5	4.31	1,716.52	64.83	41,171.38	4.00	4.15

Remarks: SV = Social Value; EcV = Economic Value; SI = Social-economic Index

Table 11. Environmental Sensitivity Index for Mangrove Ecosystem

No. Unit Analysis	Unit Analysis	ESI Component			ESI	ESI Class 2014	ESI Class 2012	ESI Clas 2009
		VI	EI	SI				
	Division 1. Matak Jetty							
4A	Batu Ampar A	5	2.7	3.46	46.71	Sensitive	Sensitive	Very Sensitive
4B	Batu Ampar B	5	2.7	4.00	54.00	Sensitive	Sensitive	Sensitive
6A	Payalaman A	5	2.7	3.15	42.53	Sensitive	Sensitive	Sensitive
	Division 2. Matak Strait							
9A	Durian Bay A	5	3.3	3.63	59.90	Sensitive	Sensitive	Sensitive
10B	Butun Bay B	5	2.4	3.15	37.80	Sensitive	Sensitive	Sensitive
	Division 3. Peninting Strait							
11A	Sedak A	5	2.4	2.83	33.96	Sensitive	Sensitive	Sensitive
11B	Sedak B	5	2.7	2.83	38.21	Sensitive	Sensitive	Sensitive
12	Telayan	5	1.8	1.98	17.82	Moderate	Moderate	Moderate
14A	Peninting A	5	2.7	4.82	65.07	Very Sensitive	Very Sensitive	Very Sensitive
15A	Dusun A	5	2.7	4.64	62.64	Sensitive	Sensitive	Very Sensitive
15D	Dusun D	5	2.7	4.15	56.03	Sensitive	Sensitive	Sensitive
17A	Antang A	5	1.8	2.57	23.13	Moderate	Moderate	Sensitive
17B	Antang B	5	2.7	1.82	24.57	Moderate	Moderate	Moderate
	Division 4. Ayerbandong – Mandilang							
21A	Mandilang A	5	2.7	3.30	44.55	Sensitive	Sensitive	Sensitive
21B	Mandilang B	5	2.7	3.30	44.55	Sensitive	Sensitive	Sensitive
21C	Mandilang C	5	2.7	4.00	54	Sensitive	nad	nad
22A	Ayerbandong A	5	2.7	4.15	56.03	Sensitive	Sensitive	Sensitive
22B	Ayerbandong B	5	3.3	4.15	68.48	Very Sensitive	Sensitive	Sensitive

Remarks: VI = Vulnerability Index; SI = Social-economic Index; EI = Ecological Index;
ESI = Environmental Sensitivity Index; Nad = Not available data

Table 11 shows the values ESI and sensitivity levels of each unit of analysis in the study area. It shows that based on the 2012 study, the mangrove ecosystem in the study area have a sensitivity level ranges from moderate to very sensitive. Compare to the distribution of sensitivity levels in the 2009 study, and it can be seen that there are changes in sensitivity level at Batu Ampar A, Telayan, Antang B and Mandilang B. Significant difference of ESI in 2014 is observed at Ayerbandong B due to increasing of mangrove width and tree diameter species of *Rhizopora sp.* and *Bruquiera* sp.

The sensitivity level in Matak Jetty division ranges from less sensitive to very sensitive. The less sensitive is found along the rocky shoreline with low economic activities. In contrast, the sensitivity level is located in the mangrove area, which is highly essential both from an ecological and economic point of view. The Sensitive level is the mangrove ecosystem in Batu Ampar. The waters area of the bay is classified as a moderate level to sensitivity, while local people utilized the area as a fishing

ground. The fishing activities of local people consider as the main economic factor which determined the moderate level of sensitivity.

ESI status in Matak Strait Division, the dominant level of sensitivity is Moderate. The Sensitive level is only limited to a small area of mariculture activity of Butun Bay and Pian Pasir. The waters site of this division is classified as moderate in level of sensitivity since the area is ecologically and economically important but at a moderate level of intensity. The area is also used by local people as fishing ground but not at an intensive level.

ESI value in Peninting strait division, the sensitivity level range is moderate to very sensitive. Most of the shoreline types are categorized as less sensitive since they are dominated by the rocky substrate. The sensitive levels are found in Tarempa, Momong Cape, Tebu Cape, Antang, and Sedak. The very sensitive level is found in Tebu Cape for its tourism site, in an area between Dusun to Mabay bay, where a combination of sandy and muddy substrate inhabited by mangrove and coral reef ecosystems; Peninting, for its mangrove ecosystem and Tarempa A for its settlements.

The last ESI Ayerbadong and Mandilang division, the sensitivity level range from moderate to sensitive. This result shows changes of ESI for Ayerbandong B from a sensitive to very sensitive due to the increase of mangrove biomass. Locations that have the highest ESI value are those with the highest ecological risk. The area must be given the earliest priority in efforts to protect against various potential pollution. Locations with a lower index indicate low environmental risk and low impact on the ecosystem.

4. Conclusions

Typically for islands in the north part of Matak Island, they are characterized by rocky shoreline since they directly face the open sea of South China Sea. No mangrove ecosystem has been found in this division due to the rough hydrodynamics environment. Open waters in this area are part of the South China Sea, which is habitat for protected wildlife, i.e., the bottlenosed-Dolphin (*Tursiops* sp.) and Hawksbill sea turtle (*Eretmochelys imbricate*); hence the area is classified as very sensitive. The mangrove sensitivity range from moderate to very sensitive in two sites in which the highest are in Peninting and Ayerbadong. The other site show as sensitive dan moderate. The highest percentage of the sensitive area shows that this ecosystem potential to have an impact on human or other failure activity in offshore or nearshore. To avoid and decease of sensitivity needed a strategic plan and mitigation of pollution impact on the mangrove ecosystem.

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