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THE CHANGES OF COASTAL ECOSYSTEM IN EAST SERAM DISTRICT, MALUKU PROVINCE, INDONESIA AND ITS IMPACT ON THE JULUNG-JULUNG FISH (*Hemirhamphus* sp) RESOURCES

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Abstract

The sub-district of East Seram (SBT) is the oldest district in the East Seram Regency, Maluku Province, Indonesia. Ninety percent of this area is covered by the sea with 3 unique tropical coastal ecosystems, namely mangroves, seagrass, and coral reefs. This high productivity ecosystem provides various goods and environmental services in fisheries, tourism, and other industries. One of them is coastal resources such as Julung-julung fish (Half-beak, Hemirhamphus spp) that use this ecosystem for their primary habitat. Unfortunately, little is known about the interaction between Julung-julung and their habitat. This paper aims to assess the changes of the coastal ecosystem of the SBT and their impact on Julung-julung resources. Two satellite images of Landsat-7 ETM+ (2001) and Sentinel-2A (2018) were analyzed to monitor the condition changes of mangrove and seagrass. Six habitat classes of sea, land vegetation, mangrove, dense, medium, and sparse seagrass were classified using iso-cluster analysis, validated using ground truth data collected during intensive field survey, and then the areas of each habitat class were calculated. From the period of 2001 to 2018, the areas of mangrove and seagrass have decreased from 1401.5 to 1118.8 ha, and from 3183.8 to 2509.4 ha, respectively. The decrease of mangroves was due to mangrove cutting for firewood that use to smoke Julung-julung, one of the famous fish products from the SBT, while mining dead coral for building materials in seagrass beds decreased their areas. Interview with experienced SBT's fishers in catching Julung-julung showed that the population of this fish has decreased by about 30-50% within 20 years, which was most likely due to the impact of their habitat degradation. In contrast, the decrease of Julung-julung stocks in other province was mostly due to overfishing. Thus, maintaining, conserving, and revitalizing the mangrove and seagrass ecosystems in the SBT as the important habitat for the early life history of Julung-julung is inevitable, as well as it is necessary to immediately conduct in-depth study on biological and population dynamics of this fish, whose data is still lacking, so that the Julung-julung stocks can manage sustainably.

***Keywords**: Mangroves, Seagrass bed, Satellite images, Julung-julung fish, The SBT.*

Introduction

East Seram District (SBT) is the oldest district in East Seram Regency, Maluku Province, Indonesia. The SBT was originally the parent of several divided sub-districts. Ninety percent of

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the SBT is covered by the sea, while the coastal area consists of complete tropical ecosystems, the coral reefs, seagrass, and mangroves. These ecosystems contribute high coastal productivity more than the tropical rainforest productivity [1], which produces goods and environmental services that greatly benefit the people who live nearby [2].

According to the calculation of Conservation International/CI [3], the average net economic potential value of sustainable use of coral reefs per year in Indonesia from fisheries, shoreline protection, tourism, and aesthetic value is estimated to be US$ 1.6 billion/year or US$ 31,373/km^2. Limited data on the economic valuation of the seagrass ecosystem shows a value of US$ 3.63 million or US$ 2.3 thousand/year/ha consisting of contributions from the tourism, fisheries sectors, and aesthetic value of US$ 2.45 million, US$ 1.12 million, and US$ 55.56 thousand, respectively for seagrass beds in Bintan Island in 2006 [4]. The newest data of the total economic value of seagrass (Direct use value+Indirect use value+Option value+Existence value) in Berakit Village, Bintan Regency, Riau Islands is IDR (Indonesian Rupiah) of 6.486 billion/year [5]. The economic valuation of mangroves in several parts of Indonesia varies widely, namely an average IDR of 29.2 million/ha/year for the location of Batu Ampar, East Kalimantan; Segara Anakan, Central Java; North Subang, West Java; Bintuni Bay, Papua; and Mallacca Strait for 2004 [6], and amounting to IDR of 60.9 million/year for mangroves in Kotania Bay, West Seram, Maluku in 2005 [7]. The latest data shows a value IDR of Rp15.5 million/year for mangroves in Wori District, North Minahasa in 2015 [8], and IDR of 40.7 million/ha/year for mangroves in North Gorontalo in 2017 [9], and IDR of Rp54.1, 17.4, and 26.6 million/ha/year for the mangroves of Kutawaru, Pemogan, and Tuban Villages, East Java, respectively in 2019 [10]. In the meantime, seagrass, mangroves, and brackish swamps play an important role as carbon sinks (blue carbon) which are 55% more effective than terrestrial forests [11].

The SBT is populated by 3,300 families living across 8 small islands, which all are dependent on the sea. Out of the 3,300 families, 898 are families of fishers with the total of 1,262 people (27.2%). Based on the data collected by our sosio-economic survey team, the average income of the SBT's fishers/month is IDR 165.6 million/year or IDR 13.6 million/ month, which is 8.8 times higher than the income/capita of the average casual workers in Ambon, the capital of Maluku Province that only IDR 1.56 million/capita. This shows the fisheries sector is a leading sector, proven by the ability to boost the rate of economic growth in the SBT. The contribution of products from the ecosystem to fishers in the SBT includes seaweed and fishes, such as coral reef fishes with high potential among the Indonesian Fisheries Management Area/WPP 714, the Banda Sea [12]. Other fish resources are small and large pelagic fish (tuna) because the location of the SBT also facing oceanic waters, the Banda Sea. Another famous fish from the SBT is Julung-julung (*Hemiramphus* spp.) that is closely associated with the existence of mangrove and seagrass ecosystems.

Even though the SBT has a complete ecosystem that is rich in coastal living resources, the use of the resources was not environmentally friendly. Examples include cutting down the mangrove trees for firewood and using them to smoke Julung-julung, which is the famous fish product from the SBT. Mining of dead coral in the seagrass ecosystem for building materials has also exacerbated the damage to these two ecosystems. Meanwhile, these ecosystems are important in the early life history of Julung-julung. The lack of data and information regarding the degradation of mangrove and seagrass ecosystems makes monitoring, utilization, and sustainable management of Julung-julung resources is difficult to conduct. Furthermore, information about the dynamics between Julung-julung and mangrove-seagrass ecosystems is also still limited. This study aims to analyze the changes of the coastal ecosystem in the SBT, particularly mangroves and seagrasses through the use of multi-temporal satellite imagery data and to assess their impacts on Julung-julung resources.

Material and Methods

Study Sites

This study was conducted in the SBT, which lies between the Seram Sea in the north and the Banda Sea in the south. Study sites were specifically located in the Geser, Seram Laut, Marlaut, Kefin Islands, and some sites on the mainland of Seram Island (Fig. 1). The study was conducted from October 2017 to November 2018. These sites had extensive reef flats covered by wide seagrass and mangroves, but the main mangroves were on the coastline of the mainland of Seram Island.

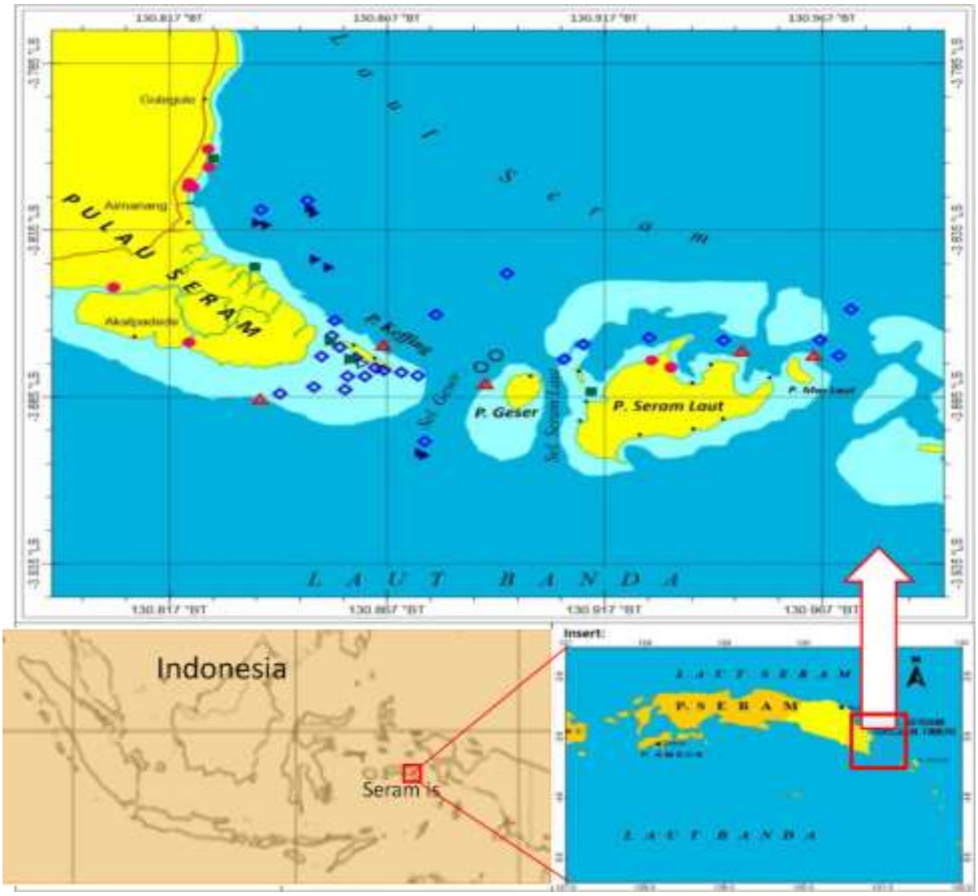

Fig. 1. Map of study sites in the SBT.
Various sampling/transect are mangrove (●), seagrass (■), and coral reef (▲) ecosystems; Oceanography parameters (◆), and seagrass fishes (▶)

Sampling the mangrove, seagrass, and coral reef ecosystems

Observation of mangroves followed the method of [13] by using transects that were made perpendicular to the coastline to the end of the mangrove forest on land (±200m). On the transect line, the number of mangroves stands categorized as trees (diameter at breast height >10cm) were counted in a 10x10m plot. The amount of sapling stands (diameter at breast height 2~ <10cm) was counted using a 5x5m plot that was established within the same 10x10m plot for the tree's categorization. The collected mangrove field observations data were then used to calculate the density (D), relative density (RD_{en}), relative frequency of occurence (RF), and relative dominance (RD_{om}) in which:

RD_{en} = Density of a certain species/Density of all species x100%

RF = Frequency occurrence of a certain species/ Frequency of al species x100%

RD_{om} = Dominance of a certain species/Domination of all species x100%

The mangrove dominance was calculated based on the basal area, i.e. by measuring the circumference of the tree trunk at breast height of each species of mangrove tree in each plot. Mangrove transects were carried out in 8 locations, 4 in the east, and 2 in the south of the mainland of Seram Island. The other 2 transects were conducted on Seram Laut Island (Fig. 1). Finally, the importance value index (IVI) was calculated by the formula:

$$IVI = RD_{en} + RF + RD_{om}, \text{ with the maximum total IVI was 300\%.} \quad (1)$$

Seagrass observations followed the guidelines for monitoring seagrass beds [14] using a transect drawn perpendicular to the coastline along 100 meters towards the sea. The first frame of 50x50 cm was placed on the coastline and repeated every 10 meters. The number of seagrass cover and species inside the frame was then assessed. The seagrass data were analyzed by assessing the species number and the frequency occurrence of seagrass (F) that was calculated by dividing the number of each seagrass species found in the frame by the total number of frames. Seagrass identification followed [15]; Seagrass watch manual for community [16], and the status of Indonesian Seagrass 2018 [17].

Observation of coral reefs was carried out using the Line Intercept Transect (LIT) method [18]. This method has its own advantages because the data obtained are very detailed. LIT records not only coral reef data but also biotic data associated with the ecosystem (algae, sponges, and other living biotas) as well as abiotic components (sand, rubble, dead corals, and other non-living things). However, collecting data using the LIT method takes time, while the data taken are only in the points form, so they cannot provide broad information.

LIT was carried out by placing a 100 m rolling meter parallel to the coastline at a depth of 3-6m as a transect line. All biotas that were 10 m underneath and surrounding the transect line were recorded, then the recording was repeated for three times. LIT data processing used the Benthic Lifeform Program, which calculates the percentage of coral cover and the percentage of both biotic and abiotic components. The calculation of the percentage cover of a benthic life form coral and other biotic and abiotic components was calculated in the following manner:

The percentage of living coral cover/other biotic and abiotic components = Length of for living coral species/other biotics and abiotic components/Length of transect line x 100%.

Benthic life form data for each living coral species were grouped into 4 categories as follows: Category-1: corals in bad condition (if living coral <25%); Category-2: coral is in moderate condition (25~<50%); Category-3: coral in good condition (50~75%), and Category-4: coral in excellent condition (>75%) [19-20].

Processing and analysis of satellite image data for mapping mangroves and seagrass

We mapped the mangrove and seagrass ecosystems at the study site to understand their condition using multi-temporal data of 2 satellites, the Landsat-7 ETM+ (Enhanced Thematic Mapper Plus) acquired on November 11, 2001, and the Sentinel-2A acquired on December 19, 2018, with a spatial resolution of 30x30m and 10x10m, respectively. Both satellite data were obtained free of charge from the web: https://glovis.usgs.gov/.

The first stage of image data processing was to correct the geometric and atmospheric influences from two different recording periods. Geometric corrections for Landsat-7 ETM+ data were not carried out, because based on the metadata, this image was in the Precision Terrain Level-1 image (L1TP), which is an image with high quality and suitable for multi-temporal analysis with consistent geographic regression bias within a root mean square error tolerance of <12 meters (https://www.usgs.gov/centers/eros/science/USGS-eros-archive-Landsat-archives-Landsat-7-enhanced-thematic-mapper-plus-item?qt-science-center).

Geometric correction of Sentinel-2A images was not performed either.

A simple atmospheric correction using the Dark Object Subtraction (DOS) algorithm was applied to reduce the atmospheric influences both in Landsat-7 ETM+ and Sentinel-2A images [21-24]. The atmospheric correction was done by subtracting all digital values (DN) of each band used against the minimum DN of each band (bias due to atmospheric influences, USGS, 1984) as follows:

DN Corrected Band i = DN Band i – DN Minimum Band i (bias) (2)

The radiometric correction, which converts the corrected DN to radians or reflectance values, was not performed, because the conversion coefficient for Sentinel-2A images was not available in the metadata. Therefore, in this study, the image data processing and analysis were only based on the DN value of each pixel. Sun glint and water column correction [25] were not carried out because seagrass was in shallow water, and at low tide, seagrass was exposed out of the water column, so these corrections were unnecessary.

Atmospheric effect corrected digital values (DN) were used to map the mangrove and seagrass ecosystems by using 5 bands of Landsat-7 ETM and Sentinel-2A images, respectively. Those 5 bands were 3 bands at the visible, 1 band at the near-infrared (NIR), and 1 band at the short infrared (SWIR) wavelengths (Table 1). Those 5 bands were further applied to map the habitats of mangroves and seagrass using a simple image processing method of iso-cluster analysis (unsupervised classification). Iso-cluster was then asked to classify 39 classes of habitat. The 39 habitat classes were then validated using field sampling/transects data and then reclassified into 6 habitat classes: 1. Ocean (water), 2. Land vegetation, 3. Mangroves, 4. Dense, 5 Medium, and 6. Sparse seagrass, then the area of each habitat changes between 2001 (Landsat-7 ETM +) and 2018 (Sentinel-2A) could be determined.

Table 1. Spectral band characteristics and spatial resolution of Sentinel-2A and Landsat-7 ETM +

Landsat-7 ETM+Satellite				Sentinel-2 A Satellite			
Band	Spectral Region	Wavelength Ranges (mm)	Resolution (m)	Band	Spectral Region	Wavelength Ranges (mm)	Resolution (m)
B-1	Blue	452-514	30	B2	Blue	458-523	10
B-2	Green	519-601	30	B3	Green	543-578	10
B-3	Red	631-692	30	B4	Red	650-680	10
B-5	NIR	772-898	30	B8	NIR	785-899	10
B-7	SWIR	1547-1748	30	B11	SWIR	1565-1655	20

Perceptions of fishers about fish resources

Statistical data and information on Julung-julung fisheries in the SBT are very scarce. So to get an overview of this fish resource in the SBT, we interviewed 16 fishers who have years of experience in catching this fish. Those respondents were 7 fishers who were the owners of fishing gear of mini purse seine, 8 respondents were labor fishers, and 1 respondent was Julung-julung smokers. All these respondents lived in Keving Island (Fig. 1).

Results and Discussions

Main ecosystem condition of the SBT

Table 2 shows the results of 8 mangroves transects conducted in 4 study sites. A total of 22 species of mangroves, consisting of 10 species of true (Fig. 2) and 12 of pseudo mangroves or vegetation associated with mangroves, were found during the transects campaign. The results of mangrove vegetation analysis based on the value of RF, RD_{den}, RD_{dom}, and IVI indicated that *Rhizophora apiculata* was the dominant mangrove in the SBT with frequency (RF) of IVI >100 4 times (50%) for the tree, and 75% for the sapling category. Another species was *Sonneratia alba* which also had an IVI value of >100 with a frequency of occurrence 4 times (50%) for the tree, but zero (0%) for the sapling category. Species that had an IVI of >100 and a frequency of occurrence of once (12.5%) were *Xylocarpus granatum* and *Bruguiera gymnorrhiza* for the tree category. The rest of the species had an IVI <100. These findings indicated that the diversity of mangroves in the SBT was low, the same as most mangroves found in small islands in Maluku Province that grew in the reef flat areas [12].

Woodroffe [26] observes four environmental setting scenarios of mangroves based on geomorphological processes that are dominant in a location in many islands in the Pacific, which then affect the ecological limitations and population dynamics of mangroves. These environmental settings are (1). Mangroves that grow in river-borne sediment deposit as in deltas/estuaries and affected by micro-tidal; (2). Mangroves that grow in the bedrock/hard soil layers basin that form bays or protected areas; (3). Mangroves that grow on the reef flat with carbonate deposits protected by reef shoals; and (4). Mangroves that grow on the land in lower plains, which are different from the previous three settings.

Table 2. Relative frequency (RF), relative density (RD_{en}), relative dominance (RD_{om}) and Importance Value Index (IVI) of mangrove transects for tree and saplings (numbers in brackets) at 8 transect sites

Station	Transect	Mangrove Species	RF	RD_{Den}	RD_{Dom}	IVI
Ainena	1	*Bruguiera gymnorrhiza*	28.6 (22.2)	40.0 (22.2)	33.4 (19.8)	102.0 (61.1)
		Sonneratia alba	42.9 (33.3)	50.0 (14.3)	57.4 (20.10	150.2 (67.7)
		Avicennia officinalis	14.3 (0)	5.0 (0)	0.2 (0)	24.1 (0)
		Aegiceras corniculatum	0 (33.3)	0 (61.9)	0 (55.3)	0 (150.6)
	2	*Rhizophora apiculata*	66.7 (66.7)	78.6 (63.2)	82.3 (26.7)	227.5 (156.5)
		Bruguiera gymnorrhiza	33.3 (22.2)	21.4 (26.3)	0.8 (53.7)	72.5 (102.3)
	3	*Rhizophora apiculata*	62.5 (72.7)	68.8 (79.0)	71.6 (84.6)	202.9 (236.2)
		Ceriops tagal	37.5 (27.3)	31.3 (21.5)	28.4 (15.5)	97.1 (63.8)
	4	*Rhizophora apiculata*	60.0 (88.3)	80.0 (80.0)	70.8 (84.7)	210.3 (248.0)
		Sonneratia alba	40.0 (16.7)	20.0 (20.0)	29.7 (15.3)	89.7 (52.0)
Sola Turun Kuramor	5	*Rhizophora apiculata*	41.7 (37.5)	34.8 (42.1)	27.9 (42.7)	104.3 (122.3)
		Bruguiera gymnorrhiza	25.0(37.5)	13.0 (26.3)	0.5 (24.4)	50.0 (88.2)
		Sonneratia alba	33.3 (18.7)	52.2 (15.8)	60.2 (18.5)	145.7 (53.0)
Teonota Kuramor	6	*Rhizophora apiculata*	26.3 (21.7)	23.3 (19.1)	19.2 (21.3)	68.9 (62.1)
		Bruguiera parviflora	15.4 (8.7)	10.0 (4.8)	0.3 (4.8)	32.47 (18.2)
		Ceriops tagal	10.5 (30.4)	0.3 (35.7)	0.2 (30.5)	21.1 (96.7)
		Sonneratia alba	10.5 (8.7)	0.7 (9.5)	22.4 (11.6)	49.6 (29.8)
		Xylocarpus granatum	36.8 (26.0)	43.3 (26.2)	47.8 (26.4)	128.0 (78.6)
Seram Laut	7	*Rhizophora apiculata*	33.3 (80.0)	28.6 (77.3)	13.5 (76.7)	75.4 (234.0)
		Sonneratia alba	66.7 (20.0)	71.4 (22.7)	88.5 (23.3)	224.6 (66.0)
	8	*Rhizophora apiculata*	14.3 (37.8)	4.0 (40.0)	0.1 (39.3)	18.1 (117.1)
		Sonneratia alba	42.9 (10.8)	86.0 (6.7)	66.1 (8.9)	176.9 (26.4)
		Osbornia octadanta	28.6 (8.1)	12.0 (8.4)	11.5 (10.8)	52.1 (27.3)
		Avicennia officinalis	14.3 (0)	0.0 (0)	0.9 (0)	50.1 (0)

Fig. 2. Mangrove conditions and true mangroves species found in the SBT

Therefore, according to *C.D. Woodroffe* [26] classification, the mangrove communities in the SBT are classified as setting-3 and/or 4. These settings marked by the low species diversity ranges of only 2-5 true mangrove species (Table 2). They also have stunted growth because the growth cannot reach maximum since they grow in the reef flats with carbonate deposits. The scenario of setting 3 mangroves of the islands in the Pacific are found in New Zealand, and Nauru (1 species), Tuvalu, and Saipan (2 species), Samoa, Kiribati, and Marshal Islands (4 species), Fiji, Tonga, Truck, Ponape, and Kusaie (7 species) [26]; while in Indonesia, particularly in Maluku Province are Saparua, Haruku, and Nusa Laut Islands that are relatively near to this study sites. Outside Maluku are the small islands in the Derawan Islands, Wakatobi Islands, Seribu Islands, Supiori Islands, Padaido Islands, and Numfor Islands with species diversity of around 3 to 8 species [12]. In contrast, the mangroves belong in the settings 1 and 2 have high diversity of >10 species with tall and big trees because they grow in the appropriate sediment deposits. All these environment setting scenarios will strongly correlate with mangrove management.

Table 3 shows seagrass transect data that consisted of seagrass diversity, the average seagrass density, and their percent covers. Out of 13 seagrass species of Indonesia [27], 9 species of seagrass were found in all transects that carried out at Kefin (4 sites), Seram Laut (1 site), Geser Islands (2 sites), and Aina of Seram Island (2 sites). The average seagrass density across all transects was 710.5 stands/m^2. *Thalassia hemprichii* had the highest density of 263.1stands/m^2, followed by *Syringodium isoetifolium* of 147.7stands/m^2, and *Cymodocea rotundata* of 115.2stands/m^2, while the density of other species was <62stands/m^2. The average percent cover of seagrass at all transect was 72.6%. *Enhalus acoroides* had the highest percent cover of 28.1%, followed by *Thalassia hemprichii* of 25.8% and *Cymodocea rotundata* of 11.8%, while the remaining species of <5%.

Table 3. The average density and percent cover of seagrass from 9 transect sites in the SBT

Famili/Specsies	Density (stands/m^2)	Relative Density	Percent cover	Relative Percent covers
I. HYDROCHARITACEAE				
1. *Enhalus acoroides*	61.9	8.7 %	28.1	38.8%
2. *Thalassia hemprichii*	263.0	37.0%	25.8	35.5%
3. *Halophila ovalis*	29.3	4.1%	1.6	2.3%
II. CYMODOCEACEAE				
4. *Cymodocea rotundata*	115.2	16.2%	11.8	16.2%
5. *Cymodocea serrulata*	27.8	3.9%	3.8	4.3%
6. *Halodule pinifolia*	18.4	2.6%	0.3	0.4%
7. *Halodule uninervis*	40.1	5.6%	0.4	0.6%
8. *Syringodium isoetifolium*	147.7	20.8%	1.5	2.0%
9. *Thalassodendron ciliatum*	7.1	1.0%	0.0	0.0%
Total	710.5	100%	72.6	100%

Figure 3 shows a very wide distribution of dense seagrass beds in the SBT. In general, the seagrass beds in the SBT were classified as healthy seagrass ecosystems since the average of percent cover was >70% [17] and the average density was 711 stand/m^2 (Fig. 3).

Table 4 shows transect data for corals at 5 sites. Based on the percent cover data of living corals (Acropora and non-Acropora species) of Table 4, the condition of coral reefs at 3 transect sites of west Kefin, west Geser, and the northern part of Seram Laut Islands were in good condition indicated by a high percent living coral covers of 53.5, 56.2, and 63.6%, respectively. The coral reef condition of the other 2 transect sites was categorized as an excellent condition at Air Nenang (87.8%) and in the north of Marlaut Island (94.1%). The diversity of coral in this study was composed of 102 species that belonged to 40 genera and represented 15 families. This species diversity is slightly lower than in Marine Protected Areas (MPA) of Raja Ampat, Papua, with 120 species, and 15 families, and the MPA of Wakatobi

Islands, Southeast Sulawesi, with 124 species, and 16 families (http://coremap.or.id; [28]. However, the coral reef condition in the SBT based on their percent cover is better than in the MPA of Raja Ampat and Wakatobi Islands. Figure 4 shows the diversity of corals and reef fish abundance at the sampling sites in the SBT.

Fig. 3. Distribution of large and dense segrass bed in the SBT

Table 4. Percent cover of coral and other benthic habitat at 5 transect sites in the SBT

Benthic life form	West Kevin Is.	West Geser Is.	Air- nenang	North of Seram Laut Is.	North of Marlaut Is.
Total Live Coral:	**53.5**	**56.3**	**87.8**	**63.6**	**94.1**
- *Acropora*	17.0	36.4	39.9	58.3	73.4
- *Non-Acropora*	36.5	19.9	47.9	5.3	20.7
Dead coral	13.2	21.4	4.3	7.3	5.3
Coral covered by Macro/Coraline algae/Halimeda	2.3	1.2	0.8	-	-
Other Fauna: Soft coral/Sponges/other	24.4	14.2	1.9	-	-
Abiotic: Sand and Rubble	6.5	7.0	5.2	29.3	-

Fig. 4. Coral reef in good condition with high abundance of reef fishes at sampling sites in the SBT.

Mapping of mangrove and seagrass ecosystems and their dynamics

Figure 5A shows 39 classes of mangroves and seagrass habitat as a result of iso cluster classification on Landsat-7 ETM satellite imagery. Figure 5B shows the validation of 39 classes of habitat using field transects, and other observation data. Meanwhile, Figure 5C and 5D show the map of habitat in the SBT derived using Landsat-7 ETM+ of November 2001, and Sentinel-2A of December 2018 images, respectively after validation using field transects and other observation data, and then reclass the 39 class of habitats into 6 class of habitat, namely Sea (waters), Terrestrial vegetation, Mangroves, Dense, Medium, and Sparse seagrass. Based on the image analyses of these 2 maps (Fig. 5C and D), there was a tendency of decreasing the areas in both mangrove and seagrass habitats. From 2001 to 2018 (17 years), mangroves decreased from 1401.5 to 1118.8ha (282.7ha), while seagrass habitats decreased from 3183.8 to 2509.4 ha (674.4ha). Mangrove degradation occurred not only in the SBT but everywhere in Indonesian coastal zones due to various utilities such as building materials, charcoal, firewood, tannins, paper pulp, but the most damages were due to the conversion of mangroves into fishponds (*tambak*) such as along the northern coast of Java Island [29]. These conversions reduced mangrove areas in many big islands of Java, Sumatra, Kalimantan, and Sulawesi by 155,081 ha in the 1980s and increased to 285,500 ha in the 1990s [30].

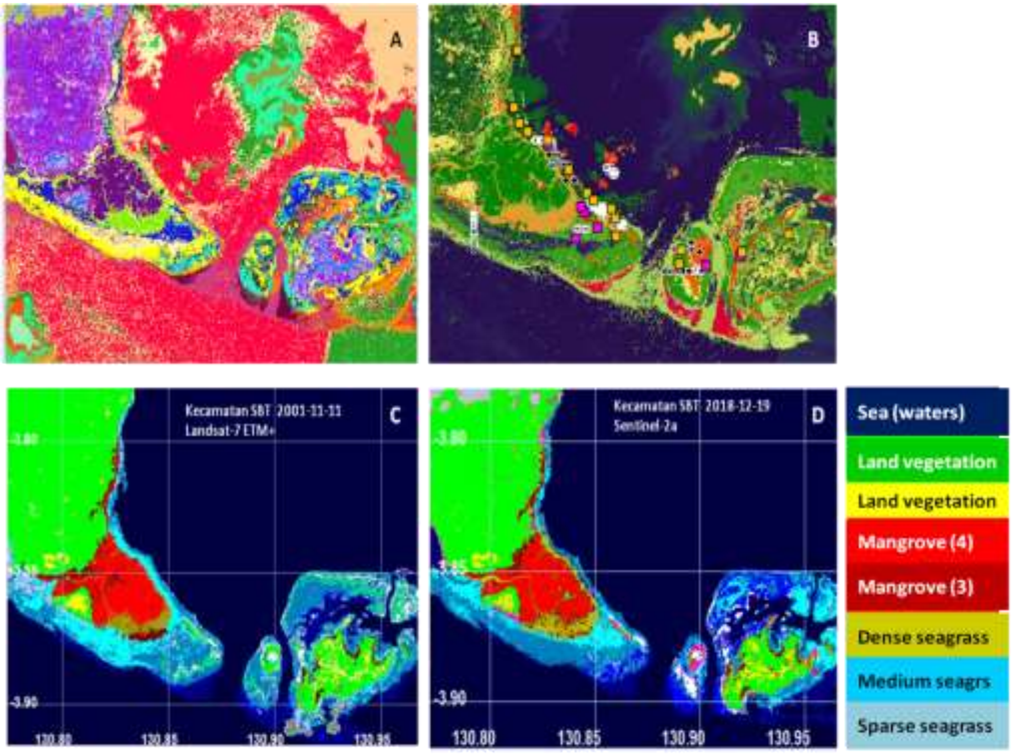

Fig. 5. (5A): Example of Isocluster analysis of habitat classification for 39 classes for Landsat-7 ETM+; (5B): Habitat validation using transect and other observatioan data; (5C): Map of mangrove and seagrass ecosystems on November 2001 (Landsat-7 ETM +); and (5D): December 2018 (Sentinel-2a)

Degradation of habitat mangroves and seagrass beds

In this study, the decreasing mangrove areas within 17 years was 282.7ha or with degradation rate of 16.6 ha/year due to cutting a large number of mangrove trees for firewood by the SBT's community (Fig. 6). The community then used the firewood to smoke Julung-julung fish. Julung-julung smoked fish is a very popular fishery product from the SBT and very famous among the people in Maluku. The practice of smoking Julung-julung using mangrove woods has been going on for decades. The Julung-julung smokers and customers strongly believe that firewood from mangroves will make the dish especially tasty, having a distinct aroma, delicious taste, and longer shelf life, that's why customers much prefer mangroves firewood.

Fig. 6. Mangrove degradation in the SBT that used as firewood, especially for smoking the Julung-julung fish

People in the SBT who live on the small islands such as Geser, Kefin, and Seram Laut Islands will continue to use mangroves as firewood because access to firewoods from terrestrial forests is too far for them. Furthermore, since smoked fish is the sole livelihood for many people in the SBT, cutting mangroves cannot be prohibited, thereby rendering logging and exploiting mangroves inevitable. Consequently, mangroves will continue to experience endangerment from their use as firewood. Figure 5C shows that the dense mangrove in the dark red color scattered over the reef flat had turned very thin or almost completely gone as shown in Figure 5D. The use of mangroves as firewood for smoking fish such as in this study also occur in Ndian and Fako, in the southwest region of Cameroon where 47% of the firewood used by local people comes from the red mangroves (*Rhizophora racemosa*). This dependence on red mangrove wood is due to its ability to produce large amounts of heat energy. The utilization of red mangroves for smoked fish has spread to other mangrove species, making it clear that the mangrove ecosystem in Cameroon under severe pressure and threatens its sustainability [31-32].

Conventional smoking of Julung-julung by continuously using firewood from mangrove trees must be stopped and a solution to that problem needs to be sought. Some alternative sources of firewood such as coconut fibrous husks and shells, sago frond, walnut shells, or naturally fallen-died mangroves (not living mangroves) can also be used. Woods can also be collected from driftwood that washed up on beaches and then used as firewood. The liquid smoke method that has developed for a long time can also be proposed as another alternative to smoke Julung-julung [33].

The liquid smoke method is effective and efficient because it can produce a uniform product, while controlling the consistency of the taste, can use repeatedly, save firewoods, applied to various types of foodstuffs, minimizing environmental pollution, and eliminating the carcinogenic compounds formed [34-35]. Furthermore, various types of liquid smoke materials such as coconut shells and many other types of hard woods are very accessible and can be purchased easily online at very affordable prices. The faculty of Fisheries, Pattimura University (UNPATTI) in Ambon has been developing liquid smoke for a long time to smoke, not the Julung-julung, but the skipjack tuna (*Katsuonus pelamis*). The Julung-julung fish smokers in the SBT then can ask UNPATTI for the assistance. Therefore, the use of liquid smoke as the smooking method is expected to reduce the use of mangrove trees as sources of firewood, and this will give a chance for mangroves in the SBT to recover.

The practice of smoking Julung-julung fish in the SBT is still conventional, using a very simple stove so that heat during the smoking process can spread evenly. This means a system that can utilize the heat when smoking is needed, so that the smoking process becomes more effective and efficient. A study by *H.D.K. Jiazet* [32] showed that the conventional smoking method takes 58 hours to smoke 528kg of fish, which consumes 1,205kg of mangrove firewood for 50€, while a cinderblock oven with the same amount of fish requires faster smoking time to only 16.5 hours and uses 403 kg firewood and costs 30.3€. Therefore, the oven system can save 33% of the use of firewood. Such cinderblock ovens can save mangrove firewood economically and ecologically. This method can be adopted /used as a solution to maintain the sustainability of the mangrove ecosystem [32].

With regard of seagrass, the rate of destruction of the world's seagrass (global) between 1879 and 2006 reached 27km^2/year [36] including Indonesia which has lost 30-40% of its seagrass beds [37-38] with an area of 293,464ha [17]. The degradation of Indonesian seagrass is still poorly documented, but in general, the degradation of seagrass that caused the decline of the seagrass areas were due to construction, reclamation, and urban development on the coast, sand mining activities, marine pollution, logging of land vegetation, and land clearing [37-39].

In this study, the decrease in the area of seagrass beds in the SBT within 17 years was 674.4ha or with the degradation rate of 39.7ha/year due to the destruction of the benthic substrate caused by mining/removing the dead coral in the seagrass beds for use as building materials (Fig. 7). The degradation of seagrass was 2.4 times bigger than mangroves. Many types of seagrass roots used benthic substrates in the form of large (bolder) or small (ruble) dead coral as anchors. So, if a lot of dead coral were removed, the seagrass roots would not be able grip the substrates firmly, and the seagrass would gradually be pulled out by current or by waves [37]. The case of using dead corals by collecting them from seagrass beds that will then destroy this important ecosystem as Julung-julung habitat is very difficult to solve, because it is difficult to stop the community of the SBT from taking dead corals to be used as building materials. This case is similar to the case of utilization of mangrove woods as firewood for smoking Julung-julung as explained above. Therefore, the local government and residents need to sit down and discuss together and agree not to mine the dead coral in the seagrass beds.

Fig. 7. Mining of dead coral for various purposes of building materials, which diminishes the area of seagrass beds.

The smaller of seagrass and mangroves areas are, the smaller the Julung-julung population is. This is because these fish use these two ecosystems as their habitat. The ecological function of mangroves and seagrass is a place for spawning and laying eggs, as a shelter, feeding, and nursery ground for various fish and invertebrate larvae and juveniles [40]. Apart from Julung-julung, many commercial reefs fish larvae and juveniles such as snapper, grouper, and many others are also highly dependent on the health of mangroves and seagrass beds [41-42].

Perceptions of SBT fishers about Julung-julung resources

The potential stock of any kind of fish resources will depend on the habitat where the fish live. However, the statistical data on the Julung-julung stock/population in the SBT is very scarce, so in order to investigate the stock changes of this fish in relation to the changes of the ecosystems, a survey was conducted through interviews. The SBT fishers on Julung-julung fishing took part in the survey, discussing their perceptions of fish resources and ecosystem dynamics in the SBT. The interviews represented respondents of 7 fishers who owned mini purse seine fishing gear (locally called *jaring giob*), 8 labor fishers, and 1 respondent of Julung-julung smoker. All these respondents lived in Kefin Island.

The interview results showed that all respondents were aware that their catches had decreased by 30-50% compared to that of 20 years ago. The mini purse seine owners stated that the Julung-julung catches did not show any increases during the peak of fish seasons, even though the operation of mini purse seine (Fig. 8) already decreased from 10 purse seines of 10 years ago (2008) to 7 purse seines that still operated until 2018. The labor fishers and Julung-julung smokers could not predict the decline in Julung-julung stocks. However, they stated that previously, even during non-fishing seasons, their income could reach higher than IDR 1 million/month, but recently (2018), it's no longer possible to get such income because the catch has decreased, despite the price of Julung-julung in the market is high. All respondents were aware that they used only mangrove woods to smoke this fish. They also already understand the function of mangrove and seagrass ecosystems related to fisheries production, but they did not have any alternatives to substitute the mangrove firewoods. Thus, this study showed, although quantitatively the decrease of Julung-julung stocks data over the past of 20 years is unavailable, qualitatively, the findings from the interview indicate that habitat degradation of mangrove and seagrass is possibly a strong reason for the decreasing of this fish stocks.

Fig. 8. Operation of mini purse seine to capture Julung-julung in the SBT. Fish schools reconnaissance around mangrove and seagrass ecosystems, operation of mini purse seine. Julung-julung catches, selling fish, clamping fish on bamboo frames (waya), and smoking Julung-julung

A study by *A. Adi* [43] emphatically showed that there was a strong positive correlation between the seagrass species density (number of seagrass species stands/m^2) and the abundance of seagrass fishes (number of fish/m^2) in Panjang Island, Jepara, with a high determination coefficient (R^2) of 0.99. The morphometric study conducted by *I.G. Suryawan et al.* [44] showed that there were many juveniles or young Julung-julung with a total length of 13-15cm caught in the dense seagrass meadows of Ekas Bay, East Lombok. Those studies prove that the healthy seagrass ecosystem plays an important role as a place of nursery, shelter, and foraging ground for seagrass fishes, including Julung-julung. Therefore, the reduced area of mangroves and seagrass in the SBT greatly possibly led to the decrease of the fish stock of Julung-julung.

Comparison between the Julung-julung fisheries outside the SBT and other reef fishes

The findings of the Julung-julung study in the waters of the Sangihe Islands Regency, the North Sulawesi Province showed that the sustainable potential of this fish was 70 tons/year but the benefit-cost ratio (B/C) was 0.94 (<1), which means that the profit was not sufficient to cover the cost and the investment so that this fishing business in Sangihe Islands Regency was no longer profitable [45]. This means that the stock of Julung-julung fish in this region had decreased from previous years, the same as the case of the present study, but not due to degradation of mangrove and seagrass habitats, as such evidence was not available, rather the strong possibility of overfishing.

The result of another study on the Julung-julung stocks assessment in the waters of the Siau Islands, Tagulandang Biaro, another district in North Sulawesi, showed that the utilization of this fish had reached 98.6% of its stock potential of 11.7 tons/year [46]. Based on this study, the addition of only 1 fishing gear or the addition of fishing trips over 145 trips/year would be dangerous to the Julung-julung stocks because it disturbed the sustainability of this fish in the region being studied.

The two examples of the above studies showed that Julung-julung stocks declined. However, the causes were not clear whether it was related to habitat degradation, as was the case with the SBT, or related to overfishing. However, the high possibility of the decrease of Julung-julung stocks in those sites was due to overfishing. The old statistical data of the Directorate General of Capture Fisheries, the Ministry of Marine Affairs and Fisheries/KKP in 2010 [47] showed that the national production of Julung-julung had decreased from 32,870 tons in 2000 to 25,711 tons in 2010 with a decreasing rate of 715.9 tons/year (2.18%/year).

In contrast to the Julung julung stocks, which showed signs of stock decline, the reef fish stocks in the coral reefs of the Watubela Islands that the SBT laid in this Islands tend to increase. The abundance of the reef fish stock indicated by fish density/m^2 increased from 5.1 (2007) to 5.8 (2017) fish/m^2 with an average density of 5,4 fish/m^2 for target fish, the reef fishes that had high economic values and became the target of fishing by the fishers [48]. The average density of reef fishes in the islands around the SBT, which is included in the Indonesian Fisheries Management Area (WPP) 714, is as follows: the Banda Sea was the highest of 5.4 fish/m^2 compared to the average density of other coral reef fishes at other locations under WPP 714. The average density of reef fishes of the Lease Islands (Ambon, Haruku, Saparua, Nusa Laut, and Ambalau Islands), the Islands that laid the north side of WPP 714 was 2.0 fish/m^2. At the center of WPP 714, the Banda Islands, the average density was 2.8 fish/m^2. On the east side, the Kei Islands, the mean density was 0.7 fish/m^2. On the south side, the islands in the south of Maluku Province, was 2.4 fish/m^2, while in the islands of Lembata, East Flores, Alor, NTT was only 0.6 fish/m^2. On the southwest side, the Wakatobi islands, the fish density was 1.5 fish/m^2; and on the west side, the islands in Kendari Bay were the lowest, 0.3 fish/m^2. The average density of reef fish of all Islands in the WPT 714 was about 2.0 fish/m^2 [48]. The reason for the highest average density of coral fish in the SBT compared to the other Islands in WPP 714 was due to the excellent condition of the coral reefs with a high percent cover of living corals of >75% (Table 4 and Fig. 4). *U.J. Wisha et al.* [49] reported in their study the high correlation between the excellent condition of living coral cover and the abundance of coral reef fishes in Simeulue Island, Aceh, while *I. Riskiani et al*. [50] found a high correlation between the percentage of living coral cover and the abundance of reef fishes ($r^2 = 0.942$) in the Kapoposang Islands, South Sulawesi.

Conclusion

This study examined the coastal ecosystem in the SBT using multi-temporal satellite data of Landsat-7 ETM+ (2001) and Sentinel-2A (2018) to analyze the habitat changes and their link to the Julung-julung resources. Mangroves and seagrass decreased about 282.7 and 674.4ha within 17 years, respectively. Degradation was due to mangrove logging for firewood to smoke Julung-julung as well as mining dead coral in the seagrass bed for building materials, which led to the decrease in the Julung-julung resources, ranging from 30-50% for a period of 20 years. Mangrove and seagrass ecosystems in the SBT will continue to be under a severe of pressure. Thus, they properly need to be managed through conservation and revitalization activities for their important function as a habitat that supports the early life history of various fish in general, and Julung-julung in particular. The excellent condition of coral reef ecosystems in the SBT also needs to be protected closely because their contribution to the abundance of reef fishes has already been proven. Therefore, establishing Marine Protected Areas (MPA) around the good condition of mangrove and seagrass ecosystems is a must, as well as prohibiting all forms of exploitation of the resources in the MPA. The fishery management of Julung-julung also must be carried out immediately through in-depth studies on the fisheries biology of this fish, so the population dynamics such as stock size, the number of allowable catches and other parameters are able to determine, the role of conservation of important fish species being well known [51-53]. Another effort is strictly to prohibit the capture of Julung-julung during it spawning season through the local wisdom of "Sasi". Sasi is a hereditary customary regulation not to exploit a certain living resource in a village (closed area) and/or at a period of time (closed season), which is highly obeyed and respected by the communities in Maluku Province.

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