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The stability of mangrove ecosystems for edu-tourism based on macrozoobenthos ecological indicators in the educational fish ponds of Hasanuddin University

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Abstract. This study was conducted from June to November 2018 around the educational fish ponds of Hasanuddin University, Bojo Village, Mallusetasi Sub-District, Barru District, Indonesia. This study aimed to identify the mangrove species present, the crustacean and molluscan macrozoobenthos associated with the mangrove ecosystem, and to evaluate the level of stability of the mangrove ecosystem for the development of edu-tourism activities at the study site employing a Macrozoobenthos Ecological Index. Data on mangrove, macrozoobenthos, and other environmental parameters, were collected at five stations with three replicates per station. Mangrove data was collected within 10 m x 10 m plots, while macrozoobenthos were collected with a shovel and sieve net. Seven mangrove species were found: Avicennia marina, Bruguiera gymnorhiza, Ceriops decandra, Rhizophora apiculata, Rhizophora mucronata, Rhizophora stylosa, and Sonneratia alba. The width of the mangrove belt ranged from 28.23 to 57.00 m meaning that it was well below the national green belt standard (50-200 m). The organisms associated with mangroves included crustaceans (three species) and molluscs (seven species) with an abundance of 0.01 - 0.07 ind/m2. The Diversity Index was in the average category (1.49 - 1.92), while the Evenness Index ranged from unstable to under pressure (0.476 to 0.64). The Dominance Index was in the unstable category (0.185 - 0.264). Based on the Macrozoobenthos Ecology Indicator, the mangrove ecosystem in the fish ponds was categorised as stable to average. The land suitability analysis indicated that the mangrove ecosystem in the study site was in the conditionally appropriate category for the development of mangrove edu-tourism activities.

1. Introduction

Mangrove ecosystems can make a positive contribution to global climate change mitigation [1]. Furthermore, mangrove ecosystems can help to stabilising neighbouring ecosystems [2] and have many ecological functions, e.g. as a source of nutrients, and as nursery, feeding, and spawning grounds [3,4]. The essential roles of mangrove ecosystems indicate that more attention should be paid to protect them from both natural and anthropogenic damage [5,6], including from edu-tourism visitors. Barru District, in South Sulawesi Province, Indonesia, has a coastline approximately 18 km long, most of which is fringed by mangroves. The mangroves cover an area of approximately 113.02 ha, around 3.16% of which are in Mallusetasi Sub-District. The educational fish ponds of Hasanuddin University (Unhas) are situated in and around Bojo Village, Mallusetasi Sub-District, with around 3.25 ha of mangroves [7,8].

A preliminary survey was conducted in the educational fish ponds of Hasanuddin University, in particular in the mangrove areas of the Crab Park Indonesia - Taman Eduwisata Unhas (Unhas Edu-Tourism Park). This park is an educational initiative run in partnership by the Faculty of Marine Science and Fisheries, Hasanuddin University (FIKP UNHAS) and the private sector in order to optimize the assets of Hasanuddin University. One mangrove-related edu-tourism activity is the installation of *Titian* or "tracking in the mangrove areas". This activity is intended to increase the ecological knowledge of visitors, who learn directly from nature through an exploration of the mangrove ecosystem and associated organisms. The edu-tourism activity could bring about two possible changes in the mangrove ecosystems. On the one hand, improved supervision and management of the mangrove ecosystem environment could be provided by competent edu-tourism managers. This should enable the mangroves to grow and thrive, increasing in density and extent, as well as species diversity of mangroves and associated organisms. On the other hand, inadequate edu-tourism supervision and environmental management could result in damage to the mangrove ecosystems. If this occurred, the mangrove ecosystem would suffer degradation, with reduced density, area and species diversity, including a decline in associated organisms.

Based on this situation, it was considered necessary to carry out research on the stability of the mangrove ecosystem in the educational fish ponds of Hasanuddin University and its suitability for the development of edu-tourism. This study endeavoured to identify the mangrove species present in the educational fish ponds of Hasanuddin University, to identify and evaluate macrozoobenthos (Crustacea and Mollusca) associated with the mangrove ecosystem using Macrozoobenthos Ecological Indicators, and apply the results to evaluate the level of stability of the mangrove ecosystem for the development of edu-tourism activities.

2. Materials and Methods

2.1. Overview of the study site

The educational fish ponds of Hasanuddin University comprise aquaculture areas, and two hatcheries. Both the fish and shrimp hatcheries are located around 80 m apart, close to the beach and to the main road from Makassar, the capital of South Sulawesi Province, to Pare-pare. The fish hatchery is located approximately 500 m from the fish ponds. The fish ponds cover an area of 212,550 m^2 located in Bojo Village, Mallusetasi Sub-district, Barru District. The area is bounded by the sea (Makassar Strait) to the north and west, by the main road connecting Makassar and Pare-pare to the east, and by fish ponds to the south (Figure 1). The area of fish ponds, with a height of about two meters above sea level and an area of 20.63 ha/m2, has sufficiently large rice field at a distance of approximately 1 km to capital of the sub-district, of approximately 35.00 km to capital of the district, and of approximately 115 km to provincial district. The population of Bojo Village is 3.564 people.

2.2. Study time and sampling stations

This study was conducted from June to November 2018. Data were collected from five areas (survey stations) in and around the educational fish ponds of Hasanuddin University, in Bojo Village, Barru District, South Sulawesi, Indonesia (Figure 1). The five stations were determined based on the distribution and species composition of the mangroves growing around the study site, to provide a representative sample. Data were collected at three replicate sub-stations within each station. The number of plots surveyed within each replicate was adjusted based on the width of the mangrove belt.

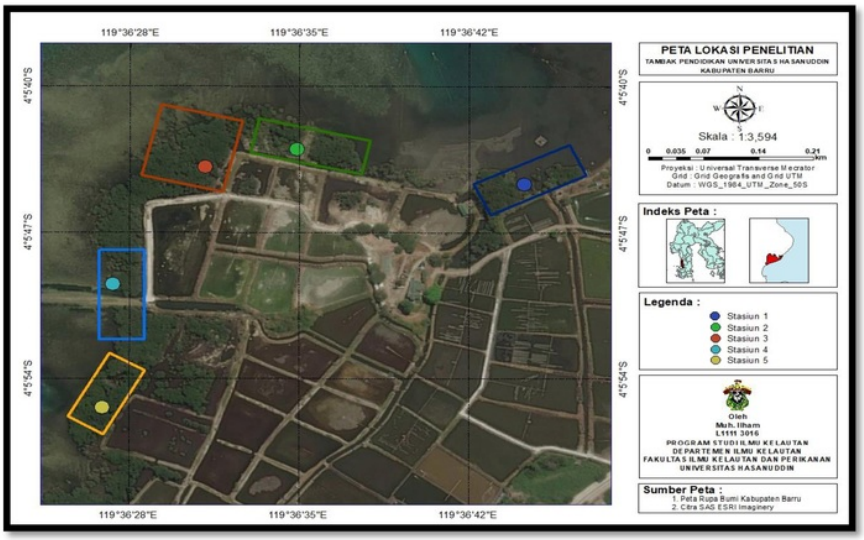

Figure 1. Map of the study site and five survey stations in Barru District, South Sulawesi.

2.3. *Data collection procedures*

Data were collected using a transect method, drawing lines perpendicular to the coastline within each station, in areas where mangroves were growing. Along each transect, observations were made within 10 m x 10 m plots, recording the number and species of mangroves present. Mangrove belt width was measured manually using a tape measure drawn perpendicular to the coastline from the mangrove seawards boundary to the landwards boundary [9,10]. Identification sheets and references on mangroves in Indonesia [11] were used for field identification. For mangroves which could not be identified in the field, samples of the branches, flowers and leaves were collected, and the species was identified later with reference to a mangrove identification book [12]. The diameter of mangrove trees (defined as woody plants with a diameter of ≥ 4 cm) was also measured [13].

Samples of the molluscan and crustacean macrozoobenthic fauna were also collected at each station, at the same time as the data on mangroves. The macrozoobenthos were collected using a shovel, and separated from the sediment using a sieve net. Sampling was carried out three times at each observation station. The animals collected were placed in labelled sample bags, and preserved with alcohol for further identification in the laboratory. Measurements of environmental variables such as temperature, salinity, pH and sediment type were conducted simultaneously at each observation station.

2.4. *Data Analysis*

The analysis of mangroves, organisms and other environmental parameters was carried out at the Marine Ecology Laboratory and Coastal Physics and Geomorphology Laboratory, Department of Marine Sciences, Faculty of Fisheries and Marine Sciences, Hasanuddin University in Makassar. The mangrove data were analysed to determine Density type (Di) and cover category (Ci) [14,15]. Mangrove condition category was based on the density and cover standards issued by the Indonesian Ministry for the Environment [16].

Macrozoobenthos identification was based on several references, including [17–22]. Macrozoobenthos data were analysed using the Shannon Wienner formulae to obtain the indices of abundance (K), diversity (H'), evenness (E) and dominance (D) [9]. The condition of the mangrove ecosystem in the study sites was evaluated using an Ecology Index [23–25], and the analysis of suitability for edu-tourism applied the methods in [7,26–29].

3. Results and Discussion

3.1. Mangrove condition

The mean belt widths of the mangrove ecosystem at stations I, II, III, IV and V were 47.67 m, 31.67 m, 46.33 m, 41.33, and 53.00 m, respectively. Station V had the widest mangrove belt. Based on belt width, stations I, II, III, and IV were categorized as poor for mangrove tourism [16,26], as they were less than 50 m wide. The mangrove ecosystem in the fish pond area is not yet widely known to either local/domestic or overseas tourists. Although a raised wooden trail had been built as a facility to enable visitors to enjoy the mangrove forest in the fish pond area, the narrowness of the mangrove forests is a limiting factor for visitor enjoyment.

3.2. Mangrove species composition and diversity

Seven species of mangroves were identified, belonging to three families: *Acvicenniaceae, Rhizophoraceae*, and *Lonneratiaceae*. The species were: *Avicennia marina, Bruguiera gymnorhiza, Ceriops decandra, Rhizophora apiculata, R. mucronata, R. stylosa* and *Sonneratia alba*. The number of species varied between stations, with four species at Station I (*A. marina, R. apiculata, R. stylosa, S. alba*); five species at Station II (*B. gymnorhiza, C. decandra, R. apiculata, R. stylosa, S. alba*); five species at station III (*B. gymnorhiza, R. apiculata, R. mucronata, R. stylosa, S. alba*); three species at station IV (*R. apiculata, R. stylosa, S. alba*); and just one species at station V (*R. stylosa*). Based on the mangrove species diversity categories in [7,26], stations I, II, III and IV fall with the good category (3-5 species) while Station V is poor with only one species. The relatively high number of mangrove species in the area is the result of mangrove rehabilitation conducted by practical work students and local community members, and is a potential asset for attracting researchers and tourists to the mangrove edu-tourism site.

3.3. Species composition of the mangrove

Results showed that there were three mangrove families, including *Acvicenniaceae, Rhizophoraceae*, and *Lonneratiaceae*. The species involved *Avicennia marina, Bruguiera gymnorhiza, Ceriops decandra, Rhizophora apiculata, R. mucronata, R. stylosa, Sonneratia alba*. Data on the mangrove species found at the educational fish pond Hasanuddin University is shown in Figure 2.

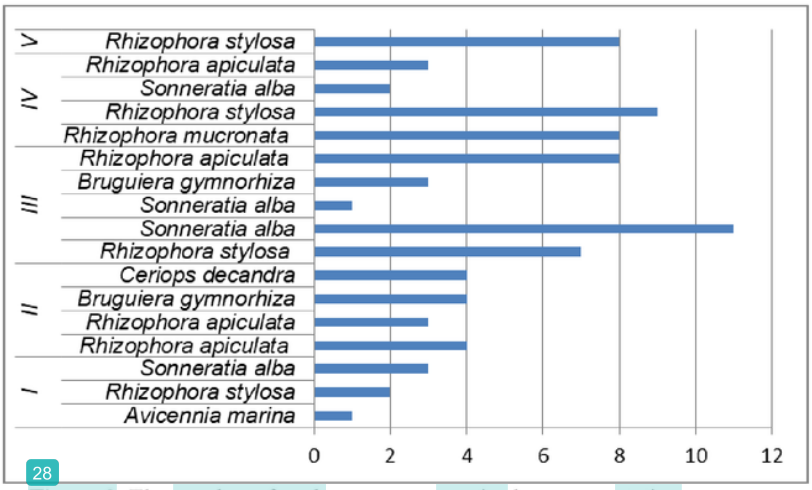

Figure 2. The number of each mangrove species by survey station.

Figure 2 shows that there are 4 species found at station I, including *Avicennia marina*, *Rhizophora apiculata*, *Rhizophora stylosa* and *Sonneratia alba;* there are five species found at station II, including *Bruguiera gymnorhiza, Ceriops decandra, Rhizophora apiculata, Rhizophora stylosa* and*Sonneratia alba*; there are five species found at station III, including *Bruguiera gymnorhiza, Rhizophora apiculata, Rhizophora mucronata, Rhizophora stylosa, Sonneratia alba;* there are three species found at station IV, including *Rhizophora apiculata, Rhizophora stylosa* and *Sonneratia alba;* and there are only one species found at station V, namely *Rhizophora stylosa.* Based on the parameters of the mangrove species [7,26], the categories of station I, II, III and IV are sufficiently good because the number of the species is between 3 and while Station V is not so good because the number of the species is only one. The large numbers of mangrove species in the area are the result of the mangrove rehabilitation conducted by practical work students and performer's fish ponds cooperating to the societies, and have potential for the mangrove edu-tourism in order to draw the researchers and tourists' attention.

3.4. Density of the mangrove species

Density is the number of individuals (e.g. plants or trees) of a species per unit area [30,31]. The density of the mangrove vegetation in the Hasanuddin University educational fish pond area (Table 1) shows that the mangrove species with the highest density was *Rhizophora stylosa.* The total mangrove density ranged from 0.22 to 0.63 ind/m^2. All stations were considered poor in terms of density, based on the recommended density range for mangrove eco-tourism of between 0.5-1 ind/m^2 [26].

Table 1. Density of the mangrove species in the educational fish ponds of Hasanuddin University.

Station	Mangrove species	Trees/plot (Ni)	Density (ind/m^2)	Station	Mangrove species	Trees (Ni)	Density (ind/m^2)
I	*Avicennia marina*	1	0.01	III	*Bruguiera gymnorhiza*	4	0.04
	Rhizophora apiculata	16	0.16		*Rhizophora apiculata*	30	0.30
	Rhizophora stylosa	3	0.03		*Rhizophora stylosa*	18	0.18
	Sonneratia alba	2	0.02		*Rhizophora mucronata*	8	0.08
	Total	22	0.22		*Sonneratia alba*	3	0.03
					Total	63	0.63
II	*Bruguiera gymnorhiza*	4	0.04	IV	*Rhizophora apiculata*	5	0.05
	Ceriops decandra	4	0.04		*Rhizophora stylosa*	46	0.46
	Rhizophora apiculata	3	0.03		*Sonneratia alba*	3	0.03
	Rhizophora stylosa	20	0.20		Total	54	0.09
	Sonneratia alba	11	0.11				
	Total	42	0.42	V	*Rhizophora stylosa*	59	0.08
					Total	59	0.59

3.5. Environmental parameters

The study site is situated at latitude 4° 05'701 "S and longitude 119 ° 36'.684"E. The tidal pattern in this area is semi diurnal with two similar high tides and low tides per day [32,33]. Primary data were obtained from measurements on a tidal pole over 39 hours. The highest high tide was 93.0 cm on the pole and the lowest low tide was at 20.0 cm, indicating a tidal range of 63 cm. The tidal range is within the good category for mangrove eco-tourism based on considerations such as safety and influence on the vertical distribution of mangroves [26].

The mean values of salinity measured at stations I, station II, station III, station IV, and station V were 31.99 ppt, 31.50 ppt, 34.62 ppt, 34.33 ppt, and 34.11 ppt, respectively. The highest salinity was found at station III and the lowest at Station II. Because of the tidal condition in the fish pond area,

salinity greatly influences the mangrove habitat. The observed salinity values are suitable for mangrove growth, in line with the statement by Efriyeldi [34] that mangrove ecosystems can tolerate salinity levels up to 42 ppt.

3.6. Mangrove fauna

The fauna found in the mangrove forests in the Hasanuddin University educational fish pond area are shown in Table 2. The crustaceans and molluscs found attached to the mangrove trees or on the substrate were all species typical of mangrove habitat, and included the mud crab *Scylla serrata,* a high value commodity. Other fauna found in the study area included fish, birds and reptiles.

Table 2. Fauna found in the mangrove forest in the Hasanuddin University educational fish pond area.

Macrozoobenthos		Other Associated organisms	
Crustacea	*Episesarma* sp.	Fishes	*Mugil* sp.
	Scylla serrata		*Epinephelus bleekeri*
	Clibanarius sp.		*Periopthalmus* sp.
Mollusca	*Littorina* sp.		*Sphaeramia orbicularis*
	Faunus ater	Birds	*Ciconia* sp.
	Terebralia sp.		*Egretta garzetta*
	Pila sp.		*Halcyon sancta*
	Nerita sp.	Reptiles	*Dasia* sp.
	Gafrarium sp.		
	Telescopium		

The fishes found in the area were trapped in gillnets set in each station, ranging from a small cardinalfish (*Sphaeramia orbicularis*) to a grouper of economic importance (*Epinephelus bleekeri*). The mudskippers (*Periopthalmus* sp.) are true mangrove dwellers [35], and the cardinalfish *S. orbicularis* has also been described as a true mangrove resident [35]. Mullets (*Mugil* sp.) tend to use mangroves as nursery areas [36], as do groupers of the genus *Epinephelus* [37].

Several bird species are commonly found in mangrove forest, which serve as places for them to nest, interact, and look for food. In the study area, birds look for food in and around the fish pond areas in the morning and afternoon, in particular *Egretta garzetta* and *Halcyon sancta*. The reptile found was a tree skink (*Dasia* sp.). The literature on this genus seems extremely limited, but reported habitat includes mangroves and other coastal forests [35]. The skink was found crawling on mangrove trees, on the ground, and swimming. Based on these data, the faunal biodiversity parameter of the fish ponds was in the good category. Regarding the macrozoobenthos from the Crustacea and Mollusca, 116 species were found at the study site (Figure 3).

The indices of diversity, uniformity, and dominance ranged from 1.49215 to 1.91722, 0.47589 to 0.63998, and 0.185 to 0.236296, respectively. Based on the analysis of macrozoobenthos diversity in the mangrove forests in the Hasanuddin University educational fish pond area, the condition of these mangrove ecosystems is quite low. One reason for this could be the presence of pollutants in the water. The uniformity analysis of the macrozoobenthos indicates an unstable community, as described by Odum [23].

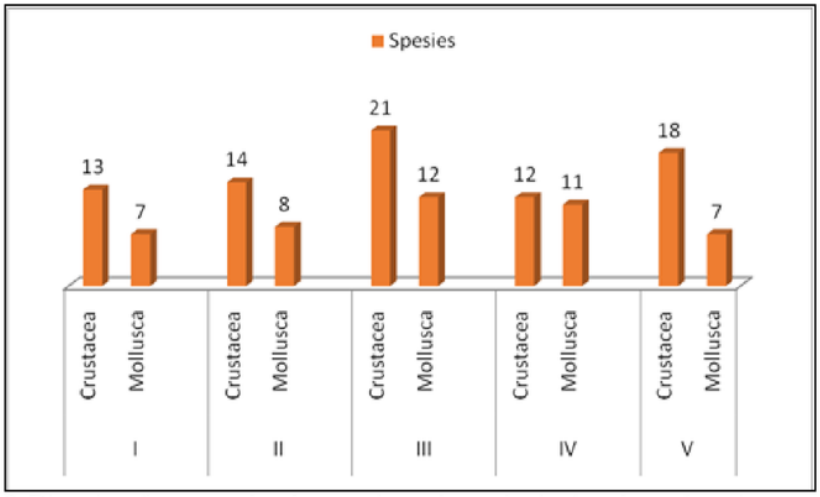

Figure 3. Diversity of macrozoobenthos species at the study site (numbers of species per station).

3.7. Analysis of site suitability and mangrove edu-tourism facilities and infrastructure concept

This study evaluated various site suitability criteria or parameters, based on the category of each parameter for each station (Table 3). This assessment of site suitability for mangrove edu-tourism also evaluated the likely outcome and suitability category of the design concept for mangrove edu-tourism facilities and infrastructure. This concept basically consists of three areas: a buffer zone, reception area, and activity area.

Table 3. Site suitability assessment for mangrove edu-tourism in the Hasanuddin University educational fish pond area based on mangrove ecosystem parameters.

Parameter	Weight	Station I		II		III		IV		V	
		Score	Value	Score	Value	Score	Value	Score	Value	Score	Value
mangrove belt width (m)	0.285	0	0	0	0	0	0	0	0	1	0.285
mangrove density (ind/100m^2)	0.238	0	0	1	0.238	1	0.238	1	0.238	1	0.238
mangrove species	0.192	2	0.384	2	0.384	2	0.384	2	0.384	1	0.192
Associated fauna	0.143	3	0.429	3	0.429	3	0.429	3	0.429	3	0.429
Tide (m)	0.095	3	0.285	3	0.285	3	0.285	3	0.285	3	0.285
Salinity (ppt)	0.047	3	0.141	3	0.141	3	0.141	3	0.141	3	0.141
Total			1.239		1.477		1.477		1.477		1.570
Suitability index			41.30 %		49.23 %		49.23 %		49.23 %		52.33 %
Suitability category[a]			C		C		C		C		A

[a] A = appropriate; C = conditionally appropriate

The site suitability evaluation of the mangrove ecosystem for edu-tourism in Table 3 shows that the parameters with the highest values are the fauna, tides and salinity. The results indicate that the educational fish ponds of Hasanuddin University have potential which could be developed. The suitability index values for stations I, II, III and IV were in the conditionally appropriate category supported by mangrove and faunal diversity, tides and salinity. However, the low mangrove belt width and density give poor values for mangrove tourism. The one station in the appropriate category was station V (suitability index 52.33%), supported by the wider mangrove belt width, diverse fauna, tides and salinity. Despite being in the appropriate categories, the low mangrove species diversity (just one

species in the plots sampled) and relatively low mangrove density were also low for a mangrove edu-tourism area.

Based on the suitability indices for the five stations, the overall site suitability category of the mangrove forests in the Hasanuddin University educational fish ponds area was placed in the conditionally appropriate category for mangrove edu-tourism. In other words, the area requires a development strategy to turn it into a suitable site.

A proposed mangrove edu-tourism concept based on the suitability indicators (Figure 4) includes supporting facilities and infrastructure. These facilities and the infrastructure in the proposed mangrove edu-tourism area make the Hasanuddin University educational fish ponds a tourism object that has the potential to be developed and placed in the good category. Based on the concept of suitability, with these facilities and supporting infrastructure, the edu-tourism area should be able to provide learning experiences to visitors, particularly students from elementary, junior and senior high schools, and even university students and researchers, enabling them to interact directly with the mangrove environment and participate in an effort to create and maintain sustainably managed mangrove areas.

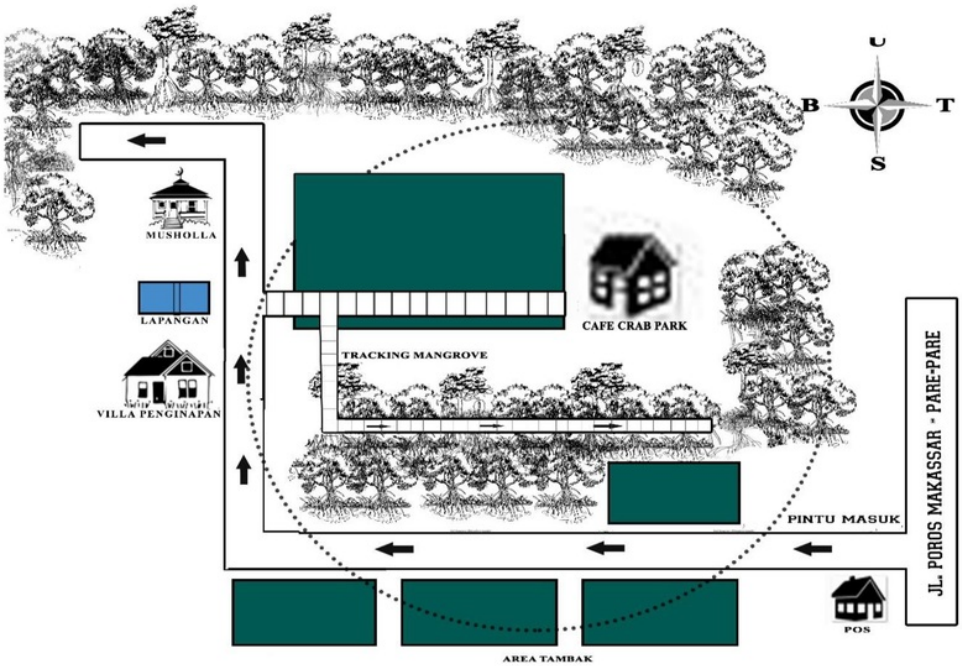

Figure 4. Design concept: mangrove edu-tourism facilities and infrastructure for the educational fish ponds of Hasanuddin University.

4. Conclusion

Seven species of the mangrove were found in the educational fish ponds of Hasanuddin University. From a biodiversity perspective, this places the mangroves in the good category, although the narrow mangrove belt width is classes as poor. Based on the Macrozoobenthos Ecology Indicator for crustacea and molluscs, the condition of the mangrove ecosystem was suitable for the development of the mangrove edu-tourism. Nevertheless, the mangrove edu-tourism area still requires attention,

particular for mangrove rehabilitation and the development of the proposed supporting facilities and infrastructure.

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