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House Reef Farming Development Model to Strengthen Marine Tourism in North Minahasa Regency

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ABSTRACT
The urgency of this research is to maintain the sustainability of tourism, protect marine ecosystems, improve community welfare, and as an alternative in dealing with climate change. To measure the urgency of this research, it was identified that there was quite significant coral degradation over a period of 10 years in Bunaken National Park. In the core zone area, the percentage of damaged coral reefs in 2008 was 14% and in 2017 it rose to 38,42%. Furthermore, in the tourism zone, coral damage in 2008 was 5,98% and in 2017 it reached 20,05%. Development of House Reef Farming tourism to protect coral reef ecosystems. Coral reefs for life and the environment are able to prevent global warming, namely by absorbing carbon dioxide gas and converting it into limestone. One of the causes of climate change is global warming. Based on the above, this research was carried out to maintain the sustainability of tourism, protect the marine ecosystem, improve community welfare, and as an alternative in dealing with climate change through the development of House Reef Farming. The tourist attraction offered is coral planting.

KEYWORDS
Coral, Transplantation, Marine Tourism.

1. Introduction

Tourism is one sector that can improve the economy and community welfare. Currently, tourism is one of the priorities for Indonesian developers because it is one of the economic pillars and a major foreign exchange contributor (Goh et al., 2022). Tourism is closely related to the development of the industrial sector of the economy, where people who visit tourist attractions are consumers who use tourism services (Martomo et al., 2022; Runtunuwu & Kotib, 2022). The Organization for Economic Co-Operation and Development (OECD) in its 2022 Tourism Trends and Policies report stated that in 2019, the tourism sector contributed 5% of Indonesia's gross domestic product (GDP) (OECD, 2022). However, in 2020, it experienced a decline of 56%, reducing its contribution to 2.2% due to the COVID-19 pandemic (Purwawowidhu, 2023).

According to Runtunuwu in Runtunuwu and Kotib (2022), tourism is essential for the country, improving the economy, particularly for local governments where tourist attractions are located, by generating revenue from each tourist site. Raharso in Angmalisang (2021), notes that in many countries, tourism boosts income, creates jobs, and serves as an alternative to overcoming economic crises. Tourism is one of the largest and fastest-growing economic sectors, playing a significant role in realizing sustainable development in many countries. In 2019, tourism contributed US$ 8.9 trillion to world GDP (Jus in Nababan et al., 2021).

The government has made various efforts to revive the tourism sector through the national economic recovery program (PEN). The central government has designated five Super Priority Tourism Destinations (DPSP), one of which is Likupang. Likupang is located in North Sulawesi Province, North Minahasa Regency. These five DPSPs are new attractions for Indonesian tourism, capable of attracting tourists from all over the world. One focus of DPSP infrastructure development is the development of tourist villages.

Bahoi Village is located in West Likupang District, within the DPSP area. The beauty of white sand beaches, fish, coral reefs, mangroves, and seagrass beds makes Bahoi an Ecotourism Village capable of competing with other tourist destinations. With its potential and attractions, the development of marine tourism in Likupang can attract tourists. Tourism can be deemed successful if the number of tourist visits increases (Tangian et al., 2020).

Tourism development can focus on natural, cultural, and marine tourism activities such as diving, snorkeling, swimming, sport fishing, and outdoor recreation (Amiman et al., 2017). Marine tourism is the leading tourism sector in North Minahasa Regency. To support marine tourism, the North Sulawesi Provincial Government, through Governor's Decree Number 407 of 2018, established the North Minahasa Regency Water Tourism Park Conservation Area, covering 25,883.91 hectares (Mokoginta et al., 2023).

Currently, we are facing a significant challenge: climate change. The climate continuously changes due to interactions between its components and external factors such as volcanic activity, variations in sunlight, and human activities such as land-use changes and the use of fossil fuels. Continuous climate change will impact people's lives, causing high rainfall, prolonged dry seasons, rising sea levels due to polar ice melting, natural disasters such as tornadoes, and water shortages. Factors contributing to climate change include the greenhouse effect, global warming, ozone layer depletion, deforestation, uncontrolled use of chlorofluorocarbons, and industrial waste gases. Marine ecosystems are among the most vulnerable sectors affected by climate change. Climate change is a natural event with a significant impact on the global population, particularly in the triple bottom-line sectors: social, economic, and ecological. One of the causes of climate change is global warming.

Coral transplantation is verry important for carried out, considering that coral reefs have a very vital role in maintaining sustainability of marine ecosystems (Malik & Anzani, 2023). The tendency of small coral fragments to encrust and fuse over a variety of surfaces can be exploited for a variety of applications such as coral cultivations, assays for coral growth and reef restoration (Forsman et al., 2015). Coral reef ecosystems play an important role as spawning grounds, foraging areas, and nurseries for marine biota, as well as a source of germplasm (Yudasmara, 2015). Coral reefs contribute to life and the environment by preventing global warming through the absorption of carbon dioxide gas and converting it into calcium carbonate (Orami, 2024). One method of rehabilitating coral reefs is coral transplantation, which involves grafting or cutting live corals and planting them in damaged areas (Coremap in Yudasmara, 2015). The development of House Reef tourism, which offers coral planting as a tourist activity, allows visitors to Bahoi Village to enjoy the natural beauty while also contributing to environmental preservation and global sustainability.

2. Objectives

The aim of this research is to create a house reef farming tourism model as a form of conservation tourism that offers coral planting attractions for tourists who visit it.

To determine a suitable location for coral transplantation, coordination was carried out with various stakeholders, including BPSPL Makassar (Manado working area), DKP North Sulawesi Province, and the Bahoi Village Government.

3. Scope and Methodology

This research was conducted in Bahoi Village which is located in West Likupang sub-district, North Minahasa Regency, North Sulawesi Province.

This research uses a descriptive approach, namely describing existing phenomena, both natural and caused by humans, or analyzing and describing the results without intending to provide wider implications (Adiputra et al., 2021).

This research uses a descriptive approach to describe the phenomena that occur at the research location.

This research was carried out in several stages, where the first stage was preparation, namely coordinating to determine the location for coral transplantation. The factors that are taken into consideration are the bathymetric conditions, water quality parameters (physical and chemical), the condition of the surrounding coral reef ecosystem, the suitability of zoning in the coastal and marine waters of North Sulawesi Province (for the needs of KKRL documents), the condition of the surrounding marine space utilization activities around fishing boat route, floating net cages (KJA) or other activities. The second stage is to transplant corals using the rack method, the third stage is to carry out an analysis of the suitability of coral rehabilitation, the fourth stage is to carry out coral transplantation, and the next stage is monitoring to see the growth rate and life level of the coral.

3.1. Parameter

The main parameters in this research are coral growth and coral survival rate. The measurement technique is by measuring coral height horizontally and vertically, while for coral survival, measurements are made using T0 – T1.

3.2. Tools and Materials

The tool used to attach coral fragments is a PVC pipe frame. The materials used in this research were coral fragments taken from several coral fragments around the research location.

3.3. Data Collection Techniques

The frame media for binding coral fragments uses a PVC frame which is assembled in the shape of a pyramid with a height of 80 cm and a width of 1 meter. Each frame can accommodate 50 coral saplings. Coal growth monitoring will be carried out 5 (five) times, where for the first 3 (three) month period it will be done once every month, and for subsequent monitoring, it will be once every two months and once every three months.

3.4. Data Analysis Techniques

3.4.1. Current Measurement

Measurements are carried out using the following steps: (1) Flowter is thrown into the research water area; (2) The release of the flowter is followed by a time count by stopwatch via cell phone; and (3) Until the string stretches straight due to being pulled by the current, the stopwatch is stopped. Note the time shown on the stopwatch.

Calculation of current speed uses the following formula.

$v=s/t$

where:

v = speed,

s = distance (total length of rope),

t = time (the time required for the rope to stretch perfectly).

The current speed criteria <0.1 m/s is a weak current, >0.1 m/s is a strong current. Then, brightness measurements were carried out using a Secchi disk.

3.4.2. Brightness Measurement

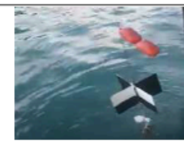
Brightness measurements were carried out using a Secchi disk with the following steps: (1) Weights (stones) are attached to the Secchi disk; (2) Determine the station using GPS; and (3) The Secchi disk is lowered slowly until it is not visible, the Secchi disk rope is marked with a rubber bracelet, and the length of the rope used is measured until it is not visible.

3.4.3. Temperature and Salinity Measurements

Temperature and salinity measurements using a Salinometer. The equipment used to measure water condition parameters can be seen in Table 1.

Table 1. Equipment Used in Measuring Environmental Parameters

No.	Tool's name	Function	Figure

1	Stopwatch	Counting time	
2	Compass	Determine the direction	
3	Flowter	Measure current speed	
4	Salinometer	Temperature and salinity measuring equipment	
5	Secchi disk	Brightness meter equipment	

3.4.4. Coral Growth Analysis

Coral growth analysis was carried out using a plastic meter/ruler with the following formula (Ricker in Luthfi & Nurmalasari, 2015):

$$\beta = L_t - L_0$$

Where:
β = Growth Length/width of coral (mm)
Lt = Length/width of coral at time t (mm)
Lo = Coral length/width at time 0 (mm)
T = Coral observation time (months)

3.4.5. Survival Rate Analysis

This analysis was carried out to determine the success rate of coral transplantation through the percentage of live coral. The formula used is as follows:

$$SR = \left(\frac{N_t}{N_0}\right) x\ 100\%$$

Where:
SR = Coral survival rate (%)
Nt = Number of coral fragments at the end of planting
No = Number of coral fragments at the start of planting

3.4.6. Analysis of Location Suitability and Coral Reef Rehabilitation Index

Analysis of location suitability and coral reef rehabilitation index can be seen in Table 2 (Sahetapy, 2016 in Tanamal et al., 2019).

Table 2. Matrix of Criteria for Aquatic Biophysical Environmental Parameters with Weights, Classes, and Scores for the Suitability of Coral Reef Rehabilitation Using Coral Transplantation Methods

Parameter	weight	S1	Score	S2	Score	S3	Score
		Class					
Water depth (m)	4	3-7	3	8-15	2	<3 or >15	1

Water brightness	4	High/bright	3	Medium/less bright	2	Low/not bright	1
Water turbidity	4	Low (sediment-free)	3	Medium (a bit cloudy)	2	High (turbid)	1
temperature (^{0}C)	4	25-29	3	25-35	2	<23 or >35	1
Salinity (0/%)	4	31-36	3	30 or > 36	2	<30	1
Current speed	4	0,3-0,4	3	0,1 - > 0,3	2	<0,1	1
wave	3	A bit choppy	3	Less choppy	2	Calm	1
Basic substrate type	3	Hard (rock, dead, coral, ruble)	3	Semi-soft (rubbless and sand)	2	Soft (sand), mud	1
Reef exposure	2	Relatively flat	3	A bit steep	2	Steep	1
Protection	2	Relatively open	3	Quite sheltered	2	Protected	1
Coral cover	1	<25 - <50	3	50-75	2	>75	1
Distance to recourse of seeds	1	<100 - 300	3	300-500	2	>500	1
Total weight x score		108		72		36	12

To analyze the land suitability index for the rehabilitation of damaged coral reefs, the following formula is used (Sahetapy, 2016 in Tanamal, 2019):

$$IKR = \frac{(Ni)}{(Nmaks)} x100\%$$

Where:
IKR = Rehabilitation Suitability Index
Ni = value of the i parameter
Nmax = Maximum value of kindergarten rehabilitation suitability parameters.
Total = Score x weight

The criteria or classes for land suitability for coral reef rehabilitation are as follows: S1: Very suitable for the class value (>75-100); S2: According to class score (50-75): and S3: Does not match the class value (<50%).

3.4.7. Coral Transplantation

Coral transplantation uses a pyramid-shaped PVC pipe with dimensions: Length = 1.2 (m); Width = 1.2 (m); and Height = 80 (cm). The number of modules is 24 with each module having 50 coral saplings.

4. Literature Review

Tourism is one sector that plays a very important role in helping economic growth, including underwater tourism. The tourism sector is a sector that has an important role in the economic development of a region. This is due to the multiplier effect of the tourism sector on the development of other sectors and contrinuting to a region’s income (Adhiyaksa & Sukmawati, 2021).

Marine tourism is a type of tourism that uses the beauty of the beach and sea as an attrantion. According to Mareni and Septiviari (2018), as an archipelagic country, Indonesia’s waters are widely used in sectors, especially maritime and fisheries, iol, and gas and tourism. Especially for tourism activities, Indonesian waters are of great interest to domestic and foreign tourists.

Indonesia has made significant achievements due to the breathtaking beauty of its underwater world, earning recognition as a premier diving destination. According to the Professional Association of Diving Instructors (PADI), Indonesia ranks among the top 10 feature destinations for scuba diving, boasting areas rich in biodiversity, including unique sea creatures such as sharks. Additionally, renowned dive sites such as Derawan, Raja Ampat, Komodo, and Tulamben have been classified by CNN as some of the 10 best dive sites in Asia. Among these, three of Indonesia's dive sites—Tulamben, Nusa Penida, and Komodo National Park—are recognized as being among the 10 most popular in the world. Furthermore, the USS Liberty Wreck in Tulamben is highlighted by Scuba Travel as one of the top 10 dives globally, showcasing Indonesia's remarkable underwater offerings and solidifying its status as a top destination for divers.

Based on the results obtained, it can be seen that Indonesian marine tourism has international competitiveness. The tourism industry is an industry that will not run out and will continue to grow (Rahmat, 2021). however, in the current era, global warming also has an impact on marine biota, especially coral reefs which are experiencing a bleaching process. To overcome this, coral transplantation is needed. The phsycal and chemical parameters of waters are a mandatory study when starting activities to improvebthe condition of coral reefs (Subhan et al., 2014).

5. Result and Discussion

5.1. Bahoi Village Profile

Bahoi Village was founded in 1934 as the result of an agreement between 16 people led by Natanael Prong. The village name is derived from the Siau language phrase "Mubaho Dingdang U 'Naung Matuluse, Selamate Mukoa U' Banua," where "baho" means "determination" (I) "endaong ini tampa ikite" means "this is where we live. Bahoi's definition reflects "a noble determination based on the spirit of togetherness to build this place." The area of Bahoi Village spans 186 hectares or 6.25 km² at an altitude of 3-76 meters above sea level, including marine swamp areas and mangrove forests. To the north, Bahoi Village borders Serei, Batu Peli, and the Lihaga Strait. To the east, it borders the Lihaga Strait, Napo Bahoi, and Napo Ila. To the south, it borders Batu Krois, the Bulutui Village Area, and the Mubune Village Area, and to the west, it borders the highway leading to Serei Village.

Bahoi Village is rich in natural resources, with mangroves, marine protected areas, and coastal regions being the most prominent. Additionally, Bahoi Village has economic resources that have gained both local and international recognition. In 1999, the Coastal Resources Management Project (CRMP) and the Japan International Cooperation Agency (JAICA), sponsored by the USA, established three marine protected areas in North Sulawesi: Talise, Bentenan, and the Lembeh Strait, which helped create coral reefs for fish. The CRMP program caught the interest of Bahoi villagers, leading them to propose making Bahoi a marine protected area in 2000. The proposal focused on the community's visibility of the coral reefs, mangroves, and seagrass conditions.

Following the CRMP program, activities were initiated to transform Bahoi into a marine protected area. Through the "Mantatou" initiative, coral reefs in Bahoi Village were monitored and evaluated. In 2002, a village meeting discussed establishing Bahoi as the center of the DPL (Marine Protected Area), and it was officially ratified in March 2003 based on regulations covering 23 laws, including local regulations and ministerial decrees.

In 2000, Bahoi Village participated in the National Environmental Community Empowerment Program (PNPM LPM), alongside 49 other villages. In addition to the PNPM LPM program, Bahoi became a well-known diving spot, thanks to its endemic marine life, such as dugongs, beautiful coral reefs, and other attractions.

By the 1990s, the coastal areas in West Likupang, especially the islands, had been developed into tourist attractions. This development, carried out by the coastal communities, aimed to preserve and enhance Bahoi Village's natural resources. In 2008, Bahoi Village was designated as an ecotourism area through the LNPM LPM program and village meetings. That same year, in collaboration with environmental organizations such as the Wildlife Conservation Society (WCS), YAPEKA, Good Planet (France), and OMEGA (Switzerland), ecotourism training was conducted with funding from PNPM LPM. Bahoi Village was officially recognized as an ecotourism area in 2010, through village regulation No. 2 of 2010, which outlines activities permitted and prohibited in protected environmental areas.

In 2009, Bahoi Village participated in the Ministry of Maritime Affairs and Fisheries' national competition, where it won second place in the national category for coastal and small island management and received the ADIBAKTI MINABAHARI award. In 2012, the village received further support from the Ministry of Maritime Affairs and Fisheries, including artificial coral, fish houses made of bamboo, and fish apartments.

Bahoi Village is officially recognized as an ecotourism area under village regulation No. 2 of 2010, which governs activities in protected areas such as coastal regions, mangroves, coral reefs, and seagrass. Through ecotourism training, nine villagers have obtained diving certifications.

5.2. Bahoi Village Water Environmental

Conditions

It is necessary to measure aquatic environmental parameters to determine the condition of the waters at an observation point. The growth and development of coral reefs have a huge influence.

Based on the result of observations at five observation stations, the current speed was > 0.1 m/s, which is included in the strong current category (Table 3).

Table 3. Current Speed

Station	Coordinate Point	Current Speed (m/s)	Environmental Quality Standards	Caption
1	Lat. 1.719371° Long 125.019044°	0.27	< 0,1 m/s, weak flow >0,1 m/s, strong current	The current speed at 5 observation stations was >1.0 m/s, including strong currents.
2	Lat. 1.719415° Long 125.022683°	0.26		
3	Lat. 1.699682° Long 125.012483°	0.17		
4	Lat. 1.71769° Long 125.022184°	0.23		
5	Lat. 1.720559° Long 125.022452°	0.27		

The brightness of the waters in Bahoi Village at the five observation points is in the optimal brightness category, this shows that the water conditions in Bahoi Village are conducive to coral transplantation activities (Table 4).

Table 4. Water Brightness Data in Bahoi Village

Station	Coordinate Point	Brightness (m)	Environmental Quality Standards	Caption
1	Lat. 1.719371° Long 125.019044°	10 – 15	Coral: > 5 m Mangrove: - seagrass: >3 m	Optimal brightness, this shows that the water conditions in Bahoi Village are conductive for coral transplantation activities.
2	Lat. 1.719415° Long 125.022683°	10 – 15		
3	Lat. 1.699682° Long 125.012483°	10 – 12		
4	Lat. 1.71769° Long 125.022184°	10 – 15		
5	Lat. 1.720559° Long 125.022452°	10 – 15		

Furthermore, pH and salinity are in the good category, while temperature is in the cold category (Table 5).

Table 5. Temperature, pH, and Salinity

Water Parameter	Value	Quality Standards	Caption
Temperature	22.6 °C	Coral: 28 – 30 °C mangrove: 28 – 32 °C seagrass: 28 – 30 °C	Cold
pH	7.04	7 – 8,5	Good
Salinity	32.8 ppt	Coral: 33 – 34 mangrove: s/d 34 seagrass: 33 – 34	Good

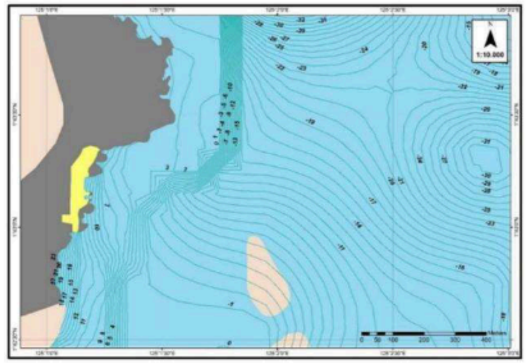
Based on the results in Table 5, the current value at the five observation stations is in the category >1.0

m/s, indicating a strong current. However, the condition of these waters is still conducive for coral transplantation, as evidenced by the abundance of coral reefs in the waters of Bahoi Village. The brightness value is classified in the optimal category, with visibility greater than 5 meters at a depth of 10-15 meters, which is favorable for coral transplantation. The temperature value is below the quality standard, namely 22.6°C. This occurred because the measurements were taken during rain, which caused the temperature to be lower than usual. Therefore, it is necessary to measure the temperature again when the weather is sunny. However, based on previous research conducted by Undap et al. (2018), the average temperature in the morning (07:00-09:00) is 27.9°C, in the afternoon (12:00-14:00) 31.7°C, and in the evening (17:00-19:00) 28.0°C, with an overall average temperature of 29.1°C. Furthermore, Fahruddin et al. (2022) conducted research that found the average temperature of Bahoi waters at three observation stations to be 29.2°C.

The pH of Bahoi waters meets environmental quality standards, with a value of 7. According to Kordi and Tancung in Undap et al. (2018), during the day, the pH of water increases due to photosynthesis, as aquatic plants or phytoplankton consume carbon dioxide. At night, the pH decreases because aquatic plants and phytoplankton consume oxygen and produce carbon dioxide.

According to Nybakken in Yudasmara (2015), the normal salinity range for coral reefs is 32-35 ppt, but coral reefs can survive within a salinity range of 25-40 ppt. The salinity of Bahoi waters is 32.8 ppt, rounded up to 33 ppt, which meets environmental quality standards based on the decree of the Minister of Environment Number 51 of 2004 concerning seawater quality standards. This indicates that the water conditions in Bahoi Village are suitable for coral transplantation activities. In Figure 1, the bathymetric conditions of the waters in Bahoi Village can be observed.

Figure 1. Bathymetric Map of Bahoi Village



Source: Mokodongan et al. (2021)

5.3. Hydro Conditions – Oceanography

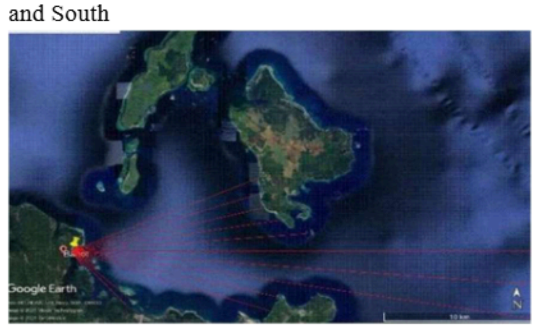
Hydro Oceanography is a marine scientific scope that specifically studies the properties of seawater movements which include waves, tides, and ocean currents (Lolong & Masinambow, 2011).

5.3.1. Wave

Waves are events of vertical rise and fall of sea level from a sinusoidal curve/graph (Mulyabakti et al, 2016). Formation wave generally occurs in offshore areas and when waves are formed they move across the sea with only a small loss of energy (Wakkary et al., 2017).

The dominant wind direction in the waters of Bahoi village comes from the northeast, east southeast, and south, as in Figure 2. The maximum wave occurred from the east in September 2012 with a wave height of 1,132 m and a period of 3,411 seconds.

Figure 2. Fetch towards North East, East South East and South



5.3.2. Tide

Tides are a phenomenon of the periodic rise and fall of water levels caused by celestial bodies such as the sun and moon which have gravitational and gravitational forces (Donkers in Rompas et al., 2022). According to Hamuna et al. (2018), tides are one of the Hydro Oceanographic parameters that influence changes in the profile of coastal and coastal areas.

Tides in the waters of Bahoi Village, West Likupang District, North Minahasa Regency are in the mixed category and tend to be semi-diurnal. The highest tide of 195 cm (1.95 m) occurs at 23.00 - 24.00 WITA and the lowest low tide is 57 cm (0.57 m) at 12.00 - 13.00 WITA. Mixed tides prevailing semi-diurnal (mixed tide prevailing semi durial) are tides that occur twice as high and twice as low in a day but sometimes there is one high and one low with different heights and times (Dien et al., 2016).

At the coral planting location, the lowest tide is 3 (three) meters and the highest tide is 5 (five) meters. The distance from the beach is 139.12 meters while the coral planting area is 195.67m2.

Figure 3. Coral Transplantation Location

5.4. Analysis of Coral Transplantation Land Suitability

The parameters used in the suitability analysis for coral reef rehabilitation are depth, brightness, turbidity, temperature, salinity, current speed, waves, bottom substrate type, shelter, coral cover, and distance to the seed source. Each parameter has a weight, each score is given based on the results of observations in the field. The total results of the scoring calculations obtained were then compared with the maximum values of the parameters to obtain the rehabilitation suitability index (Table 6).

Table 6. Calculation Result of Coral Reef Rehabilitation Suitability Parameter values

Parameter	Weight	Score	Value
Water depth (m)	4	3	12
Water brightness	4	3	12
Water turbidity	4	3	12
Temperature (^{0}C)	4	2	8
Salinity (0/%)	4	3	12
Current speed	4	2	8
Wave	3	3	9
Basic substrate type	3	2	6
Reef exposure	2	3	6
Protection	2	3	6
Coral cover	1	3	3
Distance to the resource of seeds	1	3	3
Total			93

Table 6 shows that the results of the suitability assessment for coral reef rehabilitation in Bahoi Village fall into the "very suitable" category, with a score of 93%. The depth of the waters in Bahoi Village ranges from 3 to 5 meters, as measured by the depth gauge on diving equipment. According to

Tanamal et al. (2019), the success of coral transplant growth is influenced by water depth and the amount of light required by zooxanthellae for photosynthesis. The brightness or light intensity of the water plays a crucial role in the success of coral transplantation. Hutagalung et al (1997) in Tison et al. (2016) explained that a Secchi disk was slowly inserted into the water, and the depth was measured when the black and white colors began to fade. The brightness of the water in Bahoi Village, measured with a Secchi disk, ranged from 10 to 15 meters.

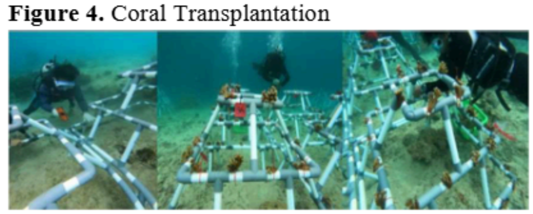
Water turbidity also affects the photosynthesis process of aquatic plants, reducing oxygen production. Refendi in Undap et al. (2018) stated that materials in the water absorb heat, increasing water temperature and decreasing dissolved oxygen. According to Tanamal et al. (2019), high water turbidity stresses zooxanthellae, causing them to leave coral tissues, leading to coral bleaching and death. Direct observations during diving in Bahoi Village indicated low water turbidity. Bengen in Tanamal et al. (2019) notes that the optimal temperature range for coral growth is 23–35°C. Using the EZ 9909 5-in-1 measuring device, the water temperature in Bahoi Village was recorded at 22.6°C, likely due to recent rainfall and cloudy weather. Previous studies by Fahruddin et al. (2022) and Undap et al. (2018) found average temperatures ranging from 26.8°C to 29.8°C. The highest recorded temperature during hot weather was 29.6°C, in line with the water quality standards outlined in the Decree of the Minister of Environment (KEPMENLH) No. 51 of 2004, which sets the acceptable range at 28–32°C.

Salinity also plays a critical role in coral health. Dahuri in Muhlis (2011) explained that corals are sensitive to large changes in salinity, with optimal growth occurring in coastal areas where salinity ranges from 30 to 35 ppt. Using the EZ9909 device, the salinity in Bahoi waters was recorded at 32.8 ppt. Current speed, another factor in coral health, is essential as it brings plankton, the food source for many marine organisms. Nonjti in Tanamal et al. (2019) note that strong currents (>0.1 m/s) are observed at the five observation stations in Bahoi, but the area is still conducive to coral transplantation due to the presence of abundant coral reefs. Wave height in Bahoi waters, measured by Mokodongan et al. (2021), ranged from 1.017 to 1.223 meters at depths of 1 to 10 meters, placing the wave conditions in the medium category.

The substrate in Bahoi Village consists primarily of sand and rubble, requiring modules to be staked into the substrate to prevent displacement by currents and waves. Prasetyo et al. in Fikri et al. (2021) explained that sand substrates contain less calcium carbonate than coral fragments, affecting the coral metamorphosis process. Calcium carbonate formation begins at the base of the coral and extends to the mouth during the formation of the first polyps. Coral cover in Bahoi Village remains in good condition due to its status as a Marine Protected Area (DPL) and the community's high level of environmental awareness (Kindangen et al., 2024). Field monitoring supports this conclusion.

Although the outer edges of the coral reef in Bahoi Village are sloped and steep, rehabilitation modules were placed on flatter areas to optimize coral growth. Santoso and Kardono in Tanamal et al. (2019) explained that coral reefs thrive in open seas with good food and oxygen supplies, whereas growth is limited in enclosed waters. Bahoi Village is geographically protected by several surrounding islands, including Talise, Gangga, Bangka, and Kinabahutan to the north, and Big Talabe and Small Talabe to the east. The distance between coral seeds and the mother colonies is only 5–10 meters from the module installation location, with many large coral colonies, some exceeding 30 cm in diameter, serving as a robust source of broodstock.

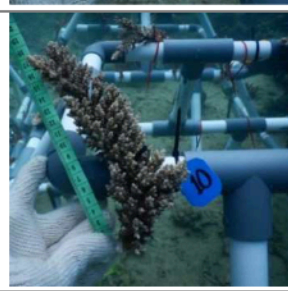
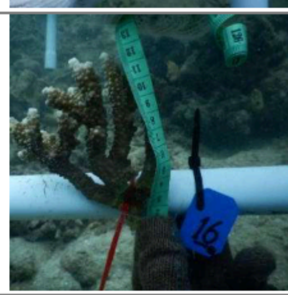
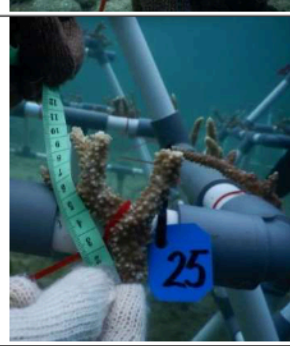
Figure 4. Coral Transplantation

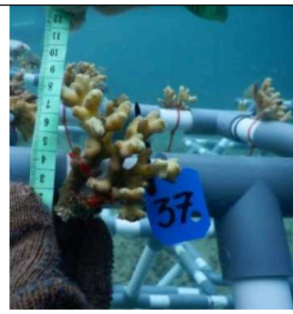
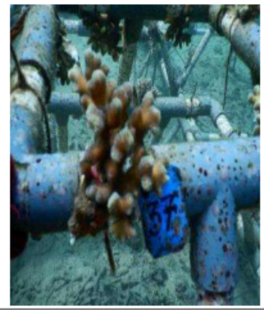


The types of coral that were transplanted were Acropora pulchra, Acropora yongei, Acropora Formosa, Styllopora sp, Pocillopora Sp, Seriatopora Sp, Acropora Carduus, Acropora Sp, and Echinopora Sp. The length of the coral that is planted is then measured to make it easier to monitor coral growth and to see which type of coral is able to adapt more quickly to the new environment. The types and growth of coral can be seen in Table 7. Coral type Acropora yongei from 7 samples taken, the average growth was 1.64 cm, Acropora Carduus from 7 samples taken, the average growth was 2.18

cm, Acropora Sp from 7 samples taken, average growth was 0.65 cm, Acropora Pulchra from 7 samples taken, average growth was 0.45 cm, Pocillopora sp from 7 samples taken, average growth was 1.04 cm, Stylophora sp from 5 samples taken, the average growth was 1.52 cm, Seriatopora hystrix from 7 samples taken, the average growth was 1.25 cm, Acropora Formosa from 7 samples taken, the average growth was 1.24 cm, and seriatopora hystrix from 7 samples taken, the average growth was 0.8 cm. the highest coral growth was the Stylophora sp coral type, 1.25 cm and the lowest was the Acropora Pulcra coral type, namely 0.45 cm. The average coral growth is as follows:

Table 7. Coral Types and Growth

Rack Number	Sample number	Coral type	Size T0 (cm)	Size T1 (cm)	Coral Image 24 May 2024	Coral Image 29 June 2024
60	1	Acropora yongei	16.4	17.5		
61	10	Acropora carduus	17.7	19.8		
65	16	Acropora sp.	12.0	12.9		
51	25	Acropora pulchra	9.5	9.9		

67	37	Stylophora sp.	8.2	10.1		
74	48	Acropora formosa	12.5	14.5		

The survival rate of coral transplants can be seen in Table 8, where the highest survival rate is for the coral types Acropora Formosa, Pocillopora sp, Seriatopora hystrix, Acropora carduus, and Echinopora sp, reaching 100%. Next is the coral type Styllopora sp reaching 98.6%, Ancropora sp, Ancropora pulchra reaching 87.2%, and the lowest is Acropora yongei, namely 84.7%. the overall survival rate of coral transplants is in the very good category, reaching 95.6%.

Table 8. Coral Survival Rate

Rack Number	First Fragment Number	Final Fragment Number	Number of Death Fragment	SR (%)
1	16	15	1	93.75
2	16	16	0	100
3	16	13	3	81.25
4	16	14	2	87.5
5	16	10	6	62.5
6	16	14	2	87.5
7	16	16	0	100
8	16	16	0	100
9	16	16	0	100
10	16	13	3	81.25
11	16	16	0	100
12	16	15	1	93.75
13	16	16	0	100
Average	208	190	18	91.35

Table 9 shows that the Acropora Formosa coral species has a survival rate of 100%, with an average growth rate of 1.24 cm, placing it second among the species observed. The coral type Pocillopora sp also has a survival rate of 100%, with an average growth of 1.04 cm. Meanwhile, the Seriatopora hystrix species, despite having a survival rate of 100%, has a lower growth rate, reaching only 0.8 cm. The highest growth rate is observed in the Stylophora sp coral species, with a growth of 1.25 cm and a survival rate of 98.6%. On the other hand, the lowest growth rate is found in the Acropora pulchra coral species, which grows at a rate of 0.45 cm, although it still maintains a survival rate of 87.1%.

These results are consistent with the calculated values of the suitability parameters for coral reef rehabilitation in Bahoi Village, which yielded a value of 93, indicating that the location is highly suitable for coral transplantation.

Table 9. Coral Reef Transplant Survival Rates

Coral Reef Transplant Survival Rates				
Species	First Fragment Number	Final Fragment Number	Number of Death Fragment	SR (%)
Acropora pulchra	20	14	6	70
Acropora pulchra	20	13	7	65
Acropora pulchra	20	17	3	85
Acropora pulchra	20	19	1	95
Acropora pulchra	20	20	0	100
Acropora pulchra	20	19	1	95
Acropora pulchra	20	20	0	100
	140	122	18	87,14286
Acropora yongei	20	13	7	65
Acropora yongei	20	14	6	70
Acropora yongei	20	18	2	90
Acropora yongei	40	38	2	95
Acropora yongei	40	37	3	92,5
Acropora yongei	40	38	2	95
Acropora yongei	10	8	2	80
Acropora yongei	10	9	1	90
	200	175	25	84,6875
Acropora Formosa	40	40	0	100
Acropora Formosa	40	40	0	100
Acropora Formosa	40	40	0	100
Acropora Formosa	40	40	0	100
Acropora Formosa	40	40	0	100
	200	200	0	100
Styllopora sp	20	19	1	95
Styllopora sp	20	19	1	95
Styllopora sp	20	20	0	100
Styllopora sp	20	20	0	100
Styllopora sp	10	10	0	100
Styllopora sp	10	10	0	100
Styllopora sp	10	10	0	100
	110	108	2	98,57143
Pocillopora sp	20	20	0	100
Pocillopora sp	20	20	0	100
Pocillopora sp	20	20	0	100
Pocillopora sp	20	20	0	100
Pocillopora sp	15	15	0	100
	95	95	0	100
Seriatopora hystrix	10	10	0	100
Seriatopora hystrix	10	10	0	100
Seriatopora hystrix	10	10	0	100
Seriatopora hystrix	5	5	0	100
	35	35	0	100

Acropora carduus	40	40	0	100
Acropora carduus	10	10	0	100
Acropora carduus	20	20	0	100
Acropora carduus	10	10	0	100
	80	80	0	100
Acropora sp	20	19	1	95
Acropora sp	20	17	3	85
Acropora sp	20	18	2	90
Acropora sp	20	19	1	95
	80	73	7	91,25
Echinopora sp	10	10	0	100
Echinopora sp	10	10	0	100
	20	20	0	100

Based on the research above, it can be seen that the waters of Bahoi Village are an ideal place for coral transplantation with the result of 5 types of coral with a survival rate of 100% and the rest above 80%.

6. Findings

The development of the tourism sector in Indonesia is one of the key factors supporting the economy, with coral reef cultivation playing a significant role. The impact of global warming has caused many coral reefs to experience bleaching or death, making coral reef cultivation crucial for preservation efforts. In Bahoi Village, North Sulawesi, coral reef cultivation is being carried out. To ensure the success of these efforts, it is essential to measure aquatic environmental parameters to assess the condition of the water at specific observation points, as these conditions greatly influence the growth and development of coral reefs. Based on research conducted in Bahoi Village, the waters have been found to be ideal for coral transplantation, evidenced by the high survival rate of the transplanted corals.

7. Limitations and Research Gaps

The aims of tourism include improving community welfare and preserving the environment. However, it cannot be denied that tourism can also have negative impacts in the form of environmental degradation if planning is not carried out carefully. One form of attention to environmental sustainability is by developing house ref farming tourism. The tourist attraction offered is coral planting. Tourists who visit not only come to enjoy the natural beauty, but they can also be directly involved in environmental conservation.

The aims of the tourism include improving community welfare and preserving the environment. However, it cannot be denied that tourism can also have negative impacts in the norm of environmental degradation if planning is not carried out carefully. One form of attention to environmental sustainability is by developing house reef farming tourism. The tourist attraction offered is coral planting. Tourists who visit not only come to enjoy the natural beauty, but they can also be directly involved in environmental conservation.

Local community awareness is also needed to protect the tourist area, care for and clean the newly planted coral so that tourism can run sustainably.

8. Conclusion

The results of the study indicate that Bahoi Village is an ideal location for coral reef rehabilitation, with a suitability parameter value of 93, signifying excellent conditions for coral transplantation. Additionally, the average survival rate of the transplanted corals is 95.6%, demonstrating a high level of success in sustaining coral life in this environment. The average coral growth rate is 1.2 cm, further confirming the favorable conditions for coral development in Bahoi Village.

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