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Analysis of Total Economic Value as a Key to Sustainability of the Mangrove Ecosystem of Permata Pilang Probolinggo

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Abstract: Mangrove ecosystems play an important role in maintaining the balance of the coastal environment and provide economic and ecological benefits to communities. This study aims to calculate the total economic value of the mangrove ecosystem at Permata Pilang Beach, Probolinggo City, and to estimate the entrance fee based on the Willingness to Pay (WTP) tourists. Data was collected through incidental sampling for tourists, with a total of 60 respondents over the 7 days of research. The analysis used total economic value (TEV) and WTP. The results showed that the total economic value of the mangrove ecosystem reached IDR 20.851.241.160 per year, with the main contribution coming from direct (43.47%) and indirect (44.13%) benefits. The majority of tourists are willing to pay an entrance fee of IDR 5,000, with a potential income of IDR 240,000,000 per year that can be used for mangrove management and conservation. Management of this ecosystem needs to be carried out in a planned manner with the development of supporting infrastructure and strengthened coordination between the government, the community, and related parties.

Keywords: Total economic value; Willingness to Pay; Mangrove ecosystem; Permata Pilang

1 Introduction

Mangrove forests are tropical coastal vegetation communities, dominated by several types of mangrove trees that are able to grow and thrive in muddy coastal tidal areas [1]. Mangrove forests are commonly found on coasts, shallow bays, estuaries, deltas, and sheltered coastal areas [2]. The physical functions of mangroves include maintaining coastal stability from abrasion and erosion, while their ecological functions such as maintaining biodiversity in coastal areas, and providing nesting, spawning and breeding grounds for various types of coastal biota such as fish, shrimp, crabs, and other fauna [3]. Mangroves also play an important role as an attraction in the ecotourism sector, supporting the local economy and promoting environmental awareness [4]. Mangroves play an important role in supporting local and regional coastal communities with ecosystem services and thus improving people's livelihoods [5]. There have been many studies on the economic valuation of mangrove ecosystems, including in the BJBR Probolinggo area which also highlighted the economic value of environmental services. However, previous studies tend to focus on ecotourism and conservation aspects that have been commercially managed, while this study specifically evaluates the total economic value (TEV) of mangrove ecosystems in the Permata Pilang area, a location that has not been touched by large-scale management and still relies on direct use by local communities. By combining a Willingness to Pay (WTP) approach and the identification of direct, indirect, and existence value components, this research provides a new perspective on the economic dependence of communities on mangroves and offers a stronger empirical basis for community-based sustainability planning.

Permata Pilang Beach is one of the mangrove forest tourism developments in Probolinggo City. Permata Pilang Beach is 7 km long and partially covered with mangroves. The concept of Permata Pilang Beach Tourism is focused on community empowerment through 3 main pillars namely conservation, tourism recreation, and education. Permata Pilang Beach is a tourist attraction managed by Tourism Awareness Group and under the auspices of the Probolinggo

City Youth, Sports and Tourism Office [6]. Mangrove forests in Probolinggo City cover an area of 74.68 ha spread across various sub-district, including Ketapang Village with 6.13 Ha of mangroves, Mangunharjo Village with 19.34 Ha of mangroves, Mayangan Village has12.30 Ha mangroves, Pilang Village has 20.09 Ha mangroves, and Sukabumi Village has16.82 Ha mangroves. The condition of mangrove forests in Probolinggo has experienced significant degradation due to various human activities, such as land conversion into ponds, settlements, and excessive exploitation of natural resources [7].

The potential of mangrove area in Permata Pilang Beach is quite developed. This area has 7 types of mangroves including *Rhyzopora mucronata, Rhyzopora stylosa, Rhyzopora apiculata, Avicennia alba, Avicenna marina, Ceriops tagal*, and *Ceriops decandra*. However, only three species are stably growing and planted in the Permata Pilang Beach area, namely *Rhyzopora mucronata, Avicennia alba*, and *Avicennia marina* [8]. Mangrove ecosystem management efforts require the application of concepts based on economic value and environmental sustainability [9]. The importance of economic valuation is because many people do not aware the significant economic benefits of mangrove forests, so indiscriminate logging needs to be avoided. For human life, the destruction of mangrove forests can backfire both directly and indirectly [10].

This study uses TEV analysis to measure the economic value of mangroves and is based on people's WTP to determine the price of mangrove entrance tickets. This study aims to provide a quantitative description of the economic benefits of mangrove ecosystems through this approach. The results of this study are expected to be the basis for developing more effective mangrove area management strategies, particularly in Permata Pilang Coastal Area, Probolinggo City.

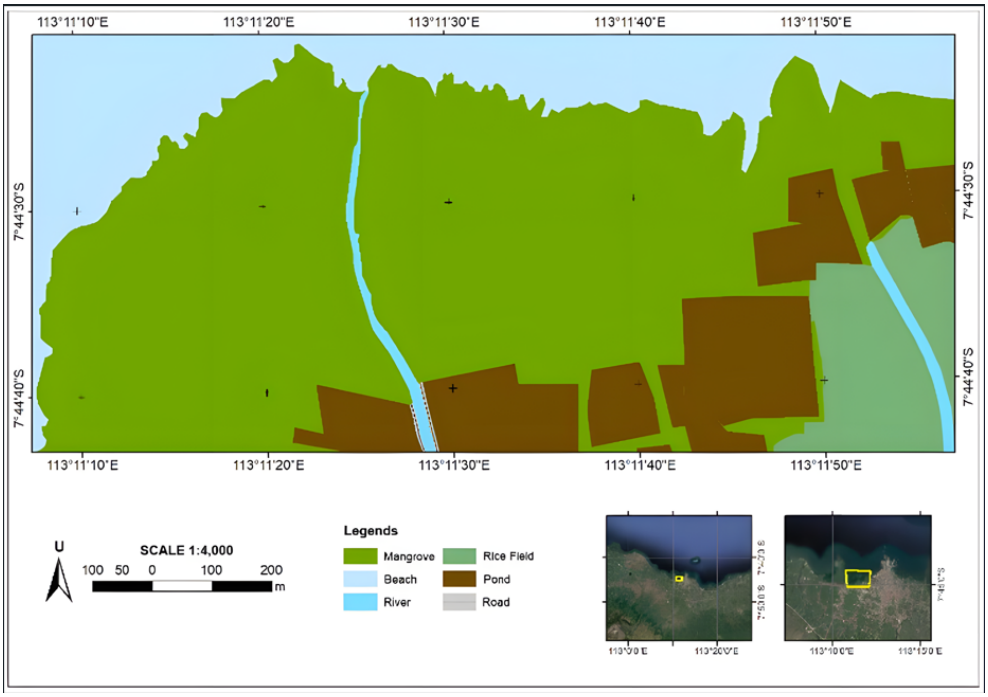

Figure 1. Map of the study area

2 Material and Methods

The research was conducted in Permata Kilang, Probolinggo City, East Java (Figure 1). This research uses a descriptive approach with quantitative methods. Data collected through surveys and interviews with purposive sampling technique which is a technique of sampling data sources with certain considerations [11]. This technique is used for tourist respondents. The number of tourist samples was calculated using the Linear Time Function (LTF) formula, which is the determination of the number of samples based on the estimated time constraints [12] as follows:

$$n = \frac{N}{1 + N\,(e^2)} \tag{1}$$

where,

n = number of samples

N = average tourist population in the study period

e = *error tolerance*

Based on the calculation with this formula, the optimal number of samples used in this study was 60 respondents in the research period of seven days. This number of samples is stated to be sufficient and in accordance with statistical rules which state that the minimum number of samples that can explain the population is 30 [13].

This study analyses data using the Contingent Valuation Method (CVM) approach, which is a method to assess the amount of economic value that individuals give to a good or service [14]. This approach is used to calculate the total economic value of mangrove ecosystems with the concept of WTP, which describes a person's Willingness to Pay a certain amount to get the benefits of the ecosystem [15].

2.1 Total Economic Value Analysis

Economic valuation of mangrove forest resource benefits, by identifying the benefits and functions of mangrove resources assigned to good and sparse mangrove forests. Components of total economic value include direct use value, indirect use value, option value, existence value, and bequest value [16].

2.1.1 Direct-use value

The value of direct benefits is the value obtained from the direct benefits of the mangrove forest ecosystem, such as pond products (shrimp, fish, crabs), and non-farm products (coffee and flour). Maintaining and managing mangroves properly in the long term will provide benefits to the mangrove ecosystem and make a greater contribution to regional economic growth [17].

The formula is as follows:

$$\text{TML} = \text{ML1} + \text{ML2} + \text{ML3} + \text{n} \tag{2}$$

where,

TML = Total direct benefits
ML1 = Direct benefit of shellfish
ML2 = Direct benefits of fish
ML3 = Direct benefits of crab
n = Other types of direct benefits

2.1.2 Indirect-use value

Indirect benefits are the value perceived indirectly for goods and services produced by natural resources and the environment [18]. According to Widiyanto et al. [19], the value of these benefits is USD 142.64 so that the economic value of the nursery area, foraging area, and spawning area can be seen in the following formula:

$$\text{Land area} \times \text{USD} \times \text{IDR} \tag{3}$$

2.1.3 Option value

Option value is a way of assessing estimated benefits from elsewhere (where resources are available) and then transferring these benefits to obtain a rough estimate of the benefits from the environment. The method is approached by calculating the value of biodiversity in the mangrove ecosystem. The value of the benefits of choice is approached by referring to the value of biodiversity of mangrove forests in Indonesia, which is USD 1,500 per km^2 per year or USD 15 per ha per year [20]. To determine the value of selected benefits from mangrove ecosystems, an approach with the following formula is used:

$$\text{MP} = \text{MPb} = (\text{USD15 per ha} \times \text{area}) \tag{4}$$

The calculation of the benefit value of the option is done by converting USD 15 per ha biodiversity value into rupiah value. This value can be used for all mangrove forests in Indonesia if the mangrove forest ecosystem is ecologically important and is maintained naturally.

2.1.4 Existence value

The value of existence will be carried out with the CVM approach or survey method, which is obtained by conducting a direct survey to determine the WTP for the existence of the mangrove forest. Measurement of this benefit is done by summing up all WTP values given by respondents and then averaged based on the number of respondents. This method is particularly useful for estimating non-market values associated with environmental goods, such as the presence of mangrove forests, which provide significant ecological and economic benefits [5, 21].

2.1.5 Bequest value

Mangrove ecosystems are a highly valued legacy. Legacy benefits are benefits that can be passed on to future generations [1]. The value of bequest can be known by conducting interviews to find out the WTP value paid by the community. The TEV approach is used to capture the overall economic benefits of mangrove ecosystems, both those that can be enjoyed directly and indirectly. In this study, existence value is defined as the value that individuals place on the existence of mangroves even though they do not directly use or benefit from them, while bequest value refers to the value that individuals place on the sustainability of mangroves for future generations [22]. These two values were estimated using the CVM approach through hypothetical WTP questions to respondents. By explicitly incorporating this non-use dimension, this research seeks to provide a more comprehensive picture of the importance of mangroves as irreplaceable ecological and social assets.

2.1.6 Total economic benefit value

The total economic benefit value is the sum of all benefits that have been identified from the mangrove forest ecosystem at Permata Pilang Beach, Probolinggo City. The formula according to the study [23] as follows:

$$\mathrm{NET} = \mathrm{DUV} + \mathrm{IUV} + \mathrm{OV} + \mathrm{EV} + \mathrm{BV} \tag{5}$$

where,

TEV = Total economic value
DUV = Direct use value (direct use value, such as the economic value of mussels, fish and crabs)
IUV = Indirect use value (Indirect use value, as a breakwater that can prevent flooding)
OV = Option value (optional value, potential future benefit)
EV = Existence value (existence value, satisfaction from ecosystem sustainability)
BV = Bequest value (legacy value, benefits to future generations)

2.2 CVM Analysis with WTP Method

According to Wahyuni et al. [1] in the measurement method with this technique, respondents are given a rupiah value and then given a question whether they agree or not. In its operation, to carry out the CVM approach, several stages of activity or process are carried out. These stages are:

2.2.1 Making market hypotheses

At the beginning of the CVM process, a hypothetical market for the resource to be evaluated was created. Respondents had previously answered questions about perceptions of mangrove forest environmental services. To form this hypothetical market, respondents were asked to listen to a statement containing the current condition of mangroves on Permata Pilang Beach, Probolinggo City. Furthermore, respondents are given information about the conditions that are more if there is no diminishing mangrove forest. Based on this statement, the respondent's behavior will be obtained in a hypothetical situation rather than in a real situation.

2.2.2 Getting the quote value of the WTP value

If a survey tool has been developed, the survey can be conducted by direct interview. Respondents are given a dollar value and then asked whether they agree to pay for environmental improvements with respondents who are not inclined to pay for environmental improvements.

2.2.3 Calculating the estimated average of WTP

After the survey was conducted, the next step was to estimate the estimated average value of the WTP of each respondent. This value was calculated based on the bid values obtained in stage two. This calculation is based on the meaning and median values. If there are values that deviate significantly from the meaning, they are usually not included in the calculation. WTPi can be estimated by using the middle value of the WTPi class or class interval. The estimated average of WTP is calculated with the formula:

$$\mathrm{EWTP} = \sum_{i=1}^{n} \mathrm{W}_i \mathrm{Pf}_i \tag{6}$$

where,

EWTP = Estimated mean WTP
W_i = i-th WTP value (lower limit of class)
Pf_i = Relative Frequency
n = Number of respondents
i = i-th respondent who is willing to pay

2.2.4 Determine aggregate WTP or total WTP (summation of data)

Data aggregation is the process by which the median offer value is converted to the total population in question. Aggregate WTP or total WTP can be used to estimate the WTP of the population as a whole. After estimating the median WTP value, the WTP value of households can be estimated using the formula:

$$\text{TWTP} = \sum_{i=1}^{n} \text{WTP} \left(\frac{ni}{N}\right) P \tag{7}$$

where,

TWTP = Respondents' total WTP

WTP = WTP of the i-th sample respondent

ni = Number of i-th samples that are willing to pay WTP

P = Number of populations

i = The i-th respondent who is willing to pay.

3 Results and Discussion

Permata Pilang Beach is rich in mangrove species, including *Rhizophora mucronata, Rhizophora stylosa, Rhizophora apiculate*, and *Avicennia alba*, which play an important role in maintaining the coastal ecosystem, preventing erosion, and improving water quality.

3.1 Total Economic Value of Mangroves in Permata Pilang Beach

3.1.1 Direct use value

Direct benefits are the benefits that people get from mangrove ecosystems directly either from catching or utilising mangrove tree parts. Measurement of direct benefits is done using a market value approach. Calculation of the value of direct benefits of mangrove ecosystems is done by multiplying the average net income by the number of people who use. In the calculation of direct benefits, data obtained from respondents in the form of total income, selling price, and expenditure costs.

(1) Direct benefit value of gill net fishermen

Based on Table 1, 80 gillnet fishers in the mangrove area of Permata Pilang Beach conduct fishing activities for about 120 days a year, especially in months with relatively stable weather conditions, from March to October. This period coincides with the dry season, which supports fishing activities around the mangrove ecosystem. Every day, the average income earned by fishermen reaches IDR 75,000, with operational costs per trip of IDR 50,000, so the net income per day is IDR 25,000. If calculated for one year, each fisherman earns a net income of IDR 3,000,000, and overall the total annual net income of all gillnet fishermen reaches IDR 240,000,000. Common catches include fishes that live in shallow and muddy waters such as red snapper, grouper, mullet and baronang, which are often found around mangrove roots as shelter and food sources.

Table 1. Direct benefit value of gill net fishermen

Description	Value
Number of fishermen (people)	80
Total days at sea (days/year)	120
Average income (IDR)	75,000
Operational cost (IDR)	50,000
Netto per day (IDR)	25,000
Total Netto/year (per fisherman)	3,000,000
Value of fish benefits/year (all of fisheries) (IDR)	240,000,000

(2) Direct benefit value of bubu fishermen

Based on Table 2, as many as 25 bubu fishers in the mangrove area of Permata Pilang Beach go to sea for about 240 days a year, which is generally done during the dry season and part of the rainy season, starting from February to November. This period allows fishers to go to sea more often because the water conditions are relatively calm and safe for the use of bubu fishing gear placed on the bottom of shallow waters. Every day, fishermen earn an average income of IDR 60,000, with operational costs of around IDR 20,000 per trip, so the net income received is IDR 40,000 per day. If multiplied by the number of days at sea, one fisherman earns a net income of IDR 9,600,000 per year. With 25 fishermen, the total annual net income of this group of bubu fishermen is IDR 240,000,000. The main catches of

bubu fishers generally come from aquatic species that settle around mangrove root habitats, such as mangrove crabs, shrimps and crabs.

Table 2. Direct benefit value of bubu fishermen

Description	Value
Number of fishermen (people)	25
Total days at sea (days/year)	240
Average income (IDR)	60,000
Operational cost (IDR)	20,000
Netto per day (IDR)	40,000
Total netto/year (per fisherman)	9,600,000
Value of fish benefits/year (all of fisheries) (IDR)	240,000,000

(3) Direct benefit value of line fishermen

Based on Table 3, as many as 15 fishing rods in the mangrove area of Permata Pilang Beach conduct fishing activities around 160 days a year. This fishing period generally takes place from March to October, when weather conditions tend to be stable and the waters are relatively calm, making it safe for traditional fishing activities. Every day, fishing line fishers earn an average income of IDR 50,000, with operational costs per trip of around IDR 10,000. Net income per day reaches an IDR of 40,000. If multiplied by the total number of fishing days in a year, the annual net income earned by each fisherman is IDR 6,400,000. The total net income of all fishing line fishers in a year reaches IDR 96,000,000. The types of catches from fishing rods include red snapper, grouper, mullet, and baronang fish, which are known to feed around mangrove roots.

Table 3. Direct benefit value of line fishermen

Description	Value
Number of fishermen (people)	15
Total days at sea (days/year)	160
Average income (IDR)	50,000
Operational cost (IDR)	10,000
Netto per day (IDR)	40,000
Total Netto/year (per fisherman)	6,400,000
Value of fish benefits/year (all of fisheries) (IDR)	96,000,000

(4) Direct benefit value of scallop fishermen

Based on Table 4, clam fishers in Permata Pilang Beach, Probolinggo City, number around 15 people and rely on simple equipment such as serok and sondong to catch clams and other marine biota in mangrove forest areas or shallow waters. They go to sea about 150 days per year, with less time at sea compared to traditional fishermen who use large boats. This activity is influenced by weather and tides, so their catch tends to increase during the east wind season, which runs between May and October.

The search for clams is conducted in the morning, during low tide, as clams are easier to find in shallow waters with little mud. This activity is carried out using bare hands, which is more environmentally friendly and does not damage the mangrove ecosystem around the beach. The various types of clams caught included blood clams (*Anadara granosa*), green clams (*Perna viridis*), scallops (*Amusium Pleuronectes*), tofu clams (*Mactra violacea*), lokan clams (*Polymesoda erosa*), and oysters (*Crassostrea spp.*).

Table 4. Direct benefit value of scallop fishermen

Description	Value
Number of fishermen (people)	15
Total days at sea (days/year)	150
Average income (IDR)	50,000
Value of fish benefits/year (all of fisheries) (IDR)	112,500,000

(5) Direct benefit value of mangrove coffee

Based on Table 5, the estimated annual income for 100-gram packaged coffee at Permata Pilang Beach is 240 packs sold in one year. With a unit price of IDR 15,000 per pack, the total revenue generated from the sale of packaged

coffee reached IDR 3,600,000. This figure reflects the value of direct benefits derived from the utilization of processed mangrove fruit Avicennia alba, which is processed into quality drinks with unique flavors and potential health benefits. In addition to supporting the economic activities of the surrounding community, the production and sale of mangrove coffee also plays a role in preserving the coastal environment.

Table 5. Direct benefit value of mangrove coffee

Description	Value
Sales volume per year (pieces)	240
Unit price (IDR/pieces)	15,000
Value of fish benefits/year (all of fisheries) (IDR)	3,600,000

(6) Direct benefit value of shrimp farming

Based on Table 6, vanname shrimp farming in Permata Pilang Beach has 18 plots with a size of 0.5 hectares per plot producing significant direct benefits. Each plot produces about 4,000 kg of shrimp per year, which when summed up for 18 plots produces 72,000 kg of shrimp. With a selling price of IDR 85,000 per kg, the gross revenue earned from the entire pond production reaches IDR 6,120,000,000 per year. Operational costs incurred in maintaining the ponds, including feed, labor, and others, amounted to IDR 3,600,000,000. After deducting operational costs, the net income generated is IDR 2,520,000,000 per year. Harvest time for vanname shrimp usually takes about 4 to 6 months after seed stocking. Seed stocking is usually done during the dry season, between March and May. This is because during the dry season, air temperature conditions are more stable and more supportive of shrimp growth.

Table 6. Direct benefit value of shrimp farming

Component	Shrimp Farming (18 plot)
Land area (per plot)	0.5
Amount area	18
Production per hectare (kg)	8,000
Total production per plot (kg)	4,000
Total production (kg)	72,000
Selling price per kg (IDR)	85,000
Gross revenue (IDR)	6,120,000,000
Operational cost (IDR)	3,600,000,000
Total annual income (IDR)	2,520,000,000

(7) Direct benefit value of milkfish farming

Based on Table 7, there are 7 milkfish ponds in Permata Pilang Beach, each with a size of 0.5 hectares per plot, illustrating the value of direct benefits generated. Each plot is estimated to produce around 3,000 kg of milkfish per year, so with 7 plots, the total production reached 21,000 kg per year. With a selling price of IDR 28,000 per kg, the gross revenue earned from the entire milkfish farm production is IDR 588,000,000 per year.

Table 7. Direct benefit value of milkfish farming

Component	Milkfish Farming (18 plot)
Land Area (per plot) (ha)	0.5
Amount Area	7
Production per Hectare (kg)	6,000
Total Production per Plot (kg)	3,000
Total production (kg)	21,000
Selling price per Kg (IDR)	28,000
Gross revenue (IDR)	588,000,000
Operational cost (IDR)	840,000,000
Value of fish benefits/year (all of fisheries) (IDR)	252,000,000

Operating costs incurred for pond maintenance, including feed, labor, pond maintenance, and other management, amounted to IDR 840,000,000. After deducting operational costs from gross income, the net income generated from this milkfish farm is IDR 252,000,000 per year. Stocking of milkfish fried in regions such as Probolinggo is generally done in March to May for September to November harvest, or August to October for January to March harvest. These

times are chosen because water temperature and salinity conditions are more stable. The rearing period of milkfish usually lasts for 5–6 months, depending on the cultivation system used.

(8) Total direct benefits

Based on Table 8, the total value of direct benefits from various coastal and fisheries resource utilization activities in the study area reached IDR 3,464,100,000 per year. This value reflects the significant contribution of the marine and fisheries sector to the local economy. The largest income came from shrimp aquaculture at IDR 2,520,000,000, followed by milkfish aquaculture at IDR 252,000,000, indicating the great potential of the aquaculture sector. The activities of gill net, bubu, fishing rod and clam fishermen also contributed IDR 240,000,000, IDR 240,000,000, IDR 96,000,000 and IDR 112,500,000 respectively, reflecting the diversification of fishing gear used. Mangrove coffee sales contributed IDR 3,600,000, signifying the economic value of sustainably managed mangrove forest products.

Table 8. Total direct benefits

Description	Amount Per Year (IDR)
Direct benefit value of gill net fishermen	240,000,000
Direct benefit value of bubu fishermen	240,000,000
Direct benefit value of line fishermen	96, 000, 000
Direct benefit value of scallop fishermen	112,500,000
Direct benefit value of mangrove coffee	3,600,000
Direct benefit value of shrimp farming	2,520,000,000
Direct benefit value of milkfish farming	252,000,000
Value of fish benefits/year (all of fisheries)	3,464,100,000

3.1.2 Indirect use value

Calculation of indirect benefits of mangrove forests for the environment in Permata Pilang Beach is as a break water that can prevent flooding. Economic valuation analysis through quantification of the value of indirect benefits of mangrove forests shows that the role or physical function of mangrove forests as a substitute for break water with a beach length of 7.620 m [24].

Based on the results of calculations referring to the method used by Ulum [25], the value of the cost of making a wave barrier per meter per year is IDR 1,781,468, with a recorded coastline length of approximately 7,620 meters (Table 9). Using this data, the value of indirect benefits resulting from the presence of the wave barrier is estimated to reach IDR 13,574,786,160 per year.

Table 9. Indirect benefit value

Description	Value
Wave retention value/m/year (IDR) [25]	1,781,468
Shoreline length (m) [24]	7,620
Indirect benefit value/m/year (IDR)	13,574,786,160

3.1.3 Option value

The preferred benefit value of the mangrove ecosystem at Permata Pilang Beach was calculated using the benefit transfer method from previous research. The preferred benefit value of the mangrove ecosystem refers to the standard biodiversity value of USD 15 per ha per year developed by Ulum [25]. The use of this value has been widely applied in various studies to assess the contribution of mangrove ecosystems, such as those conducted by Ulum [25] in Tongas District, Probolinggo Regency, and by Widiastuti et al. [26] in the coastal area of Merauke Regency. Both studies also used a benefit transfer approach to calculate the value of mangrove ecosystems, demonstrating the relevance of standardized values in the Probolinggo region.

Table 10. Benefit value of options

Description	Value
Mangrove biodiversity value (USD/ha/year) [25]	USD 15
Mangrove forest area (ha) [27]	60.6
Mangrove biodiversity value (USD/tahun) [25]	USD 909
USD to IDR rate	15,000
Biodiversity use value (IDR)	13,635,000

Table 10 reveals that the value of mangrove forest biodiversity benefits was calculated at USD 15 per hectare per year. With a mangrove forest area of 60.6 hectares, the total biodiversity value is USD 909 per year, which if converted using an exchange rate of IDR 15,000 per USD, is equivalent to IDR 13,635,000 per year. Research by Hadad [28] also used the same figure, USD 15 per hectare per year, to calculate the biodiversity value of mangrove forests. In this region, with a mangrove forest area of 758 hectares, the value of biodiversity benefits was estimated at IDR 154,063,500 per year. The difference in biodiversity benefit values across the different locations could be due to several factors, including differences in mangrove forest area, fluctuations in currency exchange rates, and the approach used in the calculations in each study. This value is an environmental service of mangrove ecosystems calculated using a benefit transfer approach that is approximated using the value of biodiversity benefits so that the value depends on each condition of the biodiversity of the mangrove ecosystem [29].

(a) Existence value

The value of the benefits of the existence of mangrove ecosystems on the coast of Tongas District is calculated based on the value of the existence of mangrove ecosystems with a Willingness to Pay categorised in 4 options, namely IDR 10,000, Existence Value IDR 15,000, IDR 20,000, and IDR 50,000. The WTP is to give the value given by respondents to the mangrove ecosystem to keep it useful for respondents. In addition, WTP is used to determine tourist preferences for mangrove ecosystems in ecotourism activities in Rekawa coastal wetlands using CVM [30]. According to researchers [31], income factors have a significant influence on community WTP for mangrove ecosystems.

Based on the results of Table 11, the highest WTP value is at a value of IDR 10,000 with 43 respondents. The value of the benefits of the existence of mangroves on Permata Pilang Beach is IDR 1,836,048,000. This result is obtained from the average WTP value per year of IDR 174,000 multiplied by the number of households, namely 10,552. From the above data, the WTP demand curve of existence value is obtained as in Figure 2.

Table 11. Benefit value of existence

WTP (IDR)	Total	Total WTP/month (IDR)
10,000	43	430,000
25,000	15	375,000
40,000	1	40,000
50,000	1	50,000
Total	60	895,000
Average WTP/respondent (IDR)		14,500
Average WTP/respondent/year (IDR)		174,000
Number of households		10,552
Total WTP/year (IDR)		1,836,048,000

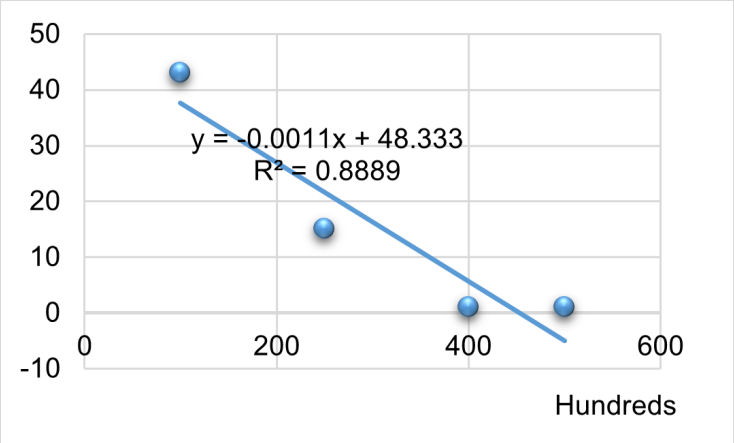

Figure 2. WTP for existence value

Based on Figure 2, the equation that describes the relationship between the number of respondents willing to pay and the amount of WTP is y = -0.0011x + 48.333. The coefficient of determination (R^2) of 0.8889 indicates that this regression model can explain 88.89% of the variation in the number of respondents willing to pay, indicating a very good model fit. The negative regression coefficient indicates that the higher proposed WTP value the less the number of respondents willing to pay according to the basic principles of demand [32]. Linear regression offers a

simple and interpretive model structure, which is well suited to explain the direct relationship between economic variables (such as catch value, costs, and ecosystem benefits) and ecological factors (such as mangrove area, area accessibility, or fishing intensity). The model makes it easy for policy makers to understand the influence of each variable without excessive mathematical complexity. In natural resource economics, basic regression methods are widely used to estimate economic values when data limitations restrict the use of advanced techniques [33].

(b) Bequest value

The value of mangrove ecosystem legacy benefits at Permata Pilang Beach is calculated based on the value of mangrove ecosystem legacy with a WTP categorized in 4 options, namely IDR 10,000, IDR 25,000, IDR 40,000, and IDR 50,000. WTP is to give the value given by respondents to the cost of nursery and maintenance of mangrove ecosystems to remain sustainable. This relates to the economic rationale for mangrove restoration, and the total economic benefits of mangrove restoration can account for about two-thirds of the benefits of natural mangroves [34].

Based on the results of Table 12, the highest WTP value is at a value of IDR 10,000 with 40 respondents and the lowest is IDR 40,000 with 2 respondents, while for a value of IDR 50,000 no respondents chose. The value of mangrove legacy benefits at Permata Pilang Beach is IDR 1,962,672,000. This result is obtained from the average WTP value per year of IDR 186,000 multiplied by the number of households, namely 10,552. From the above data, the WTP demand curve of legacy value is obtained as shown in Figure 3.

Table 12. Benefit value of bequest

WTP (IDR)	Total	Total WTP/month (IDR)
10,000	40	00,000
25,000	18	450,000
40,000	2	80,000
50,000	0	-
Total	60	930,000
Average WTP/respondent (IDR)		15,500
Average WTP/respondent/year (IDR)		186,000
Number of households		10,552
Total WTP/year (IDR)		1,962,672,000

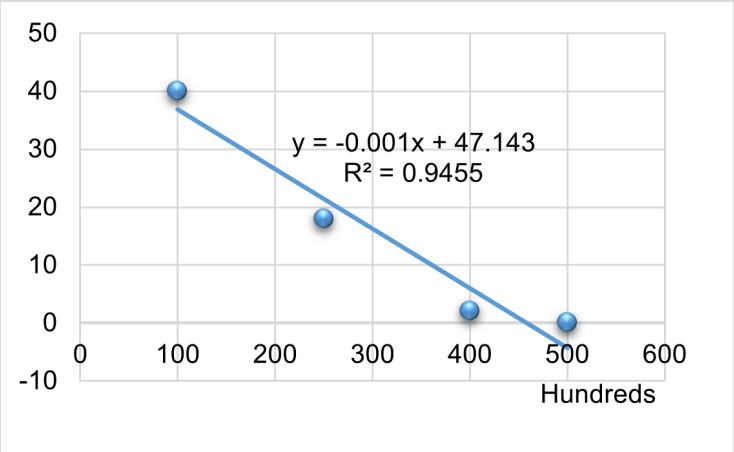

Figure 3. WTP bequest value

Based on the graph above, the regression equation y = -0.001x + 47.143 is obtained, which shows that the higher the proposed WTP value, the less the number of respondents willing to pay, in accordance with the basic principle of demand. The coefficient of determination (R^2) of 0.9455 indicates that the regression model can explain 94.55% of the variation in the number of respondents willing to pay. This value indicates a good model fit. The negative regression coefficient indicates that the higher the WTP value offered, the less the number of respondents willing to pay, in accordance with the basic principles of demand [32].

3.2 Total Economic Value

The results of the total economic assessment are obtained from the sum of the value of direct benefits, indirect benefits, choice benefits, existence benefits, and legacy benefits. The total economic value of mangrove ecosystem

services can be assessed from a combination of benefit transfer research results by previous studies and real data calculations [35].

The value of direct benefits is obtained from the direct benefits of clams, direct benefits of fish, and direct benefits of crabs. The value of indirect benefits is obtained from the function of mangrove ecosystems as coastal protection with the approach of the cost of making wave-breaking buildings. The value of optional benefits is obtained from the value of biodiversity of mangrove ecosystems. The value of existence benefits and the value of bequest benefits are obtained from the value of respondents' WTP.

Based on Table 13, the total economic value of the mangrove ecosystem in Permata Pilang Beach is IDR 20,851,241,160 per year, with the largest contribution coming from direct benefits (16.61%) and indirect benefits (65.10%). Mangrove ecosystems provide a range of economically valuable environmental services, both directly and indirectly. In the context of Permata Pilang, the high value of indirect benefits (65.10%) reflects the important role of mangroves in ecological functions such as coastal protection, abrasion buffering, and providing habitat for various coastal biota, which although not always visible to the naked eye, contributes greatly to the socio-economic sustainability of the surrounding community. This is in line with the findings of Barbier et al. [36], who stated that mangrove ecosystems often have a greater indirect value than their direct value, especially in environmentally stressed coastal areas. Therefore, the total economic value (TEV) approach in this study not only reflects the economic perception of the community but also emphasizes the importance of ecosystem services as a basis for sustainable management [36]. This figure is lower compared to other areas such as BJBR IDR 584,347,909,947 [37] or Tongas District IDR 39,835,001,653 [25]. This difference is due to the size of the mangrove area, the level of tourist visits, and more optimal ecosystem management in other locations.

Table 13. Total economic value

Value	IDR/year	Precentage (%)
Direct benefit value	3,464,100,000	16.61
Indirect benefit value	13,574,786,160	65.10
Option value	13,635,000	0.07
Existance value	1,836,048,000	8.81
Bequest value	1,962,672,000	9.41
Total economic value	20,851,241,160	100

3.3 Entrance Ticket Estimation Based on WTP of Mangrove Tourists at Permata Pilang Beach, Probolinggo City

The development of mangrove ecosystem-based tourism can be a source of income for neighbouring communities and support the local economy. The value of mangrove-based recreation is estimated to reach USD 16,958/ha, contributing USD 62 million to the industry [38]. Educational tourism, scientific research, and community-based conservation activities are some of the potentials that can be developed in the mangrove area at Permata Pilang Beach, Probolinggo city. Mangrove ecotourism management in this area, especially in determining the entrance ticket price, needs to consider the WTP of visitors as one of the main indicators. WTP refers to the willingness of visitors to pay the entrance ticket as a contribution to the conservation and management of mangrove ecosystems. As the offer increases, the likelihood of people agreeing to pay will decrease. This is like the findings of most studies on WTP for conservation of national parks and nature reserves around the world [21].

Based on Table 14, the IDR 3,000 offer was accepted by 80.95% of respondents and rejected by 19.05%. At an offer of IDR 5,000, respondents were evenly split, with 50% accepting and rejecting respectively. When the offer was raised to IDR 10,000, only 23.08% of respondents accepted, while 76.92% rejected. The offer of IDR 15,000 showed complete rejection, with 100% of respondents refusing. Most respondents were more likely to accept lower costs, while higher costs were considered not worth the benefits obtained. Part of the reason respondents did not support WTP was because they were unable to contribute to the goals of community-based mangrove ecotourism [39].

Table 14. Distribution of WTP

Relative Frequency of Acceptance and Refusal				
Bid	3,000	5,000	10,000	15,000
Accept	80.95	50.00	23.08	0.00
Reject	19.05	50.00	76.92	100.00

Figure 4 clearly illustrates the significant drop in revenue levels as costs increase with the equilibrium point.

Table 15, mean total WTP was obtained at an offer of IDR 5,000. This shows that most respondents are more likely to accept lower costs. This is also in line with demand theory, where prices that are too high will reduce the percentage of respondents willing to pay [40, 41], while reasonable prices can maintain a balance between the benefits received and the costs incurred.

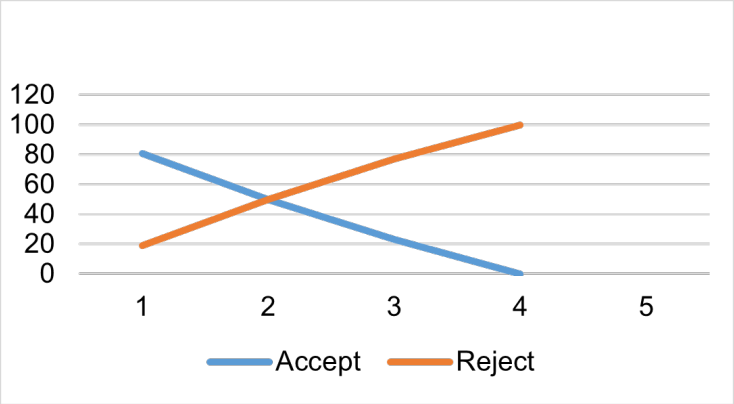

Figure 4. Frequency of acceptance and rejection of WTP at various cost levels

Table 15. Cumulative frequency of max WTP

Cumulative Frequency of Max WTP				
Mean WTP for each class bid	1,500	4,000	7,500	12,500
Cum frequency (accept)	0.81	0.50	0.23	0.00
Mean WTP × Freq	1,214	2,000	1,731	0.00
Mean WTP non Parametic for all classes (total)				5,000

Figure 5 shows a regression graph illustrating the relationship between ticket prices and measured WTP, with the regression equation y = -0.0006 + 19.954 which shows a linear relationship between ticket prices and WTP chosen by visitors, which is then used to calculate consumer surplus. The result of consumer surplus with a value of IDR 15,342,000. By examining WTP, consumer surplus (CS) can be determined in response to policy changes based on direct research results [42].

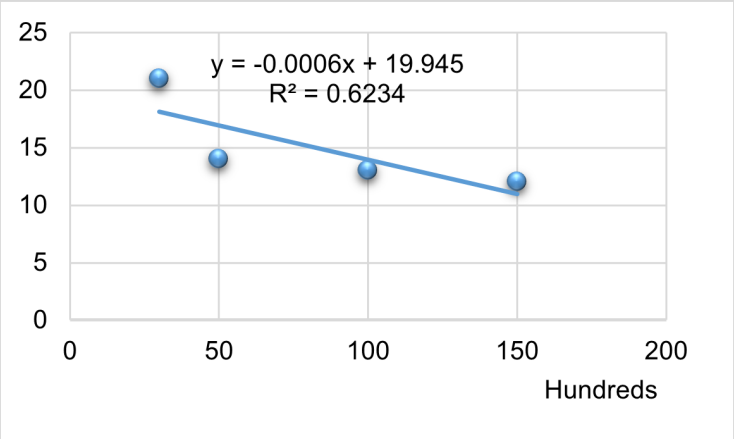

Figure 5. WTP of enterance ticket

This finding is in line with research conducted at Wonorejo Mangrove Ecotourism, Surabaya, which found an average visitor WTP of IDR 28,661 for boat tour activities [43]. However, research at Mekar Beach Mangrove Ecotourism, Bekasi, showed a much lower figure, namely IDR 9,209.30 [44]. This difference indicates that visitors' purchasing power, available facilities, as well as the level of promotion and accessibility have a significant influence on visitors' WTP. In addition, socio-demographic factors also affect WTP such as age, education, level of care and income [45].

4 Conclusions

Based on research on the economic valuation of mangroves in Permata Pilang Beach, Probolinggo City, the total economic value of the mangrove ecosystem reached IDR 20.851.241.160 per year, reflecting the high dependence of the community on direct benefits. If not managed properly, these risks accelerate ecosystem degradation. Most visitors are willing to pay an entrance ticket for mangrove ecotourism of IDR 5,000, with the number of visits around 4,000 people per month, so the potential income generated reaches IDR 21,000,000 per month. This revenue can be used for infrastructure improvements, waste management, and the development of education and conservation programs. Despite its great potential for sustainable ecotourism, mangrove management still faces challenges in terms of coordination and community involvement. Infrastructure, economic activities, and the quality of human resources are the main factors in the development of ecotourism, so strategies to improve these aspects need to be prioritized to support the sustainability of the ecosystem and the welfare of the surrounding community. This study provides an empirical application of the TEV framework in valuing the mangrove ecosystem at Permata Pilang Beach, Probolinggo City. The estimated annual economic value reflects the critical role of both use and non-use values in supporting local livelihoods. These findings reinforce the theoretical proposition in ecological economics that ecosystems deliver multidimensional benefits, often undervalued in traditional market mechanisms.

Author Contributions

Conceptualization, M.P.; methodology, S.S., and M.P.W.; software, A.F.A.M., S.K.A.N., and E.D.N.; validation, M.P.; formal analysis, M.P.; investigation, M.P.; resources, M.P.; data curation, M.P.W; writing—original draft preparation, M.P., and S.S.; writing—review and editing, M.P., M.P.W., S.S., and A.F.A.M; visualization, S.K.AN., and E.D.N.; supervision, M.P.; project administration, S.S.; funding acquisition, M.P. All authors have read and agreed to the published version of the manuscript.

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Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

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Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Nomenclature

BV	Bequest value, IDR/year
DUV	Direct use value, IDR/year
EV	Existence value, IDR/year
IUV	Indirect use value, IDR/year
MP	Option benefit value, IDR/year
n	Number of respondents or samples
N	Population size (average during study period)
NET	Total economic value, IDR/year
OV	Option value, IDR/year
P	Total population size
Pf_i	Relative frequency of respondent i
TWTP	Total Willingness to Pay, IDR/year
W_i	Lower bound of WTP class i
WTP	Willingness to Pay, IDR
WTP_i	WTP value of respondent i
EWTP	Estimated average WTP, IDR
USD	United States Dollar