Bioedukasi
Jurnal Biologi dan Pembelajarannya
Vol. 22 No 3, October 2024, page 466-473
e-ISSN: 2580-0094; p-ISSN:1693-3931
DOI: 10.19184/bioedu.v22i3.52567
jurnal.unej.ac.id/index.php/BIOED

Morphological Characteristics and Economic Value of Mangroves (Rhizophora and Avicennia) in Penunggul Village, Pasuruan Regency, East Java, Indonesia

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Article Info

Article history:
Received July 12, 2024
Revised October 3, 2024
Accepted October 9, 2024

Keywords:
Avicennia
Economic Value
Mangrove
Morphology
Rhizophora

ABSTRACT

Mangroves are ecosystems with high productivity levels and functions from an ecological/biological, physical, and economic perspective. Mangroves have a high diversity of plant species. The morphological and anatomical adaptations of mangrove species are very relevant from an ecological point of view. Generally, the dominant plants in mangrove ecosystems usually come from Rhizophora, Avicennia, and Sonneratia genera. Indonesia is a country with the highest mangrove forest area in the world. Mangrove ecosystems spread across almost all islands, one in East Java, precisely in Penunggul Village, Pasuruan Regency. Can study the potential of the mangrove ecosystem in Penunggul village from an ecological and economic perspective. To explore information related to mangrove plant diversity in Penunggul Village with morphological observations of plants and compare with the literature. Can explore the economic value of mangroves in Penunggul Village by conducting interviews with people who utilize mangroves in terms of monetary value. The dominant mangrove plants found in Penunggul Village are *R. mucronata*, *R. stylosa*, *A. alba*, and *A. marina*. The community uses the economic potential of mangroves in seedlings, chip production, and buying and selling marine biota that live around mangrove ecosystems, such as oysters and crabs.

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1. INTRODUCTION

Mangroves are ecosystem-resistant to areas with high salinity levels found in tropical and subtropical regions. Mangroves are wetland ecosystems with a high level of productivity and a wide variety of species (Mitra *et al*., 2021). Mangrove ecosystems have three biological/ecological, physical, and economic functions. Biologically/ecologically, mangroves are spawning, nursery, and feeding grounds for marine life. Mangrove plants can also store the most significant carbon compared to terrestrial forests. Physically, mangroves can maintain coastal stability, prevent marine erosion, capture waste, prevent salt intrusion onto land, and process organic waste (Harini *et al*., 2019). Economically, mangroves offer numerous livelihood for local communities by providing resources such as fish, crabs, fuel, and medicinal plants. These ecosystem services, including fisheries and tourism significantly contribute to direct economic benefit for local populations by generating income sources (Bimrah *et al*., 2022).

Divide mangrove plant species into three groups: significant mangroves, minor mangroves, and mangrove associations. Effective mangroves play an essential role in the community. Found the semi-mangrove species in land fringe habitats that experience irregular tides. Associated mangrove species are non-flowering, herbaceous, sub-timber, and usually grow near the tidal margins (Mitra *et al*., 2021). Generally, the classification of mangrove species applies to plant species with specific adaptations in tidal areas; species that can live in intertidal marshes and habitat dominate terrestrial environments that do not include the mangrove group (Hamilton, 2020). Anatomical and morphological adaptations in mangrove species are highly relevant from an ecological point of view (Yanez-Espinosa & Flores, 2011).

Mangroves consist of trees and shrubs with 12 flowering plants, namely Avicennia, Sonneratia, Rhizophora, Bruguiera, Ceriops, Xylocarpus, Lumnitzera, Laguncularia, Aegiceras, Aegiatilis, Snaeda, and

Conocarpus. Indonesia has a high level of mangrove vegetation diversity, with a total of 202 recorded species, including 89 tree, 5 palm, 19 liana, 44 epiphyte, and 1 cycad. However, four main families dominate the mangrove forest ecosystem in Indonesia: Rhizophoraceae (Rhizophora, Bruguiera, and Ceriops), Sonneratiaceae (Sonneratia), Avicenniaceae (Avicennia), and Meliaceae (Xylocarpus) (Kustanti, 2011). Data from the Direktorat Jenderal Pengelolaan Ruang Laut in 2020 states that Indonesia has 3.4 million hectares of mangrove forests out of 16.5 million hectares of total area in the world or 21% percent of the entire mangroves in the world are in Indonesia (Marbun *et al*., 2022).

One area in Indonesia with mangrove forest potential is Penunggul Village, Pasuruan Regency. Several types of mangrove plants have stood firmly for 33 years as a green belt in Penunggul Village. The mangrove ecosystem in Penunggul Village has benefits in terms of ecological and economic aspects (Hafidah *et al*., 2023). Mangrove forests are a treasure trove of biodiversity in Indonesia with significant ecological and economic significance (Kristiningrum *et al*., 2019). Indonesia's mangrove areas could contribute US$ 1,5 billion from the fisheries sector (Harini *et al*., 2019).

Mangrove ecosystems have been studied for decades by botanists, ecologists, and oceanographers. In addition, combined studies of mangrove botany, ecology, economics, and ethnography are also gaining attention (Walters *et al*., 2008). Research focusing on the botany and economic value of mangroves in high-potential areas is crucial for gathering data on mangrove plant diversity in Indonesia and providing information on their numerous functions. This research aims to enhance public awareness of mangrove forests through several key steps to generate data that will inform and educate the community. First, comprehensive field surveys were conducted to collect data on mangrove species and their ecological and economic impacts. Detailed observations and analyses were performed to understand the functions and benefits of mangroves. The findings from this research are then utilized to develop targeted outreach materials and educational content, which highlight the significance of mangrove ecosystems and help raise awareness about their importance.

2. RESEARCH METHOD

The research was conducted in Penunggul Village, Pasuruan Regency, East Java, Indonesia. The located from penunggul Village at 7°42''11.1" South latitude and 113°05'35.2" East longitude. Data collection was carried out from October to December 2024, with humidity and wind speed at the study site being 80% air humidity at 10:00 AM and wind speed of 20 km/h with wind direction from the south.

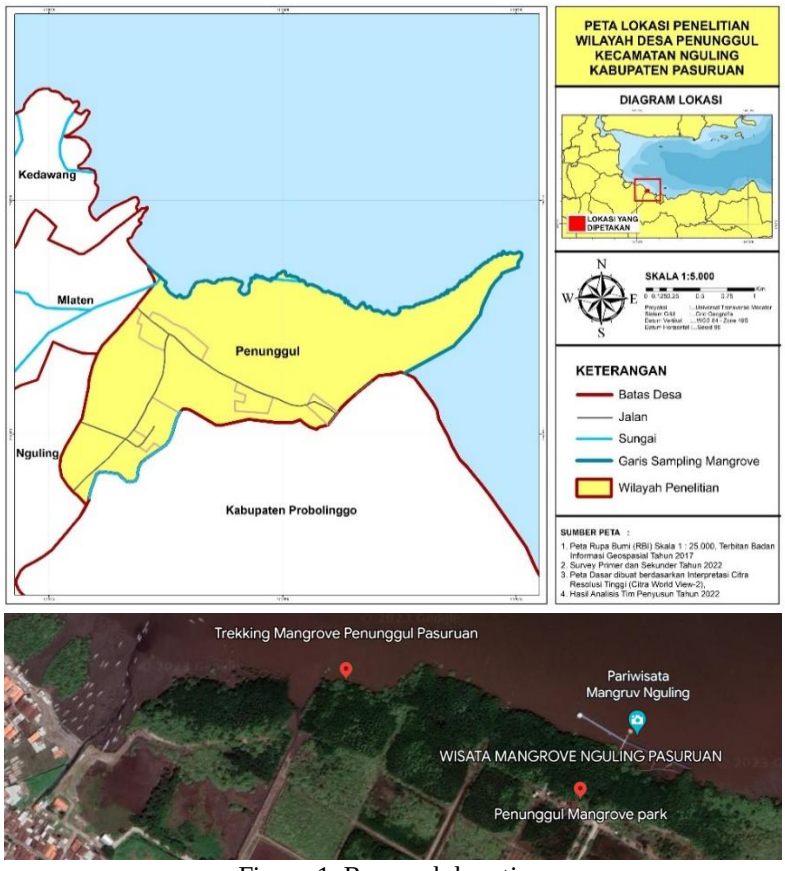

Figure 1. Research location

The type of research applied is descriptive-exploratory with a qualitative approach. The descriptive approach aims to describe the actual facts occurring at the research site, while the exploratory approach focuses on qualitatively exploring or delving deeper into the research topic (Nihayah and Lajiba, 2018). The sampling method uses purposive sampling technique, which is chosen based on the researcher's judgment and specific criteria that have been deliberately set. This technique is a non-random method that does not require a theoretical basis for its application (Etikan, 2016). Sampling is divided into morphological identification of plants and economic value analysis of mangroves.

2.1 Morphologic Identification of Mangrove Plants

Morphological identification of mangrove plants was carried out in the mangrove ecosystem of Penunggul Village by observing and describing the morphological structure of roots, stems, leaves, flowers, and fruits. The following steps are taken in the morphological identification of mangrove plants based on (Putra & Fitriani, 2018):

a. Prepare the tools and materials used
b. Do observations of the location
c. Marking the location where mangrove plants
d. Make morphological identification of plants and compare with literature guidebooks from (Djamaluddin, 2018 dan Kusmana, 2013)
e. The researcher was taking pictures.

2.2 Mangrove Economic Value Analysis

The researcher was conducting interviews with the surrounding community of Penunggul village to know the economic value of the mangrove ecosystem. The interviews were semi-structured, in which the researcher had a list of questions and delivered them casually. The questions would develop but still within the main framework of the questions (Sedayu & Azka, 2021). The sampling of interviewes is based on research (A. Samad *et al*., 2020), using the purposive sampling method. Take the sample as a subject based on the researcher's purpose: those who utilize mangrove natural resources.

2.3 Data Analysis

Qualitative data analysis is conducted by describing the research results using tables, images, and detailed explanations.

3. RESULT AND DISCUSSION

The mangrove plant species identified in the Penunggul Village mangrove ecosystem consisted of four species with different morphological characteristics.

Table 1. Mangrove species identified

Species Name	Local Name
Rhizophora mucronata	Locally known as “Bakau”
Rhizophora stylosa	Locally known as “Bakau”
Avicennia marina	Locally known as “Api-api”
Avicennia alba	Locally known as “Api-api”

Rhizophora mucronata is a species that belongs to the Rhizophoraceae family. *R. mucronata* is commonly known as red mangrove and Asian mangrove. *R. mucronata* can grow up to 20-25 meters in height (Batool *et al*., 2014). Members of the genus Rhizophora have unique characteristics in their germination, so they are called viviparous plants (Shamin-Shazwan *et al*., 2021). Members of the genus Rhizophora have unique characteristics in their germination, so they are called viviparous. The morphological characteristics of *R. mucronata* found in the mangroves of Penunggul Village have a stilt roots system, brown stems with grooves, and a part on the inside of the stem which is red/pink, single leaf phyllotaxis facing crossed elliptical-shaped, has yellow-green flower sepals with white-haired petals, the fruit is oval, and has a long cylindrical hypocotyl. The hypocotyl of *R. mucronata* grows and develops while still in the mother plant, so it is called viviparous. On the abaxial part of the leaf, the black spots almost cover the leaf's lower surface. Based on research from (The *et al*., 2018), these spots are called “cork warts” and serve as a means of air entry.

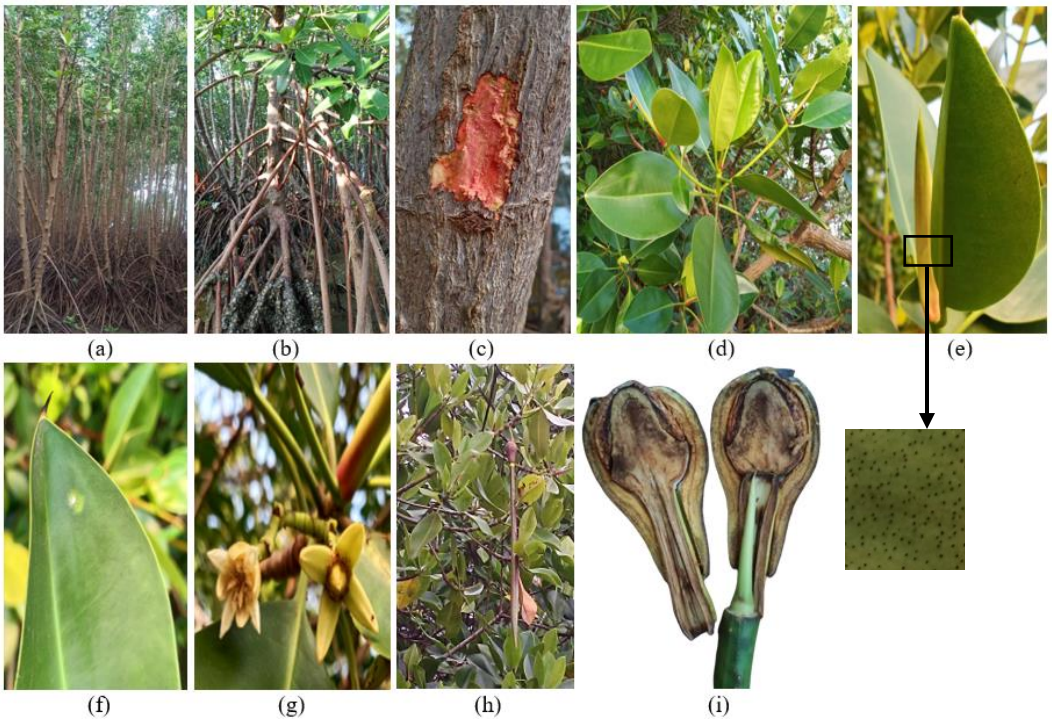

Figure 2. *R. mucronata* morphology (a) whole plant (b) stilt roots (c) leaves philotaxis (d) leaf abaxial (e) leaf apex (f) flower (g) hypocotyl (h) fruit (i) inside of fruit

Rhizophora stylosa is a type of mangrove plant with similar characteristics to *R. mucronata*, and the difference is the size of *R. stylosa* is more petite than *R. mucronata*. *R. stylosa* is widely distributed in the Indo-Pacific region. *R. stylosa* includes the Rhizophora genera, so the reproduction of *R. stylosa* starts from fertilized flowers that develop into seed-sized fruits and continue to germinate on the parent tree into viviparous seedlings or propagules (Wilson & Saintilan, 2018). *R. stylosa* is about 5-8 m tall with a trunk diameter of 25 cm and has thin but strong stilt roots (Kalasuba *et al*., 2023).

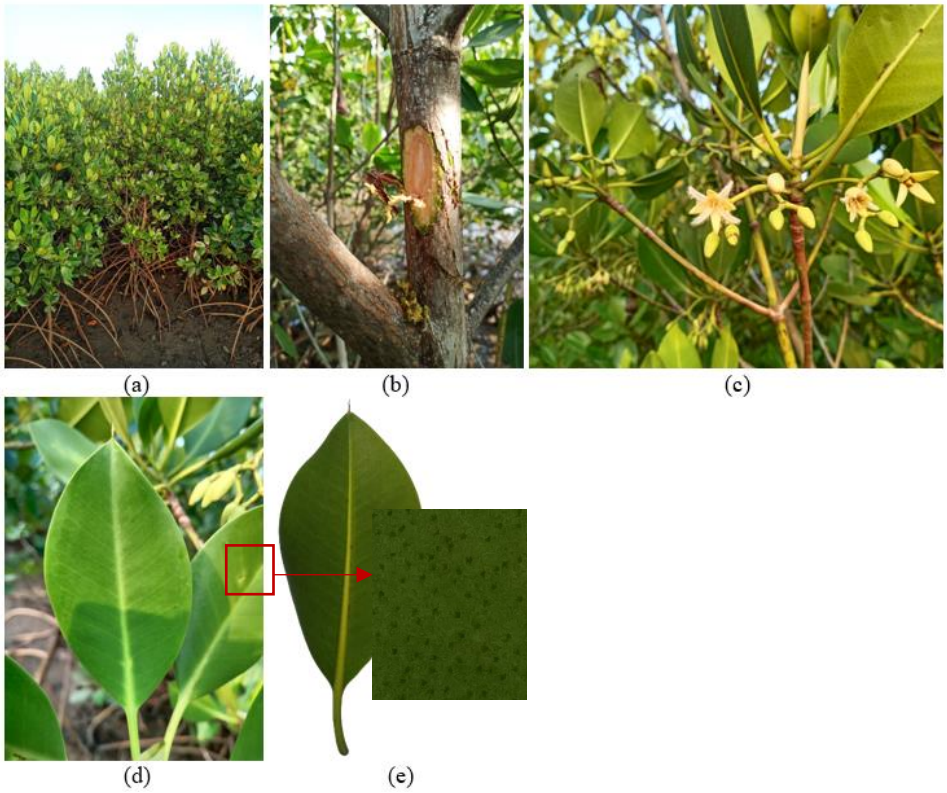

Figure 3. *R. stylosa* morphology (a) whole plant (b) stem (c) flower (d) leaf adaxial (e) leaf abaxial

Avicennia alba is common in coastal areas with medium to large size (15-20 m) with dark gray bark. The pencil-shaped roots of *A. marina* that emerge above the ground are called pneumatophores (Ranjan Kar *et al*., 2015). *A. alba* in Penunggul Village has crossed leaf phylotaxis with a lanceolate leaf shape. Define the Yellow flowers in the leaf's terminal part and the fruit's condition like a chili. According to (Kustanti, 2011), Call the Avicennia genus seeds crypto vivipary because the seeds have germinated, but fruit membranes protect before release.

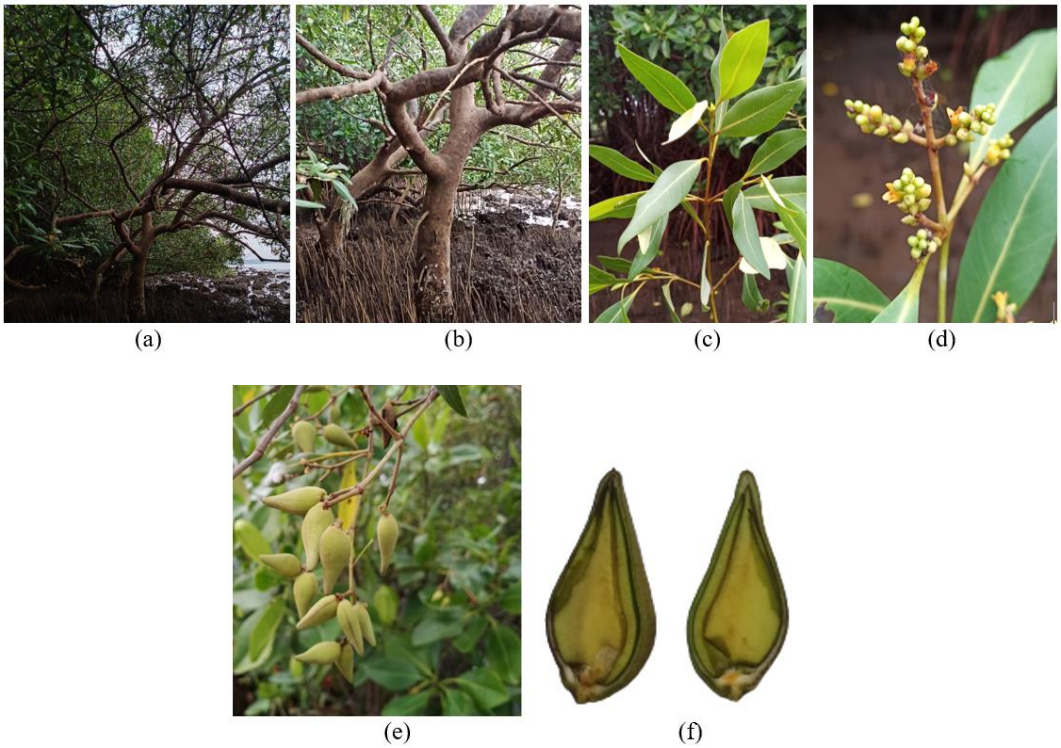

Figure 4. *A. alba* morphology (a) whole plants (b) roots and stem (c) leaf (d) flower (e) fruits (f) inside of fruit

Avicennia marina is a member of the Avicennia genus that has similar characteristics to *A. alba* but has some differences that distinguish it from *A. alba*. *A. marina* produces many upright breath roots with lenticels. The leaves are elliptical-oblong, and the fruit is rounded-heart-shaped with a short beak at the tip (Baba *et al*., 2016). *A. marina* can live in habitats with high salinity levels because it is one of the most tolerant mangrove species to salinity, drought, and water temperature (Nguyen *et al*., 2015).

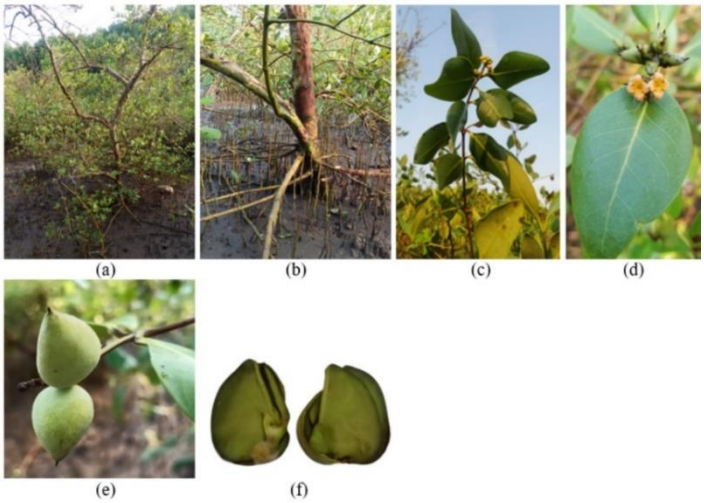

Figure 5. *A. marina* morphology (a) whole plant (b) roots and stem (c) leaf (d) flower (e) fruits (f) inside of fruit

In addition to the high diversity of mangrove plant species, the mangrove ecosystem in Penunggul Village has good economic potential and can be a place of livelihood for local people. The people of Penunggul Village utilize the existence of mangrove ecosystems to look for marine biotas such as crabs and oysters, make chips, and

build a nursery business as an effort to preserve mangroves in Penunggul Village and help the conservation of mangrove forests in addition to their high economic value.

Table 2. Economy value of mangrove in Penunggul Village

No.	Utilization Type	Capital	Profit	Month Periode
1.	Seedling business	Rp. 254.070.000	Rp. 194.030.000	June-Nov 2022
2.	Mangrove chips	Rp. 590.000	Rp. 1.110.000	October 2022
3.	Crabs sales	-	Rp. 200.000	Each sale
4.	Oysters sales	-	Rp. 100.000	Each sale

Deriving profits from the modal required less the net sales proceeds. In the seedling business, Several coastal areas of Indonesia distribute mangrove seedlings from Penunggul village. The mangrove seedlings sold are *R. mucronata, R. stylosa, A. marina*, and *A. alba*. Each month, they can sell from 5000 – 70.000 stems. This business can help the economy of up to 40 seedling farmers.

Mangrove chips are an individual business that utilizes the hypocotyls of mangrove plants (*R. mucronata*) with a mixture of other ingredients modified to become a chip product with a delicious taste and a high selling value. In addition, the mangrove ecosystem in Penunggul Village is a place for marine biota such as invertebrates, namely oysters and crabs. Some fishermen utilize it by looking for aquatic organisms, such as crabs and oysters, and then selling them to local people. In addition to the sales business, the mangrove ecosystem in Penunggul Village is starting to get attention with the development of ecotourism, which will attract tourists to visit and increase regional income.

(a) (b) (c)

Figure 6. Economic business utilizing mangroves (a) seedling (b) chips (c) oysters in mangrove stilt roots

The people of Penunggul Village can benefit from mangroves both in ecological and economic terms. As written by (Walters *et al*., 2008), Mangroves can support various ecosystem services such as helping, providing, regulating, and cultural services. Seeds, fruits, leaves, and plant stems have the economic value of mangroves. In the mangrove ecosystem, animals such as fish, shrimp, and crabs grow and develop, which has monetary value, and mangrove forests have aesthetic value as a tourism destination (Harini *et al*., 2019)..

4. CONCLUSION

Mangrove ecosystems in Penunggul Village, Pasuruan Regency, have ecological and economic benefits for the local people. The diversity of mangrove plant species that grow has dominant species, namely *Rhizophora mucronata*, *Rhizophora stylosa*, *Avicennia alba*, and *Avicennia marina*, with different morphological characteristics of roots, stems, leaves, flowers, and fruits. The community utilizes the existence of mangrove ecosystems as a livelihood with seedlings, mangrove chips processing, buying, and selling marine biota such as oysters and crabs. The economic value of the four utilizations is also high, with a profit of Rp. 194.030.000 in June-November 2022 for seedling sales, Rp. 1.110.000 every month in mangrove chips processing, sales of crabs and oysters, which have a selling value of Rp. 100.000 - Rp. 200.000 per sale.

As a follow-up, this research aims to raise public awareness about the significance and high economic value of mangrove ecosystems through the creation and distribution of an informational book. This book presents the research findings and the benefits of mangrove ecosystems in clear and easily understandable language. It was provided to village officials for display in tourist information kiosks and was also presented during community meetings to enhance public awareness and engagement regarding the economic value of mangrove resources. Additionally, it is recommended that future research focus on studies related to conservation and rehabilitation programs for mangrove ecosystem, particularly in regions of Indonesia facing critical conditions.

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