Journal of Academic Biology and Biology Education
Vol. 3, No. 1, June 2026, pp. 110~123
ISSN: 3062-9705, DOI: 10.37251/jouabe.v3i1.3378

Traditional Ecological Knowledge and Sustainable Mangrove Conservation: A Community-Based Perspective

Dora Boyd Cohen[1], Miri Pariyas Tutik Fitriya[2], Silviya Joshi[3]
[1]Ecology, Evolution, and Conservation Biology, University of Illinois Urbana-Champaign, Illinois, United States
[2]Biology Study Program, Universitas Islam Negeri Maulana Malik Ibrahim, East Java, Indonesia
[3]Landscape ecology and nature conservation, University of Greifswald, Greifswald, Germany

Article Info

Article history:

Received Mar 21, 2026
Revised Apr 26, 2026
Accepted Jun 1, 2026
Online First Jun 4, 2026

Keywords:

Community-Based Conservation
Ethnobotany
Mangrove Conservation
Small Island Communities
Traditional Ecological Knowledge

ABSTRACT

Purpose of the study: This study aimed to identify the mangrove species utilized by the Ra'as community, determine the plant parts and utilization methods employed, examine community-based mangrove conservation practices, and explore local perceptions regarding the ecological and socio-cultural importance of mangrove ecosystems on Ra'as Island, Indonesia.

Methodology: This study employed a descriptive-exploratory design using a survey method and Participatory Ethnobotanical Appraisal approach. Data were collected through field observations, semi-structured interviews, documentation, literature review, and mangrove species identification. Research tools included smartphones, field notebooks, interview guides, and taxonomic references. Data were analyzed using descriptive qualitative analysis and percentage-based quantitative analysis.

Main Findings: Nine mangrove species were utilized by the Ra'as community for ecological protection, food, traditional medicine, fuelwood, handicrafts, maritime activities, and cultural beliefs. The stem was the most frequently utilized plant part, while direct use represented the dominant utilization method. Community conservation practices consisted of direct actions through mangrove planting and indirect conservation through local beliefs, social norms, and village regulations.

Novelty/Originality of this study: This study integrates ethnobotanical utilization, traditional ecological knowledge, community perceptions, and conservation practices within a single analytical framework. It provides new empirical evidence from a small-island socio-ecological system in Indonesia and demonstrates how local knowledge and cultural values contribute to sustainable mangrove management and community-based conservation.

Corresponding Author:
Dora Boyd Cohen
Ecology, Evolution, and Conservation Biology, University of Illinois Urbana-Champaign, 320 Morrill Hall, 505 S. Goodwin Avenue, Urbana, IL 61801, United States.
Email: boydorachneend@gmail.com

1. INTRODUCTION

Mangrove ecosystems are among the most productive coastal ecosystems in the world and provide a wide range of ecological, economic, and social benefits. Mangrove forests function as natural barriers against coastal erosion, storm surges, seawater intrusion, and extreme weather events while simultaneously supporting fisheries productivity and biodiversity conservation [1], [2]. In addition, mangroves play a crucial role in carbon

sequestration and climate change mitigation through their capacity to store substantial amounts of blue carbon [3], [4]. Despite their importance, mangrove ecosystems continue to experience degradation due to land conversion, overexploitation, coastal development, and unsustainable resource use [1], [5]. Consequently, sustainable mangrove management has become an important global priority for achieving biodiversity conservation and coastal resilience.

The sustainability of mangrove ecosystems is closely linked to the interaction between local communities and coastal resources. Coastal communities have long depended on mangrove forests for their livelihoods through the utilization of timber, fuelwood, medicinal resources, food products, fishing grounds, and other ecosystem services [6], [7]. Through generations of direct interaction with nature, communities have developed extensive ecological knowledge regarding mangrove species, ecological functions, and management practices [8], [9]. This body of knowledge is commonly referred to as Traditional Ecological Knowledge, which encompasses beliefs, practices, and experiences transmitted across generations [10], [11]. Traditional Ecological Knowledge has increasingly been recognized as an important component of environmental conservation and natural resource management worldwide.

Ethnobotany provides a scientific framework for understanding the relationships between humans and plants, including the ways local communities perceive, classify, utilize, and conserve plant resources. Ethnobotanical studies have contributed significantly to documenting local ecological knowledge and identifying plant species that possess cultural, economic, and ecological value [12], [13]. In coastal regions, ethnobotanical research on mangrove plants has demonstrated that local communities possess valuable knowledge regarding species identification, utilization patterns, harvesting techniques, and resource management [14], [15]. Such knowledge not only reflects cultural heritage but also contributes to the sustainability of mangrove ecosystems. Therefore, ethnobotanical investigations are essential for preserving both biological and cultural diversity in coastal areas [16], [17].

Recent studies have highlighted the importance of integrating local ecological knowledge into conservation strategies [18], [19]. Traditional ecological knowledge enables communities to recognize environmental changes, identify ecologically important species, and establish social norms that regulate resource use [10], [20]. In many coastal societies, conservation practices are embedded within local customs, beliefs, taboos, and communal agreements that indirectly protect mangrove ecosystems from excessive exploitation. Such community-based conservation approaches are increasingly acknowledged as effective mechanisms for enhancing ecosystem resilience and ensuring sustainable resource management [21], [22]. Consequently, understanding local knowledge systems is fundamental for designing conservation policies that are socially acceptable and environmentally effective.

Indonesia possesses one of the largest mangrove areas in the world and is recognized as a global center of mangrove biodiversity. Numerous coastal communities across the Indonesian archipelago have developed unique interactions with mangrove ecosystems, resulting in diverse forms of traditional knowledge and conservation practices [23], [24]. However, rapid socio-economic changes, modernization, migration, and changing livelihood patterns have contributed to the gradual erosion of traditional ecological knowledge in many coastal regions [25], [26]. The loss of such knowledge may reduce community capacity to manage coastal ecosystems sustainably and weaken cultural connections with natural resources [27], [28]. Therefore, documenting and preserving local ecological knowledge has become increasingly important in the context of sustainable coastal management.

One coastal community that possesses strong cultural ties with marine and coastal resources is the Ra'as community located on Ra'as Island, Sumenep Regency, East Java, Indonesia. As a small island community, the people of Ra'as rely heavily on coastal ecosystems for their livelihoods and daily needs. Mangrove vegetation surrounding the island provides ecological protection while simultaneously supporting various socio-economic activities [29], [30]. Local interactions with mangrove resources have likely generated valuable ecological knowledge, utilization practices, and conservation traditions that have been maintained over generations [31], [32]. Nevertheless, scientific documentation regarding the ethnobotanical knowledge and mangrove conservation practices of the Ra'as community remains limited.

Understanding the relationship between the Ra'as community and mangrove ecosystems is important not only for documenting local knowledge but also for identifying conservation strategies rooted in community participation. Ethnobotanical information can reveal the cultural significance of mangrove species, the plant parts utilized, traditional management practices, and community perceptions regarding conservation [33], [34]. Such information is valuable for developing locally appropriate conservation programs that align ecological sustainability with community needs [35], [36]. Furthermore, documenting traditional ecological knowledge contributes to safeguarding cultural heritage while supporting biodiversity conservation efforts in small island environments [10], [37]. Therefore, research on ethnobotanical knowledge and community-based mangrove conservation among the Ra'as community is both scientifically and practically significant.

Recent studies have emphasized the importance of local ecological knowledge and ethnobiological perspectives in mangrove conservation. Pontón-Cevallos et al. [38] examined fishers' ecological knowledge in

the Galapagos, while Nijamdeen et al. [39] focused on the ethnobiological importance of mangroves in Sri Lanka. Similarly, Galvão et al. [40] investigated traditional knowledge of mangrove wood use in the Brazilian Amazon, Scott et al. [41] explored Indigenous ecological knowledge in Panama, and Elwin et al. [42] analyzed community perceptions of mangrove ecosystem health in Thailand. Although these studies provide valuable insights into ecosystem services, local knowledge, and community perceptions, they generally address these aspects separately. Research integrating mangrove species diversity, ethnobotanical utilization, traditional ecological knowledge, community-based conservation practices, and local perceptions within a single framework remains limited, particularly in small-island communities such as Ra'as Island. This gap forms the basis for the present study.

The originality of this research stems from its integrated approach to examining ethnobotanical knowledge, traditional ecological knowledge, community perceptions, and community-based mangrove conservation within a single study. While previous research has typically addressed ecosystem services, local knowledge, resource use, or conservation perceptions independently [43], [44]. This study brings these dimensions together to provide a more comprehensive understanding of the relationships between local communities and mangrove ecosystems. The research explores mangrove species diversity, plant-part utilization, utilization methods, conservation practices, and community perceptions simultaneously, offering a holistic perspective on human–mangrove interactions. In addition, the study provides new empirical insights from Ra'as Island, a small-island setting that has received limited attention in the international ethnobotanical and conservation literature. By connecting traditional ecological knowledge and ethnobotanical practices with conservation behavior, the study contributes a unique perspective on the role of local cultural knowledge in supporting sustainable mangrove management in small-island communities.

The importance of this study arises from the ongoing degradation of mangrove ecosystems and the gradual decline of traditional ecological knowledge resulting from modernization, socio-economic change, and shifting livelihood patterns in coastal communities. Although the ecological significance of mangroves has been widely recognized, relatively few studies have examined how local knowledge, cultural practices, and community perceptions interact to influence mangrove conservation, particularly in small-island settings [45], [46]. This gap in understanding may limit the effectiveness of conservation programs by overlooking social and cultural dimensions that are essential for long-term sustainability. Furthermore, the erosion of traditional knowledge threatens not only ecosystem conservation but also the preservation of cultural heritage that has historically supported the sustainable use of natural resources. Therefore, documenting the relationships between local communities and mangrove ecosystems is crucial for strengthening community-based conservation efforts and informing sustainable coastal resource management. Accordingly, this study aims to identify the mangrove species utilized by the Ra'as community, examine the plant parts and utilization methods employed, explore local conservation practices, and analyze community perceptions regarding mangrove ecosystems and their conservation.

2. RESEARCH METHOD

2.1. Type of Research

This study employed a descriptive-exploratory research design to document traditional ecological knowledge and community-based conservation practices related to mangrove plants among the Ra'as community, Indonesia. A survey method was conducted to identify the research sites, characterize mangrove habitats, and determine potential informants possessing knowledge of mangrove utilization and conservation [38], [47]. Data were collected through open-ended (unstructured) interviews, allowing participants to freely share their experiences, knowledge, and perceptions regarding mangrove resources.

To obtain comprehensive ethnobotanical information, the study applied the Participatory Ethnobotanical Appraisal approach, which emphasizes active community involvement throughout the research process. This approach enabled researchers to directly observe local practices, participate in community activities related to mangrove utilization, and gain a deeper understanding of traditional ecological knowledge embedded within the local socio-cultural context. The integration of surveys, participatory observation, and unstructured interviews facilitated the collection of detailed information on mangrove species, utilization patterns, conservation practices, and community perceptions toward mangrove ecosystems [48], [49].

2.2. Tools and Materials

The tools used in this study included a smartphone for documentation and recording interview data, writing materials for field notes, and an interview guide to facilitate data collection during interactions with informants [50], [51]. The primary research materials consisted of mangrove plant species utilized by the Ra'as community. Mangrove specimens encountered during field observations were documented and identified based on their local names, morphological characteristics, utilization patterns, and conservation-related information

provided by community members. These materials served as the main source of ethnobotanical data regarding the traditional ecological knowledge and community-based conservation of mangrove plants on Ra'as Island.

2.3. Population and Sample

The study population comprised residents of Ketupat, Jungkat, and Kerapoh villages located on Ra'as Island, Sumenep Regency, East Java, Indonesia. Informants were selected using purposive sampling, a non-probability sampling technique that allows researchers to identify individuals possessing relevant knowledge and experience related to the research objectives [52], [53]. The selection criteria included being a resident of Ra'as Island and having knowledge regarding the utilization and conservation of mangrove plants. This approach was considered appropriate because ethnobotanical studies require informants who are familiar with local ecological knowledge and traditional resource management practices.

A total of 26 respondents participated in this study, consisting of 10 respondents from Ketupat Village, 6 respondents from Jungkat Village, and 10 respondents from Kerapoh Village. The respondents were classified into two categories, namely key informants and general informants. Key informants were individuals with extensive knowledge of mangrove species, including their local names, utilization practices, methods of use, and conservation measures [54], [55]. General informants were community members who possessed basic knowledge of mangrove species and local names but had more limited understanding of their utilization and conservation practices. The inclusion of both informant groups enabled the collection of comprehensive information regarding traditional ecological knowledge, ethnobotanical utilization, and community-based mangrove conservation practices among the Ra'as community.

2.4. Research Instruments

The primary instrument used in this study was a semi-structured interview guide designed to collect information on mangrove species, local names, plant parts utilized, utilization methods, conservation practices, and community perceptions regarding mangrove ecosystems. Interviews were conducted in both Madurese and Indonesian languages, depending on the informants' language preferences and communication abilities, to ensure accurate understanding and effective information exchange [56], [57]. The use of open-ended questions allowed respondents to provide detailed explanations based on their experiences and traditional ecological knowledge. The information obtained from the interviews was systematically recorded and organized into a data matrix consisting of local and scientific names of mangrove species, taxonomic families, plant parts used, utilization methods, and conservation actions practiced by the community [24]. This instrument facilitated the documentation and analysis of ethnobotanical knowledge and community-based conservation practices associated with mangrove resources on Ra'as Island.

2.5. Data Analysis

The data in this study consists of qualitative and quantitative data. Qualitative data includes conservation measures. Qualitative data includes data on mangrove types, mangrove organs, and mangrove utilization methods. Qualitative data analysis used descriptive analysis techniques, while quantitative data used percentage analysis of mangrove types, mangrove organs, and mangrove utilization methods using the formula:

Percentage of user levels of mangrove plant species:

$$Percentage = \frac{\sum Species\ used}{\sum All\ species\ are\ utilized}\ x\ 100\% \quad .. (1)$$

Percentage of plant organs that have the potential to be utilized by the community:

$$Percentage = \frac{\sum Plant\ organs\ mentioned\ by\ respondents}{\sum Total\ of\ all\ organs\ mentioned}\ x\ 100\% \quad ... (2)$$

Percentage of Mangrove Plant Utilization Methods:

$$Percentage = \frac{\sum The\ mentioned\ method\ of\ use}{\sum Total\ of\ all\ the\ mentioned\ utilization\ methods}\ x\ 100\% \quad \dots (3)$$

2.6. Research Procedures

The research was conducted in several stages, beginning with a preliminary survey to identify potential study sites and select suitable informants. The preliminary assessment focused on determining villages where

mangrove resources were still actively utilized and conserved by local communities [58], [59]. Based on these criteria, three villages on Ra'as Island—Ketupat, Jungkat, and Kerapoh—were selected as the study sites due to the presence of mangrove vegetation and the continued reliance of local residents on mangrove resources for various purposes.

Data collection was carried out through interviews, field observations, literature reviews, and mangrove sampling. Interviews were conducted using a semi-structured interview guide to obtain information regarding mangrove species utilized by the community, plant parts used, utilization methods, conservation practices, and local perceptions of mangrove ecosystems. In addition, relevant information concerning the socio-cultural context of the Ra'as community and mangrove management was gathered from scientific articles, books, reports, and other supporting literature. Field observations were performed using an exploratory survey approach by visiting mangrove areas in the three selected villages to document mangrove species and verify information obtained from informants [60], [61].

Photographic documentation of mangrove species and community activities related to mangrove utilization and conservation was conducted throughout the fieldwork to support data validation. Mangrove species encountered during the survey were identified based on their morphological characteristics using standard taxonomic references, including Panduan Pengenalan Mangrove di Indonesia, relevant botanical literature, and taxonomic databases. The scientific identification of species was subsequently used to analyze ethnobotanical utilization patterns and community-based conservation practices among the Ra'as people.

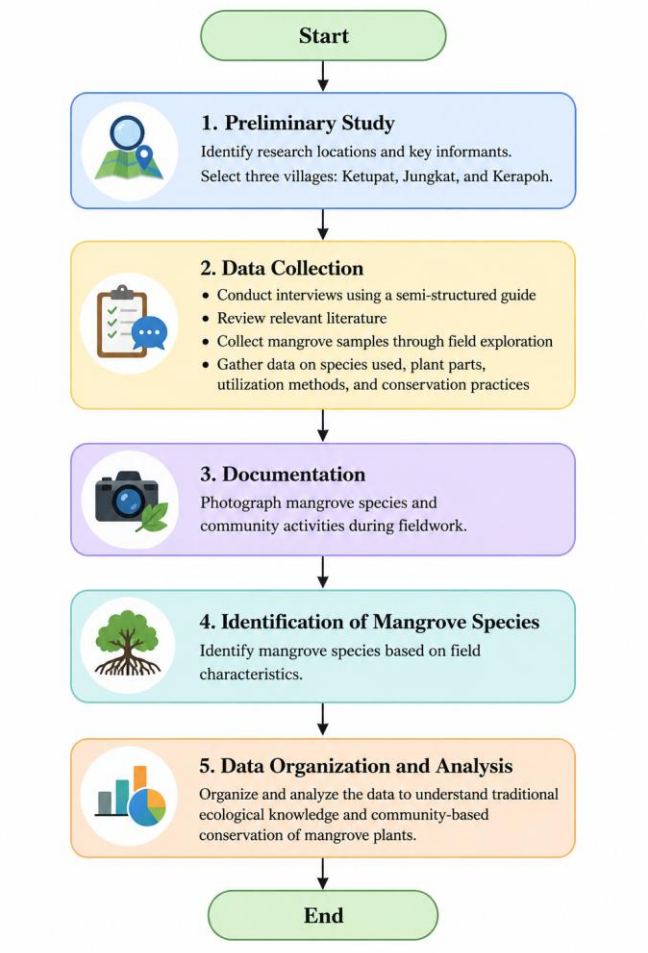

Figure 1. Research Procedures

3. RESULTS AND DISCUSSION

3.1. Types of Mangroves Used

Based on the results of interviews with 26 respondents, namely 10 respondents from Ketupat Village, 10 respondents from Karopoh Village, and 6 respondents from Jungkat Village, Ra'as District, Sumenep Regency, data were obtained on 9 mangrove plants utilized by the community as presented in Figure 2 as follows:

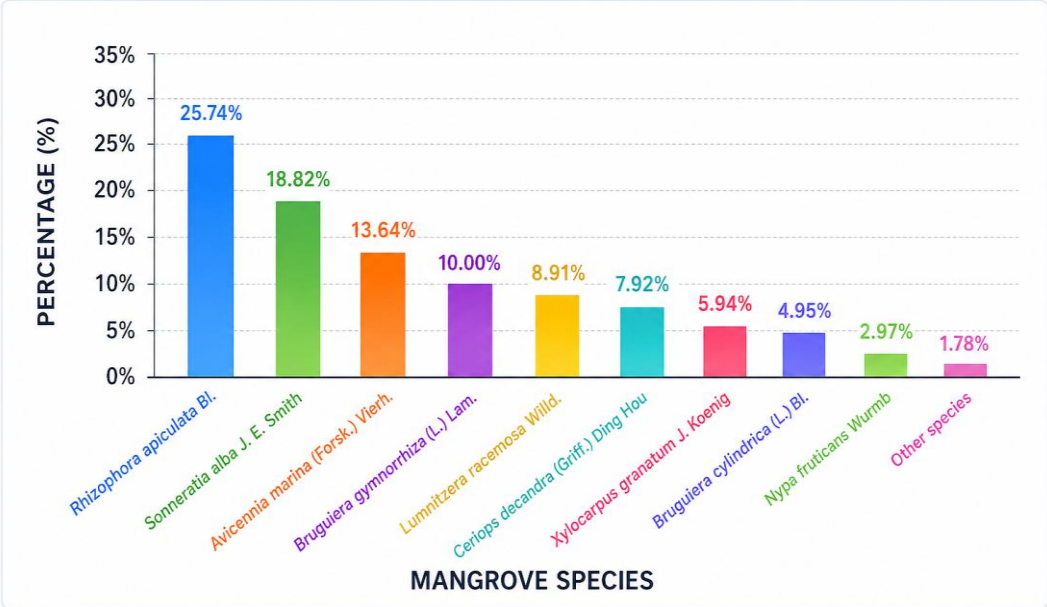

Figure 2. Bar Chart of Percentage of Mangrove Types Utilized by the Ra'as Community

Based on the data presented in Figure 2, the mangrove species most widely utilized by the people of Ra'as District, Sumenep Regency, was Tanjheng (*Rhizophora stylosa* Griff.), accounting for 25.64% of total utilization. This was followed by Paratpat (*Sonneratia alba*) at 18.81%, Peape (*Avicennia marina*) at 12.87%, Santegi or Mantegi (*Phemphis acidula*) at 11.90%, Dhudhuk (*Lumnitzera racemosa* var. *racemosa*) at 8.90%, Tanjheng Rete' (*Ceriops tagal*) at 7.92%, Tanjheng Lendur or Tanjheng Toktoan (*Rhizophora apiculata*) at 5.94%, Pukem (*Bruguiera cylindrica*) at 4.95%, and Malengen (*Excoecaria agallocha*) at 2.97%.

Tanjheng (*Rhizophora stylosa*) was the most dominantly utilized species due to its high abundance in the coastal areas of Ra'as Island. This condition is consistent with the utilization activities of communities living near the coastline, where the availability of this species is relatively high. The dominance of *Rhizophora stylosa* is also supported by findings indicating that this species is among the most abundant mangroves growing on Ra'as Island.

In contrast, Malengen (*Excoecaria agallocha*) exhibited the lowest utilization rate, accounting for only 2.97%. According to local community members, this limited use is attributed to its hazardous and toxic latex. Respondents reported that the white sap produced by this mangrove can cause skin irritation, itching, and even potential blindness if it comes into contact with the eyes. Consequently, its utilization is highly restricted and is generally limited to use as firewood. The latex of *Excoecaria agallocha* is known to contain toxic compounds that may cause skin lesions and serious eye disorders upon exposure.

3.2. Utilization of Mangrove Species by the Ra'as Community

Based on interviews conducted with 26 respondents from Ketupat, Jungkat, and Kerapoh Villages, mangroves are utilized by the Ra'as community for various purposes, including ecological functions, food, traditional medicine, cultural beliefs, fuel, handicrafts, and marine and fisheries activities. This diversity of uses indicates that mangroves play an important role in the social, economic, cultural, and environmental aspects of coastal community life.

Respondents stated that mangroves serve as natural coastal protectors by reducing shoreline erosion, attenuating wave energy, and preventing seawater intrusion during high tides. The community explained that the presence of mangroves helps maintain shoreline stability and supports the daily activities of people living in coastal areas. According to local perceptions, all mangrove species found in the study area, namely *Rhizophora stylosa*, *Sonneratia alba*, *Avicennia marina*, *Lumnitzera racemosa*, *Ceriops tagal*, *Rhizophora apiculata*, *Bruguiera cylindrica*, *Phemphis acidula*, and *Excoecaria agallocha*, contribute to these ecological functions.

In addition to their ecological role, interview results revealed that several mangrove species are used as alternative food sources. The community utilizes *Avicennia marina*, *Ceriops tagal*, and *Rhizophora stylosa* as substitutes for carbohydrate-rich staple foods, particularly when access to primary food resources is limited. Other species, such as *Avicennia marina*, *Lumnitzera racemosa*, *Rhizophora apiculata*, and *Rhizophora stylosa*, are also consumed as vegetables. Respondents further reported that the fruits of *Rhizophora stylosa* are processed into mangrove coffee and consumed as a traditional beverage. In addition to human consumption, the leaves of *Avicennia marina* and *Lumnitzera racemosa* are used as livestock feed.

The use of mangroves as traditional medicine is also still practiced by the Ra'as community. Based on interview responses, the species most frequently used for medicinal purposes are *Rhizophora stylosa*, *Avicennia marina*, *Sonneratia alba*, and *Rhizophora apiculata*. These mangroves are used to treat various health conditions, including diabetes, hypertension, fever, headaches, diarrhea, reproductive health disorders, and wounds. Knowledge regarding the medicinal use of mangroves has been passed down through generations and continues to be practiced by some community members.

Cultural values are also reflected in the use of mangroves as symbols of belief. Respondents explained that *Phemphis acidula* is believed to repel negative energy and evil spirits when planted around houses. Similarly, *Lumnitzera racemosa* is considered to provide spiritual protection when its wood is placed in certain parts of a house. These beliefs have been transmitted across generations and remain an integral part of the cultural heritage of the Ra'as community.

Interview findings also showed that nearly all mangrove species are utilized as household fuel. Community members use mangrove wood for cooking and other domestic purposes because it is readily available and produces long-lasting embers. In addition to fuel, several mangrove species are used for handicrafts. Respondents reported that *Phemphis acidula* is commonly cultivated as bonsai due to its unique form and high aesthetic value, while the fruits of *Sonneratia alba* are used as materials for traditional children's spinning-top games.

In the marine and fisheries sector, mangroves also play a significant role. According to respondents, the wood of *Rhizophora stylosa* is used for boat construction and as a mooring structure because of its strength and durability. Furthermore, *Sonneratia alba* is used as part of fishing equipment because it is believed to attract fish to fishing areas. These findings indicate that mangroves not only function as protectors of coastal ecosystems but also support the economic activities of local communities, most of whom depend on fisheries for their livelihoods.

3.3. Mangrove Organs Utilized by the Ra'as Community

The parts of the mangrove that are utilized include the roots, fruit, flowers, stems, leaves, and all parts. The percentage of utilization of each part of the mangrove plant is shown in the Pie Chart Figure 3.

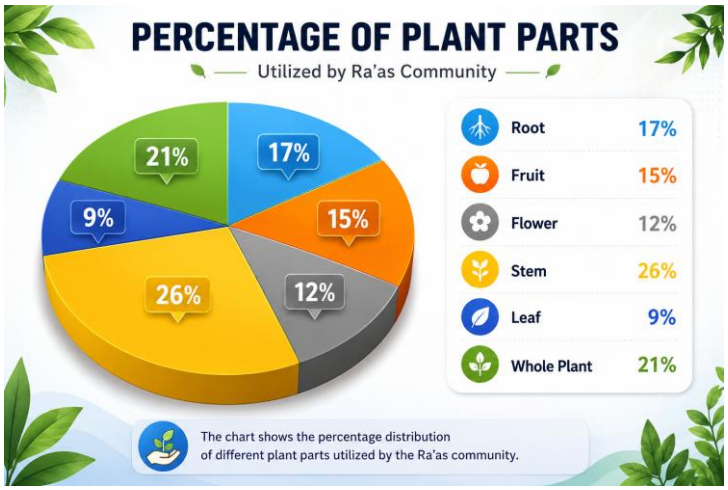

Figure 3. Pie chart of the percentage of organs utilized by the Ra'as community

The mangrove organ most frequently utilized by the Ra'as community is the stem, with a percentage of 26%. This figure is obtained based on respondents' choices of the most frequently used organ compared to the total number of mangrove organs utilized. The second-highest utilization rate is the use of all parts of the mangrove, with a percentage of 21%. Next, the leaves are utilized at 17%, the flowers at 15%, the fruit at 12%, and the roots at 9%.

The mangrove stem is the most commonly used part because it has long been used by coastal communities for generations. Furthermore, mangrove stems are considered to have great potential as a building material in coastal areas. Mangrove wood is also known for its high quality, characterized by high durability and can be used even when wet. Therefore, the use of mangrove stems is not limited to firewood, but also as a construction material and for daily needs of coastal communities. In contrast, the roots have the lowest utilization rate. This is because the Ra'as community generally only uses roots in limited ways, such as as a base for fishing boats or as part of fish bait. Furthermore, the community also recognizes that mangrove roots have crucial ecological functions, such as preventing abrasion, binding mud substrates, reducing wave energy and slowing ocean currents. For these reasons, they tend not to disturb mangrove roots to ensure their coastal protection function is maintained.

3.4. How the Ra'as Community Utilizes Mangroves

Based on research conducted and interviews with respondents, it was discovered that the methods used by the Ra'as community for their daily needs vary depending on the species and the intended use. Therefore, when grouped, the methods can be divided into seven categories: boiling, using directly, roasting, grinding, cutting, drying, and mixing. A breakdown of the percentages of these methods can be seen in Figure 4.

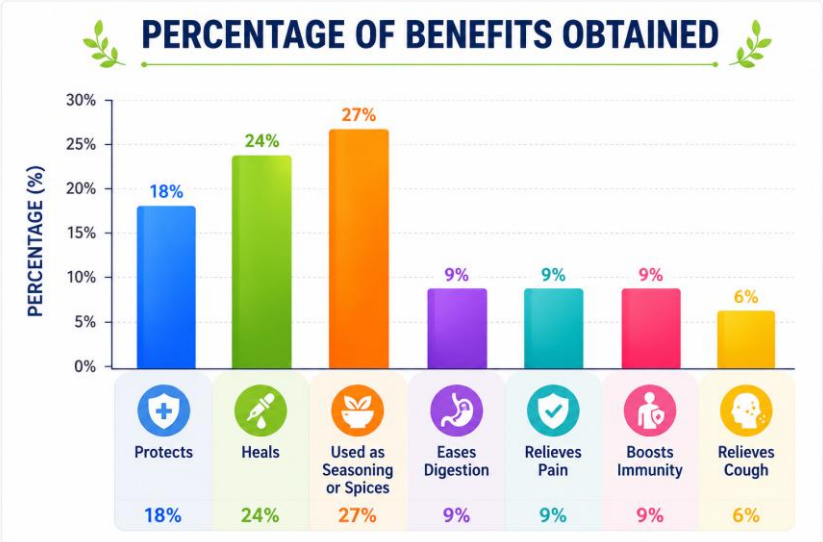

Figure 4. Percentage Bar Chart of Mangrove Utilization Methods by the Ra'as Community

The highest percentage of mangrove utilization by the Ra'as community was direct use, accounting for 27% of all utilization methods. Mangrove species utilized in this manner include Tanjheng (*Rhizophora stylosa*), Paratpat (*Sonneratia alba*), Peape (*Avicennia marina*), Dhudhuk (*Lumnitzera racemosa* var. *racemosa*), Tanjheng Rete' (*Ceriops tagal*), Tanjheng Lendur or Tanjheng Toktoan (*Rhizophora apiculata*), Pukem (*Bruguiera cylindrica*), Santegi or Mantegi (*Phemphis acidula*), and Malengen (*Excoecaria agallocha*). The high level of direct utilization indicates that the Ra'as community continues to maintain and use mangrove ecosystems in a simple manner with minimal processing. One example is the use of mangroves as natural barriers to prevent coastal erosion. The community also perceives direct mangrove utilization as closely linked to improving the well-being of coastal residents. Ecologically, mangroves play a crucial role as providers of various resources, including both timber and non-timber forest products such as food, medicine, and fuel.

The next most common utilization methods were burning (24%) and boiling (18%). Boiling is generally applied in the use of mangroves for traditional medicine. The community believes that boiling allows the active compounds contained in mangrove plants to dissolve into water, making them easier to utilize. This process is also supported by the chemical properties of plant materials, as temperature can influence the structure of proteins and other bioactive compounds. Other utilization methods, each accounting for 9%, included drying, grinding, and cutting. Drying is typically carried out in preparation for fuel use or medicinal processing. Grinding is commonly employed in traditional medicine to facilitate the release of active compounds, while cutting is generally performed as an initial step in the utilization of mangrove wood for purposes such as constructing building frameworks or boats.

The least common utilization method was mixing, representing only 6% of the total. This method is rarely practiced and is generally limited to traditional medicinal applications, where mangrove materials are combined with other ingredients such as turmeric rhizomes. Such mixtures are believed to improve blood circulation and inhibit the growth of microorganisms. Overall, the mangrove utilization practices of the Ra'as community reflect a rich body of local knowledge that has been passed down through generations. The close relationship between the community and the coastal ecosystem has made mangroves an integral part of daily life, demonstrating how natural resources can be utilized wisely to support community livelihoods while maintaining ecological sustainability.

3.5. Conservation Actions Carried Out by the Ra'as Community

Conservation is an effort to protect and preserve natural resources to maintain ecosystem sustainability. The Ra'as community has implemented conservation concepts to safeguard the mangroves on Ra'as Island. In general, conservation aims to achieve a balance between the utilization of natural resources and improving human well-being. Based on interviews, conservation actions on Ra'as Island are divided into two forms: direct conservation and indirect conservation. Direct conservation is carried out through mangrove planting activities in

coastal areas, while indirect conservation is carried out through values, beliefs, social norms, and policies from the government and community leaders. Both forms are part of local knowledge that develops through community customs and experiences in maintaining mangrove ecosystems.

Direct conservation is realized through mangrove planting activities around the coast. For the Ra'as community, "planting" is understood not only as the physical activity of planting trees in the ground, but also as an effort to cultivate life whose benefits can be felt now and for future generations. This knowledge of mangrove planting has existed for a long time and has been passed down from generation to generation. Awareness of the importance of mangroves grew after the community became aware of the direct impacts, such as tidal flooding and disruption to activities caused by seawater intrusion. One community leader, Mbah Mo, initiated mangrove planting in the Ketupat area in 1984 as a form of concern for coastal conditions. This initiative subsequently inspired other communities in surrounding villages, such as Jungkat, Karopoh, and Brakas, to carry out joint mangrove planting initiatives. This collective awareness demonstrates that the Ra'as community does not exploit mangroves, but rather relies on traditional values and local wisdom.

This local wisdom is also reflected in the community's understanding of nature as an essential part of life that must be preserved. Local knowledge, developed from the life experiences of coastal communities, fosters a wise approach to mangrove utilization [62], [63]. This aligns with the concept that local wisdom encompasses values, norms, beliefs, and knowledge that guide community life. Meanwhile, indirect conservation is achieved through a system of beliefs and social norms passed down orally. The Ra'as community believes that mangrove use must be carried out carefully, for example, only harvesting wood from mature trees. Furthermore, there is a belief that actions that damage nature with malicious intent will be repaid, indirectly acting as a social control mechanism for preserving mangroves.

Beliefs in mystical aspects also play a role in preserving mangroves, as people believe that mangrove trees have "guardians" who encourage caution in their use. These symbols are part of a cultural construct that helps prevent overexploitation of nature. Furthermore, village governments play a role in conservation through policies and appeals to protect mangroves, such as prohibiting tree felling and dumping waste in coastal areas [1], [64]. Furthermore, the development of mangrove ecotourism in several villages, such as Jungkat and Ketupat, is a form of collaboration between the government and the community to improve welfare while preserving the environment.

The role of the community, particularly the younger generation, is also increasingly visible in conservation activities. From 2015 to 2020, Ra'as youth have been involved in various activities, such as nursery work, planting, and monitoring mangrove growth. Community leaders and educators also play a role in instilling conservation values in the younger generation and students as an effort to maintain the sustainability of the mangrove ecosystem [65], [66]. Overall, conservation measures on Ra'as Island reflect a form of natural resource management based on local wisdom. Mangrove utilization is carried out wisely while maintaining ecosystem balance, so that its existence can continue to support the livelihoods of coastal communities.

The findings of this study indicate that the Ra'as community's relationship with the mangrove ecosystem is not only economic but also reflects a strong link between ecological, social, cultural, and spiritual aspects. The diverse utilization patterns indicate that mangroves have become an integral part of the coastal community's life system [29], [67]. From an ethnobotanical perspective, this condition indicates the transfer of traditional ecological knowledge that has been passed down through generations and shaped the community's way of recognizing, utilizing, and preserving the natural resources around them. This local knowledge serves as crucial social capital in supporting sustainable coastal resource management, as the community views mangroves not only as a commodity but also as part of their cultural identity and way of life.

The diverse forms of mangrove utilization identified in this study demonstrate that the Ra'as community possesses a deep understanding of the biological characteristics and functional benefits of each species. This knowledge develops through long experience interacting with the coastal environment and reflects the community's ability to adapt to limited resources in small island areas [45], [68]. Within the context of social-ecological systems, the community's ability to selectively utilize various parts of the mangrove plant demonstrates an adaptive strategy that enables them to meet their needs without diminishing the mangrove's primary ecological function as a coastal protector. This demonstrates that traditional utilization practices can coexist with conservation principles if they are grounded in strong local knowledge.

Another important finding is the existence of community-based conservation practices that develop through a combination of concrete actions, social norms, and local belief systems. This conservation approach demonstrates that successful mangrove protection does not always depend on formal regulations but can also be strengthened by the cultural values inherent in the community. Customary norms, beliefs about the social and spiritual consequences of environmental destruction, and the involvement of community leaders serve as effective social control mechanisms in preventing overexploitation [69], [70]. This demonstrates that local wisdom has a significant ecological function because it can shape sustainable conservation behavior without the need for intensive external oversight.

The results of this study also have strong relevance to the achievement of the Sustainable Development Goals (SDGs). The use of mangroves as a source of food, traditional medicine, and community economic resources contributes to the achievement of SDGs 1 (No Poverty) and SDG 2 (Zero Hunger) by increasing the economic and food security of coastal communities [71], [72]. The use of mangroves as traditional medicine also supports SDG 3 (Good Health and Well-Being). Furthermore, community mangrove conservation and planting practices contribute to SDG 13 (Climate Action) by increasing climate change mitigation capacity and blue carbon storage. Furthermore, mangrove conservation efforts directly support SDG 14 (Life Below Water) and SDG 15 (Life on Land) by maintaining the sustainability of coastal habitats, biodiversity, and the ecological functions of mangrove ecosystems [73], [74]. Thus, the traditional ecological knowledge held by the Ra'as community is not only important locally but also contributes to the global sustainable development agenda.

The findings of this study align with various recent studies that confirm that traditional ecological knowledge plays a crucial role in the sustainable use and conservation of mangroves. Research by Galvão et al., [40] Studies have shown that coastal communities possess in-depth knowledge of the characteristics and functions of various mangrove species, which is passed down from generation to generation and forms the basis for wise resource utilization. A recent study on the dynamics of Traditional Ecological Knowledge in mangrove ecosystems also demonstrated that local knowledge serves not only as a source of information on resource utilization but also as a mechanism for community adaptation in maintaining a balance between economic needs and environmental sustainability. Therefore, the results of this study reinforce the view that the local wisdom of the Ra'as community is a crucial social capital in supporting sustainable mangrove use while maintaining the sustainability of coastal ecosystems.

This research contributes to scientific understanding by strengthening understanding of the relationship between traditional ecological knowledge, ethnobotanical utilization, and community-based conservation within an integrated socio-ecological framework. Practically, the research findings can serve as a basis for local governments, coastal area managers, and conservation institutions in designing more participatory mangrove management programs based on local wisdom. Integrating community knowledge into conservation policies has the potential to increase the effectiveness of mangrove rehabilitation programs, as communities act not only as beneficiaries but also as key actors in ecosystem protection [15], [75]. Furthermore, documenting the traditional knowledge of the Ra'as community also plays a crucial role in preserving local cultural heritage, which is currently under threat from modernization and increasingly rapid social change.

While this study provides comprehensive information on mangrove utilization and conservation by the Ra'as community, it still has several limitations. The relatively limited number of respondents and the focus of the study on only three villages on Ra'as Island mean that the results cannot be generalized to all coastal communities in Indonesia. Furthermore, this study focused primarily on ethnobotanical aspects and community perceptions, thus failing to quantitatively measure the ecological condition of mangroves, the level of conservation success, or the economic contribution generated from mangrove utilization. Therefore, further research should integrate a socio-ecological approach with biodiversity analysis, ecosystem economic valuation, and measurement of environmental services to obtain a more comprehensive picture of the sustainability of mangrove management in small island areas.

4. CONCLUSION

Based on the findings of this study, it can be concluded that the Ra'as community in Sumenep Regency, East Java Province, utilizes nine mangrove species, namely *Rhizophora stylosa*, *Sonneratia alba*, *Avicennia marina*, *Lumnitzera racemosa* var. *racemosa*, *Ceriops tagal*, *Rhizophora apiculata*, *Bruguiera cylindrica*, *Phemphis acidula*, and *Excoecaria agallocha*, to fulfill various livelihood needs. The most frequently utilized plant organ was the stem (26%), followed by the whole plant (21%), leaves (17%), fruits (15%), flowers (12%), and roots, which represented the lowest proportion (9%). In terms of utilization methods, direct use was the most dominant (27%), followed by burning (24%), while boiling, drying, grinding, cutting, and mixing were less frequently practiced (each accounting for 9%). In addition to resource utilization, the community also implements mangrove conservation through two main approaches: direct conservation, involving mangrove planting in coastal areas, and indirect conservation, which is based on traditional beliefs, social norms, mystical values, and village government regulations. These practices contribute to maintaining the sustainability of the mangrove ecosystem. Future studies should investigate the relationship between traditional ecological knowledge and mangrove ecosystem health through a more comprehensive social–ecological approach. Furthermore, research on the economic valuation of mangrove ecosystem services and their contribution to the well-being of coastal communities is needed to strengthen the foundation for community-based conservation policies.

ACKNOWLEDGEMENTS

We also extend our gratitude to all those who assisted in the data collection and preparation of this article. We hope the results of this research will benefit the development of science, particularly in the field of ecology and mangrove resource utilization.

AUTHOR CONTRIBUTIONS

Conceptualization, D.B.C., M.P.T.F., and S.J.; Methodology, D.B.C. and M.P.T.F.; Software, M.P.T.F.; Validation, D.B.C., M.P.T.F., and S.J.; Formal Analysis, D.B.C. and M.P.T.F.; Investigation, M.P.T.F.; Resources, M.P.T.F.; Data Curation, M.P.T.F.; Writing – Original Draft Preparation, M.P.T.F.; Writing – Review & Editing, D.B.C. and S.J.; Visualization, M.P.T.F.; Supervision, D.B.C. and S.J.; Project Administration, D.B.C.; Funding Acquisition, D.B.C. All authors have read and agreed to the published version of the manuscript.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

During the preparation of this work, the authors used generative AI-based tools (ChatGPT) to assist in paraphrasing, language refinement, and improving the academic clarity of the manuscript. In addition, AI-assisted technology was also used in the development of several illustrative figures to enhance visualization and presentation of concepts within the study. After using these tools, the authors carefully reviewed, edited, and validated all generated content and figures to ensure accuracy and relevance. The authors take full responsibility for the content of this publication.

REFERENCES

[1] H. Akram, S. Hussain, P. Mazumdar, K. O. Chua, T. E. Butt, and J. A. Harikrishna, "Mangrove health: A review of functions, threats, and challenges associated with mangrove management practices," *Forests*, vol. 14, no. 9, pp. 1–38, 2023, doi: 10.3390/f14091698.

[2] P. Ayassamy, "Mangroves as a nature-based solution and a tool for coastal resilience," *Wetlands*, vol. 45, no. 6, pp. 89–97, Aug. 2025, doi: 10.1007/s13157-025-01971-3.

[3] J. J. Zhu and B. Yan, "Blue carbon sink function and carbon neutrality potential of mangroves," *Sci. Total Environ.*, vol. 822, pp. 1–4, 2022, doi: 10.1016/j.scitotenv.2022.153438.

[4] A. Raihan, "A review of tropical blue carbon ecosystems for climate change mitigation," *J. Environ. Sci. Econ.*, vol. 2, no. 4, pp. 14–36, 2023, doi: 10.56556/jescae.v2i4.602.

[5] S. R. Dayal, K. Ravuiwasa, and J. A. Bhat, "Deforestation and Degradation in the Mangrove Ecosystem: Implication on Environment and Livelihoods," in *Land Degradation Neutrality: Achieving SDG 15 by Forest Management*, Singapore: Springer Nature Singapore, 2022, pp. 99–116. doi: 10.1007/978-981-19-5478-8_6.

[6] S. C. Das, S. Das, and J. Tah, "Mangrove Forests and People's Livelihoods," in *Mangroves: Biodiversity, Livelihoods and Conservation*, Singapore: Springer Nature Singapore, 2022, pp. 153–173. doi: 10.1007/978-981-19-0519-3_7.

[7] P. Sarkar *et al.*, "Contribution of mangrove ecosystem services to local livelihoods in the indian sundarbans," *Sustain.*, vol. 16, no. 16, pp. 1–17, 2024, doi: 10.3390/su16166804.

[8] L. A. Ravaoarinorotsihoarana *et al.*, "Combining traditional ecological knowledge and scientific observations to support mangrove restoration in madagascar," *Forests*, vol. 14, no. 7, pp. 1–21, 2023, doi: 10.3390/f14071368.

[9] G. P. B. Marquez and R. D. Olavides, "Integrating science-based and local ecological knowledge: a case study of mangrove restoration and rehabilitation projects in the Philippines," *Disasters*, vol. 48, no. S1, pp. 1–17, 2024, doi: 10.1111/disa.12630.

[10] N. I. Sinthumule, "Traditional ecological knowledge and its role in biodiversity conservation: A systematic review," *Front. Environ. Sci.*, vol. 11, no. June, pp. 1–15, 2023, doi: 10.3389/fenvs.2023.1164900.

[11] S. D. Moloise, A. R. Matamanda, and J. I. Bhanye, "Traditional ecological knowledge and practices for ecosystem conservation and management: the case of savanna ecosystem services in Limpopo, South Africa," *Int. J. Sustain. Dev. World Ecol.*, vol. 31, no. 1, pp. 29–42, Jan. 2024, doi: 10.1080/13504509.2023.2249856.

[12] M. Dean, "Exploring ethnobotanical knowledge: qualitative insights into the therapeutic potential of medicinal plants," *Golden Ratio Data Summ.*, vol. 4, no. 2, pp. 06–18, 2024, doi: 10.52970/grdis.v4i2.491.

[13] B. Luo, Y. Tong, Y. Liu, Y. Zhang, Y. Qin, and R. Hu, "Ethnobotanical insights into the traditional food plants of the Baiku Yao community: a study of cultural significance, utilization, and conservation," *J. Ethnobiol. Ethnomed.*, vol. 20, no. 1, pp. 1–30, 2024, doi: 10.1186/s13002-024-00691-y.

[14] E. S. SIREGAR *et al.*, "Quantitative ethnobotany of mangrove plant uses by the coastal community of Sicanang Belawan, North Sumatra, Indonesia," *Biodiversitas J. Biol. Divers.*, vol. 26, no. 10, pp. 1–14, Nov. 2025, doi: 10.13057/biodiv/d261032.

[15] C. A. Martínez-Márquez, Á. Sol Sánchez, J. M. Zaldívar Cruz, S. Sánchez Soto, N. Del Rivero Bautista, and M. M. Aliphat Fernández, "Local use of mangroves on the coast of southeastern México," *Resources*, vol. 13, no. 11, pp. 1–16, 2024, doi: 10.3390/resources13110154.

[16] M. Diantaris, "The role of ethnobotany in preserving sasak cultural heritage: A case study from lombok," *Int. J. Adv. Ethnobot. Res. Appl.*, vol. 1, pp. 1–4, 2024.

[17] N. Nagaraj *et al.*, "Ethnobotanical Knowledge and Floristic Diversity of South East Indian Coastal Region," in *The Palgrave Handbook of Socio-ecological Resilience in the Face of Climate Change*, Singapore: Springer Nature Singapore, 2023, pp. 367–386. doi: 10.1007/978-981-99-2206-2_22.
[18] S. M. Haq, A. Pieroni, R. W. Bussmann, A. M. Abd-ElGawad, and H. O. El-Ansary, "Integrating traditional ecological knowledge into habitat restoration: Implications for meeting forest restoration challenges," *J. Ethnobiol. Ethnomed.*, vol. 19, no. 1, pp. 1–19, 2023, doi: 10.1186/s13002-023-00606-3.
[19] Q. Wan and W. Du, "Social capital, environmental knowledge, and pro-environmental behavior," *Int. J. Environ. Res. Public Health*, vol. 19, no. 3, pp. 1–17, 2022, doi: 10.3390/ijerph19031443.
[20] S. Souther, S. Colombo, and N. N. Lyndon, "Integrating traditional ecological knowledge into US public land management: Knowledge gaps and research priorities," *Front. Ecol. Evol.*, vol. 11, no. March, pp. 1–20, 2023, doi: 10.3389/fevo.2023.988126.
[21] S. Zafar, M. Zafar Khan, T. Mehmood, F. Begum, and M. Sadiq, "Role of community-based conservation and natural resource management in building climate resilience among vulnerable mountain societies," *Clim. Dev.*, vol. 15, no. 7, pp. 608–621, Aug. 2023, doi: 10.1080/17565529.2022.2135365.
[22] A. Surendar, "Community-based natural resource management (cbnrm) as a tool for strengthening ecosystem resilience and livelihood security," *J. Environ. Sustain. Clim. Resilience, Agro-Ecosystems*, vol. 1, no. 2, pp. 1–8, 2024, doi: 10.17051/JESCRAE /01.02.01.
[23] M. I. Aipassa, M. E. Siahaya, H. S. E. S. Aponno, Y. Ruslim, and R. Kristiningrum, "Participation of community in mangrove conservation in coastal area of the Valentine Strait, West Seram, Maluku, Indonesia," *Biodiversitas*, vol. 24, no. 4, pp. 2467–2474, 2023, doi: 10.13057/biodiv/d240462.
[24] A. Pratama and V. Ryabtsev, "Local wisdom in mangrove management and conservation in Indonesia alvin," *Yani Kusuma Perkasa Co.*, vol. 01, no. 1, pp. 1–10, 2025.
[25] J. Gudia and T. Pattnaik, "Changes and developments in the socio-cultural life of the didayi tribe in malkangiri district : A study of tradition and transformation," *Int. J. Res. Anal. Rev.*, vol. 11, no. 3, pp. 15–26, 2024.
[26] S. Maity, "Challenges faced by marine fishing communities in West Bengal, India : Insights from a social-anthropological pilot study," *Antrocom Online J. Anthropol.*, vol. 21, no. Winter, pp. 559–570, 2025.
[27] Y. Zhao, Z. Han, C. Zhang, Y. Wang, J. Zhong, and M. Gao, "Coastal cultural ecosystem services: A bridge between the natural ecosystem and social ecosystem for sustainable development," *Land*, vol. 13, no. 9, pp. 1–22, 2024, doi: 10.3390/land13091352.
[28] S. S. Begg, A. De Ramon N'Yeurt, and S. Begg, "Interweaving resource management with indigenous knowledge to build community resilience in the Pacific Islands: case of the Waimanu Catchment in Viti Levu, Fiji," *Reg. Environ. Chang.*, vol. 23, no. 3, pp. 86–97, Sep. 2023, doi: 10.1007/s10113-023-02079-2.
[29] M. T. Rahmadi, E. Yuniastuti, A. Suciani, M. S. Harefa, A. Y. Persada, and E. Tuhono, "Threats to mangrove ecosystems and their impact on coastal biodiversity: A study on mangrove management in langsa city," *Indones. J. Earth Sci.*, vol. 3, no. 2, pp. 1–14, 2023, doi: 10.52562/injoes.2023.627.
[30] S. M. Kotikot *et al.*, "Building a mangrove ecosystem monitoring tool for managers using Sentinel-2 imagery in Google Earth Engine," *Ocean Coast. Manag.*, vol. 256, pp. 1–12, Oct. 2024, doi: 10.1016/j.ocecoaman.2024.107307.
[31] S. K. Saha, S. Chakraborty, Z. Tabassum, M. M. Rahman, P. Kumar, and M. A. Khan, "Erosion of traditional ecological knowledge and its links to resilience among communities in the periphery of Bangladesh Sundarbans," *Small-scale For.*, vol. 25, no. 2, pp. 483–508, Jun. 2026, doi: 10.1007/s11842-026-09631-y.
[32] S. Tcheton, A. Marais-Potgieter, D. W. Aheto, and L. Pereira, "Advancing the understanding of indigenous and local knowledge practices in mangrove ecosystem sustainability in the mono transboundary biosphere reserve in West Africa (benin republic-togo)," *Front. Ocean Sustain.*, vol. 3, no. September, pp. 1–18, 2025, doi: 10.3389/focsu.2025.1585598.
[33] M. C. Ogwu and M. E. Osawaru, "Traditional Methods of Plant Conservation for Sustainable Utilization and Development," 2022, pp. 451–472. doi: 10.1007/978-981-19-3326-4_17.
[34] J. N. Mendoza *et al.*, "Ethnobotanical contributions to global fishing communities: a review," *J. Ethnobiol. Ethnomed.*, vol. 19, no. 1, pp. 1–24, Dec. 2023, doi: 10.1186/s13002-023-00630-3.
[35] D. Dushkova and O. Ivlieva, "Empowering communities to act for a change: A review of the community empowerment programs towards sustainability and resilience," *Sustain.*, vol. 16, no. 19, pp. 1–25, 2024, doi: 10.3390/su16198700.
[36] G. Walker, G. Severson, and S. Daniels, "Collaborative alignment: A framework for community-based collaboration for natural resource management, environmental policy decisions, and locally-led climate action," *Front. Commun.*, vol. 8, pp. 1–12, 2023, doi: 10.3389/fcomm.2023.1228650.
[37] K. E. Walker *et al.*, "Ecological and cultural understanding as a basis for management of a globally significant island landscape," *Coasts*, vol. 2, no. 3, pp. 152–202, 2022, doi: 10.3390/coasts2030009.
[38] J. Pontón-Cevallos *et al.*, "Fishers' local ecological knowledge to support mangrove research in the galapagos," *Front. Mar. Sci.*, vol. 9, no. June, pp. 1–19, 2022, doi: 10.3389/fmars.2022.911109.
[39] T. W. G. F. M. Nijamdeen, N. Ephrem, J. Hugé, K. A. S. Kodikara, and F. Dahdouh-Guebas, "Understanding the ethnobiological importance of mangroves to coastal communities: A case study from Southern and North-western Sri Lanka," *Mar. Policy*, vol. 147, p. 105391, Jan. 2023, doi: 10.1016/j.marpol.2022.105391.
[40] M. L. Galvão, T. N. M. Rodrigues, I. S. Santos, and M. E. B. Fernandes, "Traditional ecological knowledge of mangrove wood use on the Brazilian Amazon coast," *Ethnobiol. Conserv.*, vol. 13, no. 03, pp. 1–19, 2024, doi: 10.15451/ec2024-01-13.03-1-19.
[41] C. P. Scott, L. Mach, K. M. Lucas, and A. E. Myers, "Whose cultural ecosystem service values matter? exploring power inequities in diverse mangrove communities," *Hum. Ecol.*, vol. 52, no. 1, pp. 81–97, 2024, doi: 10.1007/s10745-023-00462-5.
[42] A. Elwin, E. J. Z. Robinson, G. Feola, V. Jintana, and J. Clark, "How is mangrove ecosystem health defined? A local

community perspective from coastal Thailand," *Ocean Coast. Manag.*, vol. 251, no. January, pp. 1–11, 2024, doi: 10.1016/j.ocecoaman.2024.107037.
[43] A. Hassen, K. K. Zander, S. Manes, and M. Meragiaw, "Local People's perception of forest ecosystem services, traditional conservation, and management approaches in North Wollo, Ethiopia," *J. Environ. Manage.*, vol. 330, no. August 2022, pp. 1–10, 2023, doi: 10.1016/j.jenvman.2022.117118.
[44] M. Das, A. Das, S. Seikh, and R. Pandey, "Nexus between indigenous ecological knowledge and ecosystem services: A socio-ecological analysis for sustainable ecosystem management," *Environ. Sci. Pollut. Res.*, vol. 29, no. 41, pp. 61561–61578, 2022, doi: 10.1007/s11356-021-15605-8.
[45] E. A. Hernández-Delgado, "Coastal restoration challenges and strategies for small island developing states in the face of sea level rise and climate change," *Coasts*, vol. 4, no. 2, pp. 235–286, 2024, doi: 10.3390/coasts4020014.
[46] C. Biswas, S. V. Channarayapatna, and C. N. Pandey, "Multifaceted livelihood relations of local communities with the indian sundarbans mangroves," *Hum. Ecol.*, vol. 53, no. 2, pp. 241–257, Apr. 2025, doi: 10.1007/s10745-025-00596-8.
[47] J. Come *et al.*, "A socio-ecological survey in inhambane bay mangrove ecosystems: Biodiversity, livelihoods, and conservation," *Ocean Coast. Manag.*, vol. 244, no. March, pp. 1–11, 2023, doi: 10.1016/j.ocecoaman.2023.106813.
[48] J. F. Velasco-Muñoz, J. A. Aznar-Sánchez, M. Schoenemann, and B. López-Felices, "An analysis of the worldwide research on the socio-cultural valuation of forest ecosystem services," *Sustain.*, vol. 14, no. 4, pp. 1–22, 2022, doi: 10.3390/su14042089.
[49] S. Chen, J. Qiu, M. Yang, and J. Li, "A synergetic perspective on the planning of the 'city in a park': A case study of the sichuan tianfu New Area, China," *Buildings*, vol. 14, no. 6, pp. 1–21, 2024, doi: 10.3390/buildings14061542.
[50] C. L. Arntson and M. N. Yoon, "Participant directed mobile interviews: A data collection method for conducting in-situ field research at a distance," *Int. J. Qual. Methods*, vol. 22, pp. 1–9, 2023, doi: 10.1177/16094069231188254.
[51] S. P. Chand, "Methods of data collection in qualitative research: Interviews, focus groups, observations, and document analysis," *Adv. Educ. Res. Eval.*, vol. 6, no. 1, pp. 303–317, 2025, doi: 10.25082/aere.2025.01.001.
[52] B. H. Mukti, "Methods in health research: Probability and non-probability sampling," *Heal. Sci. Int. J.*, vol. 3, no. 2, pp. 220–234, 2025, doi: 10.71357/hsij.v3i2.64.
[53] F. B. Thomas, "The role of purposive sampling technique as a tool for informal Choices in a social sciences in research methods," *Just Agric.*, vol. 02, no. 5, pp. 1–8, 2022.
[54] S. Satumanatpan and K. Kanongdate, "Ethical value of coastal resources as implicit driver for conservation: Insights into artisanal fishers' perceptions," *Sustain.*, vol. 17, no. 17, pp. 1–20, 2025, doi: 10.3390/su17177649.
[55] B. P. Nyangoko, M. S. Shalli, M. M. Mangora, M. Gullström, and H. Berg, "Socioeconomic determinants of mangrove exploitation and management in the Pangani River Estuary, Tanzania," *Ecol. Soc.*, vol. 27, no. 2, pp. 1–19, 2022, doi: 10.5751/ES-13227-270232.
[56] O. Luciana, R. K. Fatmasari, Elfandri, J. Siallagan, and D. Wicaksi, "Parental communication preferences in rural communities: A qualitative study on the use of Indonesian language in parenting," *RETORIKA J. Ilmu Bhs.*, vol. 10, no. 3, pp. 810–824, 2024, doi: 10.55637/jr.10.3.10460.810-824.
[57] D. Indarti and C. Manara, "Attitudes toward language and language choice in regional intermarriage families: A case study in Tangerang, Banten," *Stud. English Lang. Educ.*, vol. 12, no. 1, pp. 426–441, 2025, doi: 10.24815/siele.v12i1.36436.
[58] R. Triyanti *et al.*, "The transformation of community-based mangrove conservation to coastal tourism on the northern coast of Java, Indonesia," *Int. J. Conserv. Sci.*, vol. 16, no. 1, pp. 207–226, 2025, doi: 10.36868/IJCS.2025.01.14.
[59] S. Delvita, E. Izzul, and E. Nurjani, "Analysis of mangrove carbon economic potential and community based mangrove management in Mojo Village , Pemalang Regency," *Indones. J. Limnol.*, vol. 07, no. 01, pp. 1–16, 2026, doi: 10.51264/inajl.v7i1.98.
[60] S. H. A. Koda, "Strategies for improving community participation in mangrove ecosystem conservation in teluk kupang coastal areas (a case study of nunkurus and oeteta villages)," in *IOP Conference Series: Earth and Environmental Science*, 2023, pp. 1–11. doi: 10.1088/1755-1315/1266/1/012029.
[61] R. P. Nado, Y. Oktavia, and Z. Irfan, "Multi-actor communication dynamics in mangrove ecotourism management and their impact on destination sustainability: A case study of apar village, Pariaman City," *Bisnis Tani*, vol. 12, no. 1, pp. 23–32, 2026, doi: 10.35308/jbt.
[62] S. M. Baharuddin, "Living with the tides : Adaptive coastal knowledge and mangrove governance in Southeast Sulawesi," *Sustain. Equitable Earth Dev.*, vol. 1, no. 1, pp. 34–41, 2025.
[63] M. Mardianton, S. Amar, and A. Irianto, "Empowering mangrove ecotourism: Integrating governance, community, and technology for sustainable coastal development," *J. Ecohumanism*, vol. 3, no. 8, pp. 3153–3167, 2024, doi: 10.62754/joe.v3i8.4953.
[64] M. K. Mohamed, E. Adam, and C. M. Jackson, "Policy review and regulatory challenges and strategies for the sustainable mangrove management in zanzibar," *Sustain.*, vol. 15, no. 2, pp. 1–20, 2023, doi: 10.3390/su15021557.
[65] H. Gunawan *et al.*, "Empowering conservation: The transformative role of mangrove education in Indonesia's climate strategies," *Forest Sci. Technol.*, vol. 21, no. 4, pp. 374–396, 2025, doi: 10.1080/21580103.2025.2519475.
[66] K. A. Tagulao, A. B. I. Bernardo, L. H. Kei, and C. S. C. Calheiros, "Mangrove conservation in macao sar, china: The role of environmental education among school students," *Int. J. Environ. Res. Public Health*, vol. 19, no. 6, pp. 1–13, 2022, doi: 10.3390/ijerph19063147.
[67] A. W. Kamau, H. Shauri, J. Hugé, K. Van Puyvelde, N. Koedam, and J. G. Kairo, "Patterns of mangrove resource uses within the transboundary conservation area of Kenya and Tanzania," *Sustain.*, vol. 16, no. 11, pp. 1–18, 2024, doi: 10.3390/su16114623.
[68] C. Lawyer, L. An, and E. Goharian, "A review of climate adaptation impacts and strategies in coastal communities: From agent-based modeling towards a system of systems approach," *Water (Switzerland)*, vol. 15, no. 14, pp. 1–25, 2023, doi: 10.3390/w15142635.

[69] M. M. Amiruddin *et al.*, "Empowering indigenous coastal conservation: Eco-muamalat as a model for sustainable marine practices," *Cosmop. Civ. Soc.*, vol. 17, no. 3, pp. 72–93, 2025, doi: 10.5130/ccs.v17.i3.9380.
[70] A. Ossai, "Traditional ecological knowledge in igbo society: Exploring igbo culture for environmental sustainability," *Sist J. Relig. …*, pp. 19–39, 2024.
[71] E. Sungkawati and J. Umali, "Blue carbon and food security: A systematic review of mangrove ecosystem services for sdg 13 (climate action) and sdg 2 (zero hunger)," *Assyfa J. Farming Agric.*, vol. 2, no. 1, pp. 40–50, 2024, doi: 10.61650/ajfa.v2i1.871.
[72] M. Basyuni *et al.*, "Edible and medicinal uses of mangroves in Indonesia with a systematic review on blue food potential and health benefits," *Discov. Sustain.*, vol. 6, no. 1, pp. 1–19, 2025, doi: 10.1007/s43621-025-01967-3.
[73] M. Syawaludin and R. Kurniawan, "Mangrove restoration and sisheries productivity: A bibliometric and systematic review with sdg 15 (life on land) impact," *Assyfa J. Farming Agric.*, vol. 2, no. 1, pp. 27–39, 2024, doi: 10.61650/ajfa.v2i1.863.
[74] F. M. Kerton, "UN sustainable development goals 14 and 15 - life below water, life on land," *RSC Sustain.*, vol. 1, no. 3, pp. 401–403, 2023, doi: 10.1039/d3su90010j.
[75] K. Hansen and A. Świderska, "Integrating open- and closed-ended questions on attitudes towards outgroups with different methods of text analysis," *Behav. Res. Methods*, vol. 56, no. 5, pp. 4802–4822, 2024, doi: 10.3758/s13428-023-02218-x.