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Community-Based Biomonitoring in Randuboto and Manyar Sidomukti Coastal Areas for Biodiversity Conservation

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ABSTRACT: The coastal area is certainly one of the most diverse ecosystems on Earth. This unique environment is characterized by the encounter of land and sea, forming a distinct ecotone zone. Randuboto and Manyar Sidomukti, fisherman villages located in Gresik Regency, thrives within this kind of diverse coastal ecosystem. The inhabitants rely heavily on their environment. Protecting this environment ensures the continued prosperity and resilience of the village's way of life. Biomonitoring is a method used for biodiversity accounting to indicate the quality of an environment. This process involves the quantification of various biodiversity metrics, including The Shannon-Wienerdiversity index (H index). Using this method, a study was conducted to assess the ecosystem condition in the Randuboto and Manyar Sidomukti coastal area. The mangrove community in Manyar Sidomukti exhibited a higher diversity index (H' = 0.42 – 0.68) compared to Randuboto (H' = 0 – 0.082), though both areas fall into the low diversity category with H' <1. In terms of bird species, Randuboto had a greater number (40 species) than Manyar Sidomukti (37 species). However, the Shannon-Wiener diversity index for birds was higher in Manyar Sidomukti (H' = 3.33) than in Randuboto (H' = 2.80). These findings suggest that mangrove populations require additional support to enhance their resilience, whereas bird populations appear to be relatively resilient to environmental changes. Efforts to bolster this include mangrove reforestation, community service and development, and training in community-based biomonitoring.

KEYWORDS: Biodiversity, biomonitoring, coastal area, mangrove, Randuboto, Manyar Sidomukti

I. INTRODUCTION

The coastal area is certainly one of the most diverse ecosystems on Earth. This unique environment is characterized by the encounter of land and sea, forming a distinct ecotone zone [1]. The interaction between terrestrial and marine ecosystems in coastal areas creates a rich tapestry of habitats that support a wide variety of plant and animal life. These zones are often teeming with biodiversity, ranging from mangroves and salt marshes to coral reefs and sandy beaches. The dynamic nature of coastal areas also makes them highly productive and important for numerous ecological processes [2]. Consequently, preserving these vital ecosystems is crucial for maintaining environmental balance and supporting human livelihoods.

Randuboto and Manyar Sidomukti, fisherman villages located in Gresik Regency, thrives within this kind of diverse coastal ecosystem. The inhabitants rely heavily on their environment, as most of their livelihoods are centered around fishery activities [3]. The rich marine life and fertile waters provide ample resources for the villagers, supporting both their economic and nutritional needs. This close connection to the sea also shapes the cultural and social fabric of Randuboto, with traditions and daily routines deeply intertwined with fishing practices. The sustainability of the coastal ecosystem is therefore vital for the well-being of the community [4]. Protecting this environment ensures the continued prosperity and resilience of the village's way of life.

Biomonitoring is a method used for biodiversity accounting to indicate the quality of an environment [5]. This process involves the quantification of various biodiversity metrics, including the Shannon-Wiener diversity index (H index) [6]. The Shannon-Wiener index is commonly employed to characterize species diversity within a community, providing insight into the ecological health of the area. By measuring the abundance and variety of species, biomonitoring helps identify changes in environmental conditions over time [7]. This data is crucial for conservation efforts, as it can highlight areas in need of protection or restoration. Ultimately, biomonitoring serves as a vital tool for maintaining ecological balance and promoting sustainable environmental practices [5].

Using this method, a study was conducted to assess the ecosystem condition in the Randuboto and Manyar Sidomukti coastal area. The H index was calculated for mangrove vegetation and bird populations. Analyzing these components provided valuable insights into the overall biodiversity and health of the ecosystem. This study is expected to serve as a baseline for future biodiversity conservation efforts, supporting the livelihoods of the people in Randuboto and Manyar Sidomukti. The findings can guide sustainable practices and inform policies aimed at protecting and restoring the area's natural resources. Ultimately, this research underscores the importance of preserving biodiversity for the well-being of both the environment and the local community.

II. METHODS

Sampling Time and Area

Population sampling and observation were conducted in the fostered area of Petronas Carigali Ketapang II Ltd. The observation locations were divided into two points: the mangrove conservation area of Randuboto Village and the Kalimireng mangrove conservation area in Manyar Sidomukti Village. Biodiversity observation activities in Randuboto Village took place on January 23-24, 2024. Meanwhile, biodiversity observation activities in Manyar Sidomukti Village were carried out on April 19-20, 2024. Vegetation sampling was done during the day while bird observation was conducted twice in the morning at 06.00-08.00 AM and in the afternoon at 02.00-04.00 PM.

Figure 1. Sampling area in Randuboto

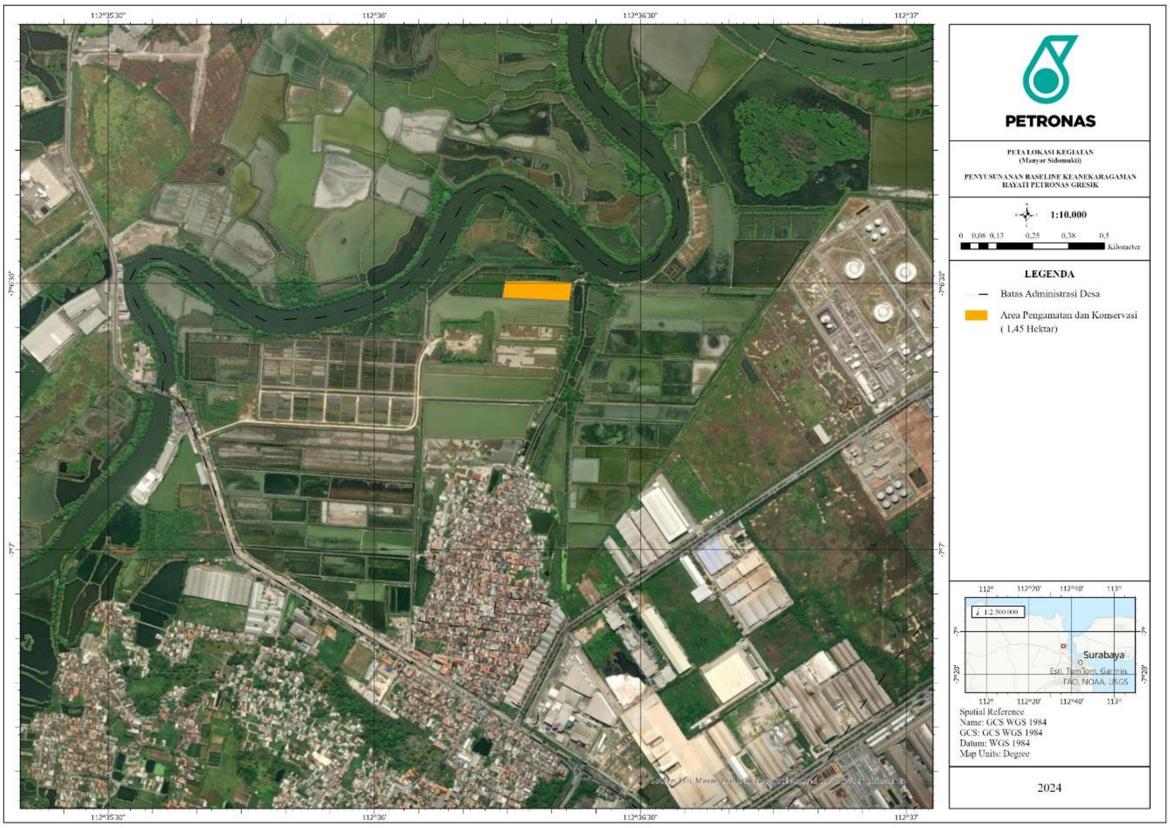

Figure 2. Sampling area in Manyar Sidomukti

Data Collection

Data collection was conducted on sample populations, including mangrove vegetation and birds in the area of study. The process involved extensive fieldwork to gather accurate and comprehensive data. Local communities played a significant role in the data collection process, contributing their knowledge and resources. Their involvement not only facilitated smoother operations but also enriched the data with indigenous insights. This collaborative approach ensured a more holistic understanding of the ecosystem [8].

1. Vegetation Population Sampling

Vegetation sampling was conducted using the transect method, a systematic approach for studying plant communities [9]. A transect line was established across the study area, and data were collected at 10 specific points along this line. At each point, the types and quantities of vegetation present were documented. This method provided a representative snapshot of the vegetation distribution and diversity within the area, allowing for an accurate assessment of the ecosystem's biodiversity. By using multiple points along the transect, the study ensured comprehensive coverage and reliable data for analysis [10].

2. Bird Population Sampling

Bird population was observed for 2 hours at a certain point, without moving. The data collected included species name, place found, and the number of populations observed. Observations were made using binoculars, cameras, bird identification books, and tally sheets. There were three observation points at Randuboto and only one at Manyar Sidomukti because the former area is larger than the latter.

Data Analysis

Each of the population diversity was determined using the Shannon-Wiener diversity index with the following formula [11].

$$H' = -\sum P_i \ln P_i$$

H' = Shannon-Wiener Diversity Index

Pi = the proportion of each species in the sample

ln = natural logarithm

III. RESULTS AND DISCUSSION

Vegetation Diversity in Randuboto and Manyar Sidomukti Coastal Area

Based on the results of field data analysis, there were 31 types of mangroves from 19 families found in all observation locations, with the composition of mangroves consisting of 17 true mangrove species and 14 associated mangrove species. True mangrove species as the main components of the mangrove ecosystem were found to come from the Aviceniaceae family (*A. alba*, *A. lanata*, *A. marina*, and *A. officinalis*), Rhizophoraceae (*Rhizophora mucronata* and *Ceriops tagal*), Sonneratiaceae (*S. alba* and *S. caseolaris*), and Acanthaceae (*Acanthus ebractiatus* and *Acanthus ilicifolius*). Other additional mangrove families from true mangroves include Combretaceae (*Lumnitzera racemosa*), Euphorbiaceae (*Exoecaria agallocha*), Meliaceae (*Xylocarpus granatum* and *Xylocarpus mollucensis*), Myrsinaceae (*Aegiceras corniculatum*), Palmae (*Nypa fruticans*), and Sterculiaceae (*Heritiera littoralis*). In addition to true mangroves, associated mangrove families were also found consisting of Pteridaceae (*Acrostichum aureum* and *Acrostichum speciosum*), Bignoniaceae (*Dolichandrone spataceae*), Asteraceae (*Pluchea indica* and *Wedelia biflora*), Convolvulaceae (*Ipomoea* sp.), Cyperaceae (*Eleocharis congesta*, *Scirpus latiflorus*, and *Scirpus littoralis*), Legumenosae (*Derris trifoliata*), Malvaceae (*Hibiscus tiliaceaus*), Verbenaceae (*Clerodendrum inerme*), and Portulacaceae (*Sesuvium portulacastrum* and *Sesuvium portulacastrum*).

Based on the distribution of mangrove species, the mangrove zoning area in Randuboto is composed of 29 mangrove species consisting of 16 true mangrove species and 13 associated mangrove species. The Aviceniaceae family is the family with the largest number of species that make up the research location. This indicates that the Aviceniaceae family has individuals with the highest tolerance and adaptation to environmental factors at the research location [12]. Meanwhile, the mangrove zonation area in Manyar Sidomukti is composed of 15 mangrove species consisting of 9 true mangrove species and 6 associated mangrove species, with Rhizoporaceae and Avicenniaceae as the dominant families. When viewed from the similarity of community composition, there are 13 mangrove species that are evenly distributed throughout the location. Meanwhile, 16 species were only found in the Randuboto Village mangrove zonation area and 2 species were only found in the Manyar Sidomukti mangrove zonation area, which were *Ceriops tagal* and *Scirpus littoralis*.

Table 1. Composition of mangrove species in sampling areas

Survey Location	Level	No	Scientific Name	Density (ind/ha)	H' Indeks
Randuboto	Seedling	1	*Avicennia marina*	69.063	0,056
		2	*Rhizophora mucronata*	469	
		3	*Lumnitzera racemose*	157	
	Sapling	1	*Avicennia marina*	6.475	0,082
		2	*Rhizophora mucronata*	400	
	Tree	1	*Avicennia marina*	319	0
Manyar Sidomukti	Seedling	1	*Rhizophora mucronate*	22.250	0,68
		2	*Avicennia marina*	8.000	
		3	*Sonneratia alba*	750	
	Sapling	1	*Rhizophora mucronate*	1.120	0,94
		2	*Avicennia marina*	360	
		3	*Sonneratia alba*	200	
		4	*Ceriops tagal*	40	
	Tree	1	*Rhizophora mucronate*	340	0,42
		2	*Avicennia marina*	60	

The mangrove community in Randuboto at the seedling and sapling levels is dominated by *Avicennia marina*. The species density value (individuals/hectare; ind/ha) of *A. marina* at the seedling and sapling levels is quite high, reaching thousands per hectare of land, having been calculated at 69,063 seedlings/ha and 6,475 saplings/ha. Meanwhile, at the tree level, only *A. marina* species was found with a density of 319 ind/ha. The value of the mangrove community diversity index is included in the low criteria with an index value of H' <1 [13]. On the other hand, the mangrove community in Manyar Sidomukti at the seedling, sapling, and tree levels is dominated by the *Rhizophora mucronata* species. The diversity index of the mangrove community in Manyar Sidomukti (H' = 0.42 – 0.68) is higher than Randuboto (H' = 0 – 0.082), but is still in the low category with H' <1.

Bird Diversity in Randuboto and Manyar Sidomukti Coastal Area

Field observations to identify bird diversity in all locations have been conducted. The results of the observations showed that the total number of bird species found in all locations was 57 species from 26 families. Based on their habitat, there were 32 species of water birds and 25 species of land birds. There were 9 families of water birds found consisting of Alcedinidae, Anatidae, Ardeidae, Charadriidae, Ciconiidae, Laridae or Sternidae, Phalacrocoracidae, Rallidae, and Scolopacidae. The water bird family is dominated by Ardeidae which consists of 10 species. Meanwhile, 17 families of land birds were identified, including Acanthizidae, Aegithinidae, Apodidae, Artamidae, Campephagidae, Cisticolidae, Columbidae, Cuculidae, Dicaeidae, Estrildidae, Hirundinidae, Laniidae, Meropidae, Nectariniidae, Pycnonotidae, Rhipiduridae, and Sylviidae. The Columbidae family is the land bird family that dominates the observation location with a total of 4 species.

Taking into account the distribution of bird species, 20 bird species were found evenly distributed in both observation locations. Bird species that were only found in the Randuboto mangrove conservation area were 20 species while 17 other species were found in the Kalimireng mangrove conservation area, Manyar Sidomukti. In addition, there were also several dominant or frequently encountered bird species and recorded during observations. The 6 dominant bird species in the Randuboto conservation area were *Ardeola speciosa*, *Egretta garzetta*, *Ardea alba*, *Sterna sumatrana*, *Sterna nilotica*, and *Phalacrocorax sulcirostris*. Meanwhile, there were 4 dominant bird species in the Manyar Sidomukti conservation area, including *Collocalia linchi*, *Ardeola speciosa*, *Lonchura maja*, *Lonchura punctulata*, and *Phalacrocorax sulcirostris*.

Based on the threat status records according to the IUCN Red List, 4 bird species have near threatened status (NT or Near Threatened), including *Anas gibberifrons*, *Charadrius javanicus*, *Anhinga melanogaster*, and *Limosa limosa*. As many as 1 bird species has vulnerable status (VU or Vulnerable), *Centropus nigrorufus*. In addition, 2 endangered bird species (EN or Endangered) were also found, those were *Numenius madagascariensis* and *Mycteria cinerea*. As many as 50 other species have low risk status (LC or Least Concern) [14].

Figure 3. A) *Sterna nilotica* and B) *Mycteria cinerea* documented at the observation sites

Table 2. Diversity and conservation status of bird species at sampling locations

No.	Scientific Name	Family	Survey Location		Conservation Status
			Manyar Sidomukti	Randuboto	
1	*Gerygone sulphurea*	Acanthizidae	**	*	LC
2	*Aegithina tiphia*	Aegithinidae		*	LC
3	*Todirhamphus chloris*	Alcedinidae	*	*	LC
4	*Todiramphus sanctus*		*	*	LC
5	*Anas gibberifrons*	Anatidae	**		NT
6	*Collocalia linchi*	Apodidae	***	**	LC
7	*Ardeola speciosa*	Ardeidae	***	***	LC
8	*Egretta garzetta*			***	LC
9	*Egretta sacra*			*	LC
10	*Butorides striatus*		*	*	LC
11	*Nycticorax nycticorax*			*	LC

No.	Scientific Name	Family	Survey Location		Conservation Status
			Manyar Sidomukti	Randuboto	
12	*Ardea purpurea*		*	*	LC
13	*Ardea cinerea*			**	LC
14	*Ardea alba*		*	***	LC
15	*Ardea intermedia*		*		LC
16	*Ixobrychus sinensis*		*		LC
17	*Artamus leucoryn*	Artamidae	*	*	LC
18	*Lalage nigra*	Campephagidae		*	LC
19	*Lalage sueurii*		*		LC
20	*Charadrius javanicus*	Charadriidae		*	NT
21	*Pluvialis fulva*		*		LC
22	*Mycteria cinerea*	Ciconiidae		*	EN
23	*Prinia inornata*	Cisticolidae	*	*	LC
24	*Treron vernans*	Columbidae	**		LC
25	*Streptopelia bitorquata*		*		LC
26	*Streptopelia chinensis*		**	*	LC
27	*Geopelia striata*		**	*	LC
28	*Cacomantis merulinus*	Cuculidae	*		LC
29	*Cacomantis variolosus*		*		LC
30	*Centropus nigrorufus*			*	VU
31	*Dicaeum trochileum*	Dicaeidae	**		LC
32	*Lonchura maja*	Estrildidae	***		LC
33	*Lonchura punctulata*		***	*	LC
34	*Hirundo rustica*	Hirundinidae		**	LC
35	*Hirundo tahitica*		**		LC
36	*Lanius schach*	Laniidae		*	LC
37	*Sterna hirundo*	Laridae (Sternidae)		*	LC
38	*Chlidonias hybridus*		*	*	LC
39	*Chlidonias leucopterus*			**	LC
40	*Sternula albifrons*		*	**	LC
41	*Thalasseus bergii*			*	LC
42	*Sterna sumatrana*			***	LC
43	*Sterna nilotica* (*Gelochelidon nilotica*)			***	LC
44	*Merops leschenaulti*	Meropidae		*	LC
45	*Merops philippinus*		**		LC
46	*Cinnyris jugularis*	Nectariniidae	*		LC
47	*Anhinga melanogaster*	Phalacrocoracidae	*		NT
48	*Phalacrocorax sulcirostris*		***	***	LC
49	*Pycnonotus aurigaster*	Pycnonotidae	*		LC
50	*Pycnonotus goiavier*		**	*	LC
51	*Amaurornis phoenicurus*	Rallidae	*	*	LC
52	*Rhipidura javanica*	Rhipiduridae	**	*	LC
53	*Actitis hypoleucos*	Scolopacidae	*	**	LC
54	*Xenus cinereus*			*	LC
55	*Numenius madagascariensis*			*	EN
56	*Limosa limosa*			*	NT
57	*Cisticola juncidis*	Sylviidae	**		LC
Species in total			37	40	
H' index			3,33	2,8	

The number of bird species in Randuboto (40 species) is greater than in Manyar Sidomukti (37 species). Meanwhile, the Shannon-Wiener diversity index (H') for the bird community in Manyar Sidomukti (H' = 3.33) is higher than in Randuboto (H' = 2.80). This higher diversity index in Manyar Sidomukti is attributed to the more stable number of individuals of each species compared to Randuboto. In Randuboto, bird species are predominantly waterbirds. This dominance is due to the wider coverage of the Randuboto mangrove conservation area, which includes riverbanks, river estuaries, and joint protection zones (ZPB), whereas the Manyar Sidomukti mangrove conservation area is only near the riverbank.

Efforts in Biodiversity Conservation

Mangrove Reforestation

Mangrove forests play crucial roles in coastal areas by providing a range of ecological and socio-economic benefits. They act as natural barriers, protecting shorelines from erosion and reducing the impact of storms and tidal waves [15]. These forests also serve as vital nurseries for various marine species, supporting biodiversity and local fisheries. Additionally, mangroves sequester significant amounts of carbon, aiding in climate change mitigation [16]. They filter pollutants from water, improving coastal water quality, and provide resources and livelihoods for local communities [17]. Thus, mangrove reforestation is essential for protecting shorelines from erosion, supporting marine biodiversity, sequestering carbon, improving water quality, and sustaining local livelihoods.

In 2022, Petronas Carigali Ketapang II Ltd launched a major mangrove reforestation initiative by planting 10,000 seedlings of *Rhizhophora* sp., *Avicennia* sp. and *Bruguiera* sp. Mangrove reforestation involves the restoration and replanting of mangrove ecosystems, which are vital coastal habitats known for their ability to protect shorelines, support biodiversity, and sequester carbon. This effort marked the beginning of a sustained commitment to restoring the local mangrove ecosystem. The following year, the company continued this reforestation activity, planting an additional 10,000 seedlings of the same species, making it a grand total of 20.000 seedlings over two years.

Through this initiative, Petronas Carigali Ketapang II Ltd has successfully planted a total of 20,000 mangrove seedlings over two years. These efforts spanned an area of 2 hectares, previously used as a community pond. Mangrove reforestation is important because it helps mitigate climate change, supports fisheries, and protects coastal communities from erosion and extreme weather events. This large-scale reforestation underscores the company's dedication to environmental sustainability and the restoration of critical coastal habitats.

Figure 4. Mangrove planting

Community Service and Development

Local communities hold significant roles in biodiversity management in coastal areas by leveraging their traditional knowledge and direct involvement in conservation efforts [18]. They contribute to the sustainable management of natural resources through practices that have been refined over generations, ensuring the preservation of local flora and fauna [19]. Their participation in activities such as monitoring wildlife, reforestation projects, and sustainable fishing practices helps maintain the ecological balance and resilience of coastal ecosystems. Moreover, local communities can advocate for and implement conservation policies, fostering a sense of ownership and stewardship that is crucial for long-term biodiversity management [20]. By engaging in eco-tourism and educational initiatives, they also raise awareness and promote the value of biodiversity, further supporting the conservation efforts [21].

Community-based Biomonitoring in Randuboto and Manyar Sidomukti Coastal Areas for Biodiversity Conservation

Efforts to support the development of local communities in Manyar Sidomukti and Randuboto included a community service activity held in March 2024 at the Kalimireng Fishermen's Hall in Manyar Sidomukti. This initiative was a collaborative effort between the Faculty of Science and Technology, Universitas Airlangga (FST Unair) and Petronas. The primary goal of the activity was to educate fishermen and local residents about the importance of maintaining the sustainability of coastal and mangrove areas. The event featured Prof. Zeev Bohbot, a senior lecturer from the KTH Royal Institute of Technology in Stockholm, Sweden, as the main speaker for the socialization session.

In May 2024, a community service event focused on mangrove planting was held in the Kalimireng mangrove zoning area of Manyar Sidomukti. This initiative involved planting 12 new mangrove species, including *Rhizophora stylosa*, *Rhizophora apiculata*, *Xylocarpus moluccensis*, *Bruguiera cylindrica*, *Acanthus ilicifolius*, *Acrostichum speciosum*, *Excoecaria agallocha*, and *Lumnitzera racemosa*. Prior to the planting, a session was conducted to educate participants on proper techniques for planting and caring for mangrove vegetation. The targets of this activity were the fishermen and local residents of Manyar Sidomukti Village. This collaborative effort involved Universitas Airlangga, Petronas, Manyar Sidomukti Village, POKMASWAS Kalimireng, POKDARWIS Kab. Gresik, and the Department of Marine Affairs and Fisheries of Gresik Regency. The goal of this community service was to increase both the number and variety of mangroves in the conservation area and to enhance the community’s knowledge of effective mangrove planting and maintenance practices.

Training in Community-based Biomonitoring

To support biodiversity conservation and empower local communities, a specialized training session was held on Tuesday, May 28, 2024, at the Kalimireng Fishermen's Hall in Manyar Sidomukti. This initiative, a collaboration between FST Unair and Petronas, aimed to enhance the local community's expertise in monitoring, managing, and conserving biodiversity within the Petronas-managed conservation area. The training was conducted by three lecturers from FST Unair and included instruction on sampling techniques for flora and fauna around the mangrove conservation area, as well as methods for evaluating seawater quality through physical, chemical, biological, plankton, and benthos analyses.

The goal of the training was for both the fishermen and the Petronas field team to acquire a thorough understanding and practical skills in biodiversity monitoring and conservation techniques, reflecting the vital role local communities play in environmental management [22]. By equipping these individuals with advanced knowledge and hands-on experience, the training aimed to foster a sense of stewardship and enable them to actively contribute to the preservation of local ecosystems. Local communities, including fishermen, are often on the front lines of environmental changes and can provide valuable insights and observations about biodiversity [23]. Empowering them with skills in monitoring and conservation not only enhances their capacity to manage natural resources effectively, but also ensures that conservation efforts are more grounded and responsive to real-world conditions [24]. This collaborative approach helps bridge the gap between scientific research and community practice, leading to more sustainable and impactful environmental management [25].

Figure 5. Community-based biomonitoring training

IV. CONCLUSION

Field data analysis revealed the presence of 31 mangrove types from 19 families across all observation locations. This included 17 true mangrove species and 14 associated mangrove species. The mangrove community in Manyar Sidomukti exhibited a higher diversity index (H’ = 0.42 – 0.68) compared to Randuboto (H’ = 0 – 0.082), though both areas fall into the low diversity category with H’ <1. In terms of bird species, Randuboto had a greater number (40 species) than Manyar Sidomukti (37 species). However, the Shannon-Wiener diversity index for birds was higher in Manyar Sidomukti (H’ = 3.33) than in Randuboto (H’ = 2.80). These findings suggest that mangrove populations require additional support to enhance their resilience, whereas bird populations appear to be relatively resilient to environmental changes. Efforts to bolster this include mangrove reforestation, community service and development, and training in community-based biomonitoring.

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