American Journal of Environment and Climate (AJEC)

ISSN: 2832-403X (ONLINE)

VOLUME 5 ISSUE 1 (2026)

PUBLISHED BY
E-PALLI PUBLISHERS, DELAWARE, USA

American Journal of Environment and Climate (AJEC)

Volume 5 Issue 1, Year 2026
ISSN: 2832-403X (Online)
DOI: https://doi.org/10.54536/ajec.v5i1.6409
https://journals.e-palli.com/home/index.php/ajec

Perceptions, Knowledge Systems, and Ecological Indicators in Evaluating Mangrove Ecosystem Health in Zanzibar

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Article Information

Received: October 27, 2025

Accepted: November 29, 2025

Published: January 29, 2026

Keywords

Community Perceptions, Mangrove Ecosystem Health, Traditional Ecological Knowledge, Temporal Ecological Change, Participatory Mapping, Zanzibar

ABSTRACT

Zanzibar's mangrove forests provide essential ecological, commercial, and cultural functions, but they are under increasing strain from environmental change and human activity. With an emphasis on variations influenced by occupation, age, and the location of coastal settlements, this study attempts to investigate how coastal residents in Zanzibar define, perceive, and assess the health of mangrove ecosystems. In order to methodically capture local ecological knowledge and temporal views, data were meticulously gathered through participatory workshops with 220 participants using integrated methodologies such as participatory mapping, historical timeline reconstruction, and organized discussions. Mangrove health was regularly evaluated by communities using metrics such as species richness, biodiversity, forest structure, and resource accessibility. Age was a significant factor ($\chi^2 = 27.6$, df = 11, $p = 0.0037$), with older participants exhibiting broader and more detailed ecological understanding. However, statistical analysis showed no significant variation in ecological knowledge across villages ($\chi^2 = 18.6$, df = 11, $p = 0.069$) or occupations ($\chi^2 = 12.4$, df = 11, $p = 0.3329$). Thus, there were clear intergenerational differences: younger participants gave priority to habitat quality and biodiversity conservation, whereas seniors stressed long-term decrease since the 1970s. Thirty-one indicators of ecosystem health were found among all participants, with biological indicators making up 67.7% of the total. Results show that mangrove health has significantly declined due to harvesting, urbanization, aquaculture, and weather events, but there is also evidence of resilience and rebound. The study emphasizes how important traditional ecological knowledge is for developing adaptable, community-driven conservation and sustainable mangrove management practices.

INTRODUCTION

Mangrove forests are an essential part of coastal seascapes in tropical and subtropical regions, forming intimate ecological relationships with coral reefs and seagrass meadows (Huxham *et al.,* 2018). In addition to being essential for maintaining biological equilibrium, these interconnected ecosystems support the livelihoods and general well-being of millions of coastal people worldwide (Ochoa-Hueso *et al.,* 2021). Mangroves in Zanzibar offer indirect advantages such coastal stabilization, carbon sequestration, and biodiversity conservation in addition to direct contributions to food security, revenue production, and cultural traditions (Mohamed *et al.,* 2024). These woods provide fuelwood and lumber, serve as fish and invertebrate nurseries, and are increasingly supporting alternative lifestyles through ecotourism and nature-based businesses (Zoysa, 2022). For tiny island environments like Zanzibar, they play a particularly important role in mitigating and adapting to climate change through sediment stabilization, erosion management, and coastal protection against storm surges and sea level rise (Iqubal, 2024; Mohamed, 2024).

Some of Africa's most ecologically and socioeconomically significant mangrove stands are found in the Western Indian Ocean (WIO) region, which includes Zanzibar (Mwanzia, 2019). These ecosystems sustain offshore fisheries, offer vital habitats for migratory birds, and serve as globally significant carbon sinks (Santojanni *et al.,* 2023). In addition to supporting local livelihoods, Zanzibar's mangroves, which are concentrated in regions like Menai Bay, Chwaka Bay, and northern Unguja, also support regional ecological connectivity by connecting with mainland Tanzania and Kenya via oceanic currents and species dispersal (Mohamed, 2024; Faulkner *et al.,* 2022). Because of their interdependence, Zanzibar's mangroves' health and deterioration have an impact outside of the islands. Mangrove resources have historically been used for trade and subsistence in Zanzibar. Mangrove poles were heavily shipped to the Arabian Peninsula for construction during the 19th and early 20th centuries, substantially degrading some places (Mohamed *et al.,* 2023; Alders, 2024). Local reliance on mangroves for fuelwood, building materials, and fisheries support is still significant even though exports have decreased, especially in rural settlements (Liman Harou *et al.,* 2023). These forces have increased the strain on mangrove ecosystems (Friess *et al.,* 2022), driving them toward unsustainable use (Ferreira *et al.,* 2022), along with rapid population growth, tourism expansion, and urbanization in peri-coastal zones (Jain & Karanth, 2023).

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Mangroves in Zanzibar are under increasing strain from both anthropogenic and climatic factors, despite their many advantages (Mohamed, 2024). Due to unsustainable wood harvesting, rapid coastal development, salt production, aquaculture, and agricultural expansion, about one-third of the mangrove cover in the islands has been lost or degraded over the past few decades, just like in many other parts of the world (Mohamed, 2024; Mohamed *et al.,* 2023). Sea level rise, shoreline erosion, and extreme weather events are examples of climate-related stressors that exacerbate these pressures (Iqubal, 2024; Guild *et al.,* 2025). International and regional initiatives like the Western Indian Ocean Mangrove Network and the Global Mangrove Alliance have prioritized the conservation and restoration of mangroves because to their socio-ecological significance (Come *et al.,* 2023). Although community-based management strategies, such as the creation of Village Conservation Committees and co-management frameworks, have demonstrated promise in Zanzibar in reducing degradation, their long-term success is still uncertain in the absence of improved governance and inclusive participation (Mohamed *et al.,* 2024; Mohamed, 2024).

Healthy ecosystems are increasingly seen in international policy frameworks as essential to sustainable development (Come *et al.,* 2023). This aligns with the United Nations Sustainable Development Goals (SDGs) 14 (life below water) and 15 (life on land) (Sayer *et al.,* 2019). The concept of "ecosystem health," which was first defined in the 1990s as ecosystems' capacity to retain resilience, structure, and function under stress (Giraudoux, 2022; Li *et al.,* 2014), has expanded to encompass ecosystem services and, more recently, the benefits that nature provides to humans (Mohamed *et al.,* 2024; Hernández-Blanco *et al.,* 2022). This change underscores the importance of indigenous and local knowledge in determining ecosystem health and stresses not only biological functions but also the various cultural, social, and economic values that people attach to ecosystems (Turner *et al.,* 2022).

Furthermore, because mangroves are referred to as "blue carbon ecosystems," their significance in global climate policy is becoming more widely acknowledged (Hilmi *et al.,* 2021). Like many tiny island states, Zanzibar stands to gain from this conversation since mangrove conservation and rehabilitation can draw carbon credit programs and climate finance that promote both biological restoration and local livelihoods (Jape & Najar, 2024; Mohamed, 2024). Nonetheless, there are still issues with monitoring, fair benefit-sharing, and making sure conservation initiatives represent local goals and knowledge systems rather than being pushed from the outside (Morgera, 2023).

However, there may be significant differences in how ecosystem health is understood depending on scale, users, and context. Perceptions of mangrove health in Zanzibar are shaped by indigenous ecological knowledge, livelihood strategies, and sociocultural values (Mohamed, 2025; Mohamed *et al.,* 2024). For example, while fuelwood collectors may concentrate on tree density and accessibility, fishermen may assess mangrove health in terms of fish quantity (Zu Ermgassen *et al.,* 2020). These variations highlight the need for locally based evaluations of ecosystem health that include both scientific indicators and community viewpoints (Izquierdo *et al.,* 2025).

This study examines how coastal communities in Zanzibar describe, view, and evaluate the health of mangrove ecosystems in order to close this gap. It specifically looks at how different user groups' impressions are influenced by factors including location, age, and occupation. The following are the guiding questions: (i) How do Zanzibar's coastal populations see the health of mangrove ecosystems? (ii) How do local definitions relate to what the community knows and has experienced about the ecosystem? and (iii) How do they view changes in the health of the mangrove ecosystem over time? With implications for conservation planning, policy design, and the long-term sustainability of these essential ecosystems, the study advances a more sophisticated understanding of how mangrove health is socially created.

MATERIALS AND METHODS

Characteristics of Study Sites

The study was conducted in the settlements of Unguja Ukuu Kae Pwani and Pete, located near each other along the southern edge of Chwaka Bay on the eastern coast of Unguja Island, Zanzibar, Tanzania (Figure 1). The Chwaka-Jozani Protected Bay, which includes vast mangrove forests, seagrass meadows, and surrounding coral reefs, is a protected region known for its high ecological diversity and environmental value (Mohamed, 2024). The northeast (Kaskazi) and southeast (Kusi) monsoon winds have an impact on the area's tropical monsoon climate. The lengthy rainy season (Masika) occurs between March and May, while the short rains (Vuli) come from October to November, adding to an annual rainfall range between 1,200 and 2,000 mm (Mohamed *et al.,* 2024; Faulkner *et al.,* 2022). The ocean's impact moderates excessive heat and keeps relative humidity levels around 75% year-round, with average temperatures ranging from 24°C to 30°C (Mohamed, 2024).

According to Faulkner *et al.* (2022) and Mohamed *et al.* (2024), the study regions' soils are mostly coralline sandy loams made of coral rag and limestone bedrock, with saline and alluvial deposits occurring near tidal flats and mangrove fringes. These soils are usually well-drained but low in nutrients, which limits agricultural productivity to crops that can withstand salt and drought, such as legumes, coconuts, and cassava. Mangrove species include Rhizophora mucronata, Ceriops tagal, and Avicennia marina, thrive in saline, poorly drained soils in lower tidal regions (Mohamed, 2024).

The study areas' topography is low-lying, gently sloping, and typically below 30 meters above sea level. It is dotted with creeks and estuarine inlets that permit sediment deposition and tidal water exchange (Mohamed *et al.,*

2024). Because of these geomorphological features, the villages are susceptible to saltwater intrusion, tidal flooding, and coastal erosion, particularly when sea levels rise and storm surges increase due to climate variability and change (Mohamed, 2025). Both surface runoff and tidal circulation have an impact on the region's hydrology, sustaining fertile wetlands and fish and crustacean nursery habitats that are essential to the local economy (Mohamed, 2025).

The ecological and socioeconomic structure of Unguja Ukuu Kae Pwani and Pete is shaped by these physical, climatic, and soil features taken together. Strong inter-village cooperation and a mutual reliance on natural resources, particularly fisheries, mangroves, and small-scale agriculture, are fostered by their proximity. However, in order to protect livelihoods and ecosystem resilience in the Chwaka Bay region, the delicate coastal environment highlights the necessity of coordinated resource management and climate adaptation methods

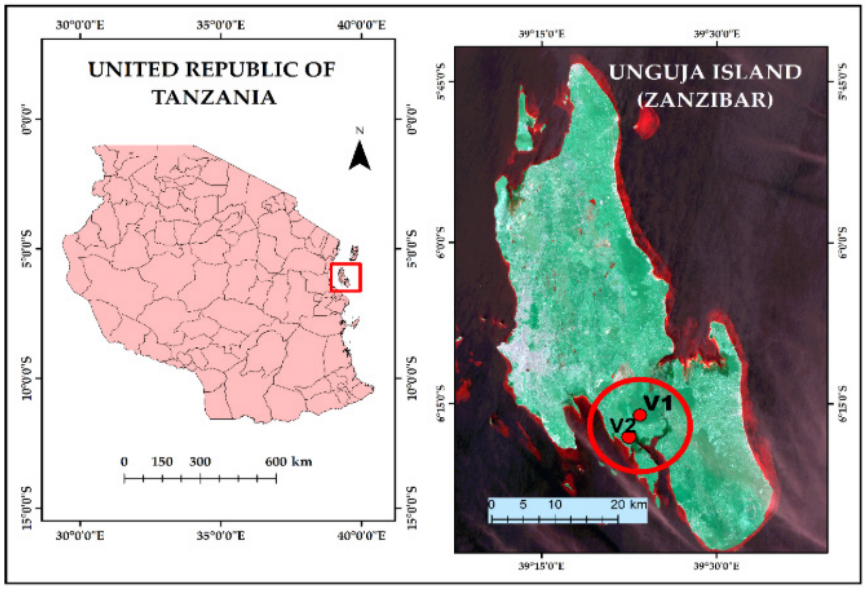

Figure 1: Study areas (V1 = Unguja Ukuu Kae Pwani (close to mangroves); V2 = Pete (Far from mangroves)).

(Mohamed, 2024).

Data Collection

In order to understand how coastal communities in Zanzibar conceptualize the health of mangrove ecosystems, perceive ecological changes over time, and relate these perceptions to their lived experiences and knowledge systems, this study used participatory methodologies. Eight participatory workshops were organized over three weeks in August 2025 in two coastal villages: Unguja Ukuu Kae Pwani in Menai Bay (Village 2, V2) and Pete, near Jozani Forest (Village 1, V1) (Figure 1). The two locations were specifically chosen to capture variations in primary livelihood activities, as well as differences in accessibility and closeness to mangrove ecosystems. The livelihoods of Pete village (V1), farther from the primary mangrove stands, are more varied and include small-scale tourism, subsistence farming, and limited pastoralism. On the other hand, fishing, shellfish gathering, and mangrove harvesting are the primary sources of revenue in Unguja Ukuu Kae Pwani (V2), which is located next to vast mangrove forests and intertidal mudflats.

The sessions were attended by 220 individuals, ranging in age from 25 to 85 (Figure 2). Participants were divided by village, gender, age (under 40 and over 40), and occupation to guarantee equitable representation among various user groups. Jobs were classified as either non-ecosystem-related (e.g., boat operators, market vendors) or ecosystem-related (e.g., fishers, farmers). Men were more frequently active in offshore fishing and mangrove crab collecting. In contrast, women made up 59.2% of the sample overall, showing their crucial involvement in inshore fishing, shellfish collection, and small-scale mangrove product trading. When people reported doing more than one activity, the activity they spent the most time on determined their major occupation. In line with the study's goal of analyzing differences in perceptions influenced by age, occupation, and location, this stratification allowed for methodical comparisons between groups.

In order to gather community viewpoints, workshops centered on participatory rural appraisal (PRA) techniques (Figure 2). The discussions were organized by two complementary activities: (i) participatory mapping (Laituri *et al.,* 2023), which encouraged participants to identify ecological features, resource use areas, and sites of degradation; and (ii) participatory timeline analysis (McCall, 2021), which enabled villagers to reconstruct ecological changes and connect them to social, economic, and environmental drivers (Xia *et al.,* 2025). These techniques were chosen because they promote communication both within and between user groups

while producing rich, location-based knowledge. The information gathered gave direct insights into historical change trajectories, community-defined markers of mangrove ecosystem health, and how daily interactions with mangrove ecosystems shape local opinions.

The research team, working with community leaders familiar with the cultural and socioeconomic backgrounds of both Pete and Unguja Ukuu Kae Pwani, facilitated participatory workshops conducted entirely in Kiswahili, the primary language of the local communities. With the consent of the participants, all workshop talks were audio recorded. The recordings were then transcribed and translated into English for methodical qualitative analysis. Every participant received an information sheet in Kiswahili outlining the goals, methods, and purpose of the study, along with their rights and obligations as volunteers, in compliance with ethical research guidelines. Before participation began, each subject provided written or spoken informed consent, depending on their reading level. No personally identifiable information, including names, addresses, or household details, was collected, and participants were informed of their freedom to leave the study at any time without repercussions. The Office of the Second Vice President of Zanzibar, the governmental body in charge of monitoring and authorizing research operations in the area, provided the required research approvals. In order to guarantee that the research was carried out with complete community awareness, transparency, and support thereby promoting ethical and responsible interaction with local populations consultations with local village leaders (Shehas) were also held prior to data collection.

Workshop Design and Implementation

Participatory mapping was used as a key methodological tool to evaluate local perceptions of the health of the mangrove ecosystem. In a variety of ecological and sociocultural contexts, participatory mapping has been extensively employed to geographically record natural resources, their uses, and local populations' perceptions of their values (McCall, 2021; Zhu *et al.,* 2025). This method integrates community-based understandings of resource distribution, consumption, and ecological state while making it easier to gather spatially explicit knowledge about ecosystems (Zhu *et al.,* 2025; Shemshad *et al.,* 2025).

A simplified, blank map of Zanzibar was given to each workshop participant, who were then asked to identify important coastal ecosystems, such as the distribution of mangroves, related habitats, species, and regions of socioeconomic and cultural significance. Participants were prompted to consider their individual and group interactions with the ecosystems through open-ended questions. "Can you describe the natural resources along the island's coast?" "Where are these resources located and harvested?" and "Which species are particularly important for your livelihood or cultural practices?" were examples of typical queries. By allowing participants to freely share their information, perspectives, and experiences, this indirect elicitation technique reduced facilitator bias or impact.

Participants were asked to rate each mapped ecosystem feature on a scale of 1 to 5, with 1 denoting severely deteriorated conditions and 5 denoting pristine or fully healthy conditions. The same prompts were used in each of the eight workshops to ensure consistency. After that, each participant entered (i) vital markers of a healthy mangrove ecosystem and (ii) their own description of "mangrove ecosystem health," emphasizing words or ideas they thought were significant. After discussing individual contributions, the group was able to come to a consensus definition that took into account a variety of viewpoints.

Participants worked together to create historical timelines of mangrove ecosystem health across their lifetimes, incorporating both positive and negative drivers of change, such as coastal development, deforestation, aquaculture expansion, or tourism growth, in order to better reflect temporal dynamics. In the past, historical timeline exercises have been used to discover causes of ecosystem change and to comprehend long-term ecological and social processes (Læhmus, 2025). Questions like "Can you recall a time when the mangrove ecosystem was particularly healthy or degraded?" were used by workshop facilitators to start conversations. and "What caused these conditions?" On a scale of 0 to 10, where 0 represented severely poor conditions and 10 represented perfectly healthy or pristine conditions, participants then retrospectively rated ecosystem health at regular intervals (e.g., 5, 10, 15 years ago). To ensure that all viewpoints were included in the overall evaluation, individual scores were then debated to reach group consensus.

In order to ensure inclusive participation and minimize potential biases resulting from social hierarchies or power dynamics, great effort was taken throughout the workshops (Ren & Clarke, 2025). This method made sure that a variety of perspectives, experiences, and knowledge were appropriately recorded, offering a solid basis for comprehending regional conceptions about the health of Zanzibar's mangrove environment.

Data Analysis

Qualitative selective coding (Lim, 2025) was used in NVivo 12 to analyze workshop transcripts, participatory maps, and historical timelines (Figure 2). Finding emergent themes, patterns, and participant conceptualizations of mangrove ecosystem health was the primary goal of the initial coding. Following that, comparative studies were carried out to investigate differences in language, perceptions, and ecosystem health indicators among various sociodemographic categories, such as age, occupation, and village location (Nyathi *et al.,* 2025). Descriptive statistics, heat maps, and bar charts were created to illustrate patterns in knowledge and attitudes among groups in order to supplement qualitative insights. Differences in ecological knowledge distribution between

age groups (<40 years versus ≥40 years), villages (V1 and V2), and profession types (ecosystem-related versus non-ecosystem-related) were evaluated using chi-squared tests of association. R (version 4.2.3; R Core Team, 2023) was used for all statistical analyses and data visualizations. Participant quotations are tagged according to age group (younger: <40; older: ≥40), occupation (ecosystem-related: ER; non-ecosystem-related: NER), and village (Village 1: V1; Village 2: V2) when presenting the results. While maintaining participant anonymity, this method guarantees clarity in connecting qualitative statements to participant attributes.

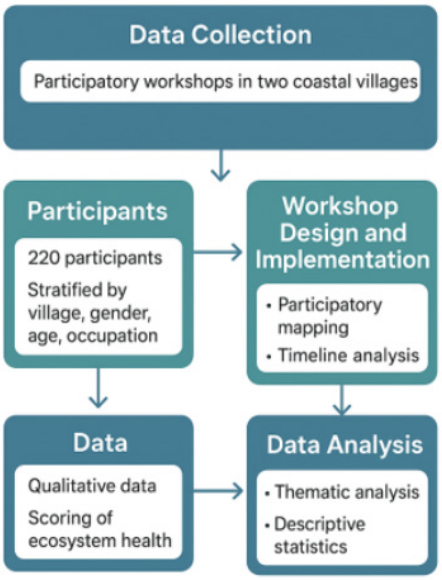

Figure 2: Data collection, workshop design, and data analysis.

RESULTS AND DISCUSSION

Demographic and Socioeconomic Characteristics of Respondents

The demographics of the respondents in the villages of Pete and Unguja Ukuu show both modest differences and commonalities that are crucial for placing the study's conclusions in context (Table 1). With an average of 99.0% of people identifying as Muslims, religion is quite homogeneous and reflects Zanzibar's larger sociocultural and religious makeup. Although women made up a slightly larger percentage in Pete (53.9%) and men were more prevalent in Unguja Ukuu (55.7%), the distribution of genders is generally balanced. The age distribution shows that the bulk of respondents (63.3% on average) are between the ages of 50 and 59, followed by those

Table 1: Demographic variables of participants in the study areas, Zanzibar.

Variable	Sub-Category	Pete (%)	Unguja Ukuu (%)	Average (%)
Religion	Muslims	99.3	98.6	99.0
	Christians	0.7	1.4	1.1
Gender	Male	46.1	55.7	50.9
	Female	53.9	44.3	49.1
Age	40–49	23.7	26.1	24.9
	50–59	57.3	69.2	63.3
	60+	19.0	4.7	11.9
Marital status	Married	88.2	92.5	90.4
	Widowed	9.0	6.3	7.7
	Divorced	2.8	1.2	2.0
Education level	Tertiary	4.1	7.6	5.9
	Secondary	41.5	59.0	50.3
	Primary	54.4	33.4	43.9
Household size	1–5	11.0	32.8	21.9
	6–10	69.8	58.4	64.1
	10+	19.2	8.8	0.9

between the ages of 40 and 49 (24.9%), and a lesser percentage (11.9%) are elderly participants (60 years and above). This distribution indicates that middle-aged and older persons, who are frequently linked to substantial agricultural and livelihood experience, make up the majority of the sample.

According to data on marital status, marriage is the most common social arrangement (90.4%), with very minor percentages being widowed (7.7%) or divorced (2.0%). This indicates that family structures are stable in the research areas. Only a tiny percentage of interviewees reported university education (5.9%), with the majority having either secondary (50.3%) or primary school (43.9%). This suggests moderate levels of educational achievement, which could have an impact on adaptability, livelihood diversification, and knowledge availability.

Nearly two-thirds of respondents (64.1%) lived in households with six to ten members, followed by smaller families with one to five members (21.9%), indicating a rather large household size. Although they were more widespread in Pete (19.2%) than in Unguja Ukuu (8.8%), extended households with more than ten members were less common overall (0.9%). Both cultural norms of extended family living and economic tactics that depend on group work for subsistence activities may be reflected in such household setups.

Perceptions of Mangrove Ecosystem Health in Coastal Zanzibar

Mangrove ecosystem health was primarily understood by participant groups in Pete and Unguja Ukuu Kae Pwani vilages, Zanzibar, in terms of ecological productivity, species richness, and the ecosystem's ability to support local livelihoods. The quantity of marine life, which supports economic activity and food security, was frequently cited by participants as a crucial indicator of health. Crabs (Scylla serrata), shrimp, shellfish, and fish are concentrated in mangrove forests, intertidal channels, and mudflats, which are important ecosystems for subsistence and small-scale commercial exploitation. "Healthy mangroves are forests full of crabs, shrimp, and fish, with extensive mudflats nearby," a young fisherman from Village 1 stressed. The waterways are consistently fertile, and it enables us to gather food nearby (V1, ER, <40).

Although the general markers of ecosystem health were widely agreed upon, there were subtle variances amongst groups according to village location, occupation, and age. A healthy mangrove should support both food species and non-food organisms, such as birds, insects, and a variety of plant species, according to younger participants, especially those involved in ecosystem-based livelihoods in Village 2. "A healthy mangrove supports crabs, fish, and shellfish, but also has many trees, flowers, and birds," explained a child participant. It sustains ecological balance by producing food and other resources (V2, ER, <40).

Materials from species and cultural values were often discussed by non-ecosystem-related people, especially younger members of the community. The usefulness of species like Rhizophora mucronata and Ceriops tagal in building, traditional crafts, and regional customs was highlighted. "Mangroves are healthy when they have large trees like Rhizophora mucronata and Ceriops tagal," a younger participant from Village 2 clarified. The wood and bark of Rhizophora mucronata and Ceriops tagal are used for building, creating traditional tools, and sustaining a variety of regional activities, such as fuelwood and artisanal crafts. Numerous species can be found in a productive forest, which supports daily life and livelihoods (V2, NER, <40). This reflects a strong recognition of mangroves' dual ecological and socio-economic value among community members.

Intergenerational variations in ecological knowledge were clearly apparent. Senior fishers and long-term mangrove resource users tended to evaluate ecosystem condition by drawing on their historical experiences of species abundance, average body size, and the relative ease of harvesting marine resources. One elder fisher from Village 1 recalled that "Around three decades ago, groupers in Zanzibar commonly weighed about 3 kg, and mud crabs were so abundant that a single trap could yield more than twelve. At present, groupers are considerably smaller, and mud crabs have become much less common, demanding far greater time and effort to collect" (V1, ER, ≥40). These reflections point to a perceived decline in resource productivity and illustrate how local ecological knowledge can offer valuable insights into long-term environmental change and ecosystem dynamics.

Younger respondents, in contrast, placed greater emphasis on indicators related to forest structure and overall habitat quality. For instance, a young participant not directly involved in ecosystem-based activities remarked that "The abundance and diversity of birds in the mangroves signal a healthy forest. When many birds are present, it shows that the ecosystem has sufficient food and is functioning properly" (V1, NER, <40). Likewise, characteristics such as tree height, stand density, and canopy cover were frequently mentioned as reliable markers of ecological condition, demonstrating an awareness of the relationship between vegetation structure and habitat integrity.

Participants exhibited a sophisticated awareness of the ecological roles that mangroves play, particularly their function as nursery habitats for juvenile marine organisms. Respondents across age groups acknowledged that young crabs, fish, and shellfish depend on mangrove environments for protection and development before migrating to open waters. As one participant noted, "Mangroves provide secure shelter for juvenile crabs, fish, and shrimp. They remain within the forest until they are strong enough to survive in the ocean. Without these forests, young marine species would face greater risks" (V1, ER, <40). The relationship between mangroves and nearby habitats, such coral reefs and seagrass beds, was also emphasized by elder fishermen from Village 2 as being crucial to maintaining marine populations:

"Healthy mangroves, coral reefs, and seagrass beds together support fish and crabs." For marine life, they resemble interconnected houses (V2, ER, ≥50; Fig. 3).

Overall, participants identified a total of 31 indicators of mangrove ecosystem health, spanning biological, physical, and human-use dimensions. Biological indicators dominated the list (21 of 31; 67.7%), underscoring the central importance of species composition and ecosystem functioning in shaping community assessments of ecological condition (Table 2; Fig. 3). These indicators encompassed measures such as species abundance, diversity, body size, and reproductive success, with particular attention given to commercially and culturally significant species, including mullet (Mugil cephalus), mud crabs (Scylla serrata), shellfish, and various finfish. Participants also highlighted additional biological markers such as seedling recruitment, rates of tree regeneration, the presence of keystone species, and the absence of visible disease or dieback.

Physical indicators (6 of 31; 19.4%) reflected attributes related to forest structure and environmental processes, including tree density, canopy cover, soil characteristics, tidal exchange patterns, and the spatial extent of mudflats and tidal channels. Human-use indicators (4 of 31; 12.9%) centered on the accessibility of mangrove resources, the ease with which materials could be harvested, and the availability of raw products for construction and culturally significant activities. Together, these indicators reveal a multidimensional understanding of mangrove ecosystem health grounded in both ecological dynamics and resource-use experiences.

Table 2: Categories of indicators of mangrove ecosystem health as identified by participants (n – 220)

Category	No. of Indicators	% of Total	Indicators Identified
Biological	21	67.7%	(i) Species abundance; (ii) Species diversity; (iii) Fish size/ weight; (iv) Reproductive success of fish and shellfish; (v) Presence/abundance of mullet (Mugil cephalus); (vi) Presence/abundance of mud crabs (Scylla serrata); (vii) Presence/abundance of shellfish; (viii) Presence of other finfish (e.g., snappers, kingfish); (ix) Seedling recruitment rates; (x) Natural regeneration of mangrove trees; (xi) Flowering and fruiting success of mangroves; (xii) Tree health and vigor; (xiii) Presence of keystone species (e.g., Rhizophora mucronata); (xiv) Absence of visible disease in trees; (xv) Absence of dieback; (xvi) Bird diversity and abundance; (xvii) Crab burrow density as habitat indicator; (xviii) Presence of juvenile fish nurseries; (xix) Presence of pollinators (insects, bats); (xx) Presence of algae and epiphytes as habitat indicators; (xxi) Overall biodiversity richness (fauna and flora).
Physical	6	19.4%	(i) Forest structure (zoning from seaward to landward); (ii) Tree density; (iii) Canopy coverage; (iv) Soil quality (fertility, texture, organic matter); (v) Tidal flow patterns; (vi) Extent of mudflats and tidal channels.
Human-use	4	12.9%	(i) Accessibility of mangrove resources; (ii) Ease of harvesting fish, crabs, and wood; (iii) Availability of raw materials for construction (poles, timber); (iv) Cultural and traditional uses (e.g., medicine, rituals, community practices).

Linking Local Perceptions of Mangrove Ecosystem Health to Traditional Ecological Knowledge

Coastal communities in Zanzibar conceptualized mangrove ecosystem health in ways that strongly reflected their ecological knowledge, as shown in Figure 3. Across both study sites, respondents consistently demonstrated familiarity with foundational ecological features, including the identification of species and the habitats they occupy. However, understanding of more complex ecological processes such as the role of mangroves in broader coastal dynamics and the ways ecosystems respond to seasonal shifts, tidal regimes, or disturbance events- was distributed unevenly within the population.

Statistical results indicated no significant differences in ecological knowledge between the two villages (χ^2 = 18.6, df = 11, p = 0.069) or among occupational groups (χ^2 = 12.4, df = 11, p = 0.3329). Age, however, was a significant determinant of ecological understanding (χ^2 = 27.6, df = 11, p = 0.0037), with older participants exhibiting a broader and more integrated knowledge base (Figure 4). Elder community members particularly those in Unguja Ukuu whose livelihoods depend heavily on natural resources- provided more detailed accounts of environmental change, drawing on long-term observations related to water quality, climatic variability, coral reef conditions, and shifts in species presence

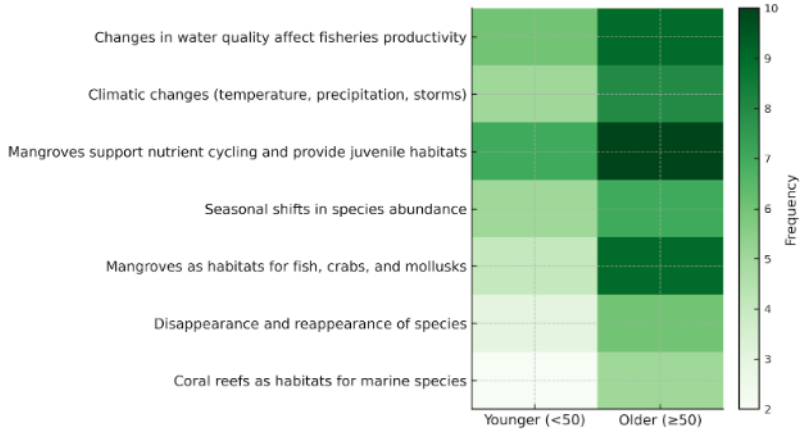

Figure 3: Distribution of ecological knowledge types across younger (<50) and older (≥50) groups.

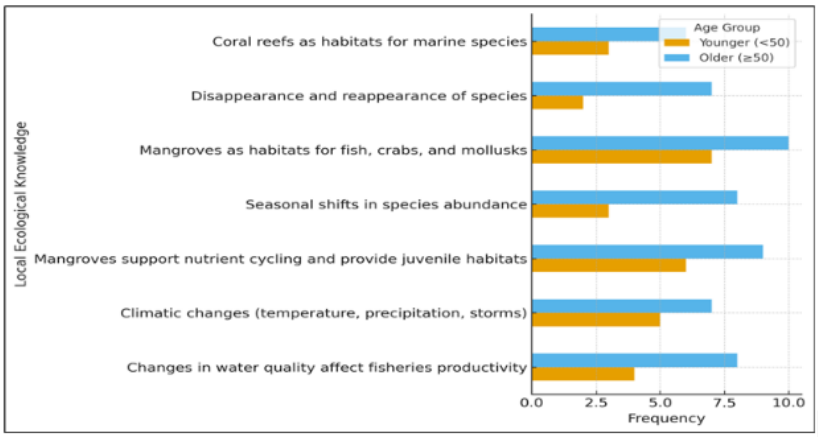

Figure 4: Frequency of knowledge types mentioned by younger vs. older participants.

or abundance. These findings suggest that ecological knowledge in Zanzibar accumulates over the lifespan, with older generations serving as important custodians of experiential understanding regarding mangrove ecosystem health.

Participants demonstrated a sophisticated and practice-oriented understanding of ecological conditions relevant to locating and harvesting marine resources, particularly within mangrove and intertidal zones. Younger respondents from Unguja Ukuu (V2) identified key species and described their distribution in relation to tidal regimes and habitat types. They noted, for example, that periwinkles (Terebralia palustris) and mangrove whelks are typically collected within mangrove stands, whereas oysters (Crassostrea cucullata) and mud clams (Anadara antiquata) are usually found on exposed mudflats. Resource availability was also understood to be strongly influenced by tidal cycles: periwinkles and whelks are more easily harvested during high tide, while oysters and clams are generally accessible at low tide.

Several participants additionally highlighted seasonal fluctuations in species abundance and diversity, associating these patterns with broader indicators of ecosystem condition. Observations that octopus (Octopus cyanea) and squid (Loligo duvaucelii) appear in greater numbers during specific months were interpreted as signs of ecological stability and productivity. Collectively, this knowledge illustrates how local communities integrate spatial, tidal, and seasonal dynamics into their assessments of mangrove ecosystem health. It also underscores the central role of lived experience in shaping nuanced understandings of resource availability and ecological change in Zanzibar's coastal environments.

Community Perceptions of Temporal Changes in Mangrove Ecosystem Health

Across all respondent groups, there was a shared perception that mangrove and coastal ecosystems in Zanzibar were significantly healthier in earlier decades, with a steady decline becoming apparent up to the mid-2000s (Figure 5). Older participants frequently traced the onset of degradation back to the 1970s, drawing on long-term observations of environmental change. The magnitude of perceived decline, however, differed among groups. For example, elder ecosystem-dependent participants from Village 2 (V2) described a pronounced deterioration, rating ecosystem health at 10.0 (100% healthy) in 1980 and only 3.1 (30.6% healthy) by 2001. By comparison, respondents from the same village who were not engaged in ecosystem-related occupations perceived

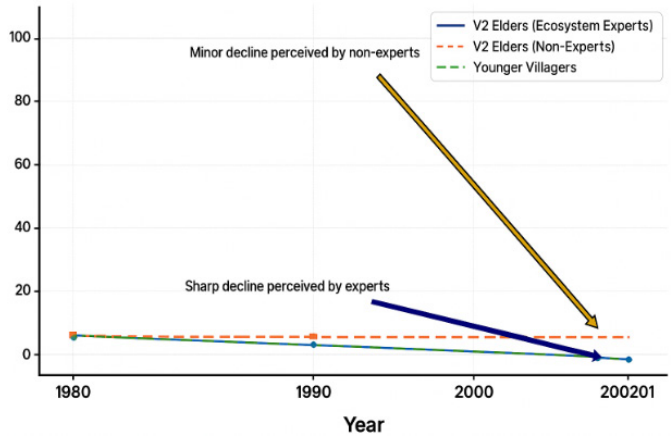

Figure 5: Perceived Changes of Mangrove Ecosystem Health

a more moderate shift, assessing health at 9.8 (98% healthy) in 1980 and 9.0 (90% healthy) in 2001. Younger participants generally associated ecological decline with the period between the 1990s and early 2000s, reflecting their limited firsthand experience of earlier environmental conditions. Together, these findings highlight the strong influence of generational exposure on perceptions of ecosystem change.

Participants attributed the ecological changes observed during the 1980s and 1990s to a range of interacting anthropogenic and environmental drivers, including coastal erosion, the expansion of shrimp aquaculture, rapid urbanization, population growth, mangrove extraction, and destructive fishing practices (Table 3). Shrimp farming, in particular, was frequently cited as a major contributor to mangrove loss and water quality degradation, with respondents noting subsequent impacts on coral reefs and declines in key marine species such as groupers, rabbitfish (Siganidae), and mud crabs resources that continue to underpin local fisheries.

Six of the seven participant groups identified the extreme climatic events of 2004 as the period in which ecosystem health reached its lowest point. They associated this downturn with a suite of environmental disturbances, including seabed alteration, coral reef degradation, reduced fisheries productivity and predictability, heightened water turbidity, increased pollution from solid waste, beach erosion, damage to coastal vegetation such as Casuarina equisetifolia, and the destruction of aquaculture structures located within mangrove channels. Conversely, one group from Village 1 (V1) reported only a marginal decline during this period, attributing the relative stability of their environment to the protective role of mangrove forests. Their perspective underscores the importance of mangroves as critical ecosystem buffers that help mitigate the impacts of extreme environmental events.

Older fishers in Village 1 (V1) noted that the ecosystem displayed a notable degree of resilience following the extreme events of the early 2000s. As one elder recalled, "During the first two years after the storms, conditions were very poor, but recovery gradually began. Some shellfish habitats were damaged, and their abundance declined for a short period, about two years, before populations began to rebound." Several participants attributed this recovery to the inherent adaptability of shellfish and other marine organisms to the seasonal patterns associated with the monsoon system.

More broadly, many respondents described the mangrove ecosystem in Zanzibar as relatively unstable, characterized by year-to-year variability influenced by both detrimental and beneficial factors. Negative pressures included urban expansion, population growth, solid waste pollution, mangrove cutting, seasonal flooding, coastal erosion, and climatic variability, often referred to locally as "unstable seasons." One elder from V1 explained, "Conditions change every year. At times, the forest appears healthy, while at other times the water becomes turbid and fish are difficult to locate. It depends on what is happening within the village and along the coastline" (V1, ER, ≥45 years).

Participants also recognized several positive drivers

Table 3: Drivers, Impacts, and Perceptions of Mangrove Ecosystem Health in Zanzibar

Time Period / Event	Drivers of Change	Observed / Perceived Impacts	Ecosystem Health Perception	Notes / Resilience Observations
1980s–1990s	Coastal erosion, shrimp farming, urban development, population growth, mangrove harvesting, and destructive fishing	Mangrove deforestation, water contamination, negative effects on coral reefs, and declines in marine species (groupers, rabbitfish, mud crabs)	Declining	Shrimp farming is particularly harmful to mangroves and water quality

2004 Extreme Events	Extreme climatic events, seabed modifications, coral reef degradation, declines in fisheries, water turbidity, solid waste pollution, beach erosion, damage to Casuarina trees, and destruction of aquaculture	Severe ecosystem degradation; lowest perceived ecosystem health across most villages	Extreme decline (lowest point in lifetime)	V1 participants noted only a slight decline due to mangrove buffering; some resilience was observed in shellfish and marine species over ~2 years
Post-2004 to Present	Urbanization, population growth, solid waste pollution, mangrove harvesting, seasonal flooding, coastal erosion, climate variability ("unstable seasons")	Year-to-year fluctuations in mangrove and coastal ecosystem conditions	Relatively unstable	Positive drivers: community campaigns, mangrove reforestation, stricter government regulations, increasing awareness of mangrove value

that contributed to ecosystem improvement, including community-based conservation activities, mangrove restoration programs, and strengthened government regulations aimed at protecting coastal forests. Respondents noted a growing awareness among villagers of the link between mangrove health and local livelihoods. As an older fisher from Village 2 (V2) emphasized, "The government has introduced rules to safeguard the forest, and many of us now understand that healthy mangroves mean more fish and a better life for our families" (V2, ER, ≥57 years).

Discussion

This study set out to examine how coastal communities in Zanzibar conceptualize and assess the health of mangrove ecosystems, with particular attention to differences associated with age, livelihood activities, and village context. By drawing on local knowledge systems, lived experiences, and community observations of environmental change, the research aimed to identify community-derived indicators of ecosystem health and to generate insights that can support more locally grounded and socially informed approaches to mangrove conservation and management.

Demographic Profile of the Respondents

The demographic and socioeconomic characteristics of respondents provide critical context for interpreting local perceptions of mangrove ecosystem health in Zanzibar. The predominance of Muslim participants mirrors the broader religious homogeneity of the islands, consistent with previous research highlighting the central role of Islam in shaping cultural norms, social practices, and approaches to natural resource management, including environmental stewardship (Macarthur, 2009). Gender distribution among respondents was relatively balanced, although notable differences between villages suggest variation in gender-specific roles within resource-dependent livelihoods. This pattern aligns with observations from other coastal regions, where women are frequently engaged in inshore fisheries, shellfish collection, and small-scale trade of mangrove products, while men dominate offshore fishing and larger-scale mangrove harvesting (Middleton, 2024).

The age structure of respondents was skewed toward middle-aged and older adults, a distribution particularly relevant for studies drawing on experiential and ecological knowledge. Older participants typically possess extensive traditional ecological knowledge, accumulated over decades, which provides crucial insights into historical trends and long-term changes in mangrove ecosystems (Ravaoarinorotsihoarana *et al.,* 2023; Treviño, 2022). Similar patterns have been documented in Southeast Asia and East Africa, where elders offer detailed perspectives on long-term ecosystem dynamics, while younger community members often focus on current forest conditions and immediate resource availability (Kuuluvainen & Gauthier, 2018; Traoré *et al.,* 2025).

Marital status and household size data indicate the predominance of married participants living in relatively large households, reflecting stable family structures and the centrality of collective labor in sustaining livelihoods in resource-dependent communities (Ghansah, 2024; Kitole & Komba, 2025). These household arrangements may facilitate intergenerational knowledge transfer, a mechanism recognized in other small island and rural contexts for sustaining traditional ecological knowledge (Ouma, 2022; Mohamed, 2024).

Educational attainment among respondents was moderate, with most having completed primary or secondary education, and only a minority attaining tertiary

levels. This pattern has implications for adaptive capacity and engagement in conservation initiatives. While higher education levels are generally associated with greater awareness of environmental policies and scientific practices, communities with lower formal education often rely predominantly on traditional ecological knowledge in resource management (Shang *et al.,* 2024; Purnomo *et al.,* 2025).

Local Community Perspectives on the Health of Mangrove Ecosystems

The findings of this study reveal that coastal communities in Zanzibar conceptualize mangrove ecosystem health through an integrated lens encompassing ecological, socio-economic, and cultural dimensions, highlighting a nuanced appreciation of the multifunctionality of these ecosystems. Participants consistently identified ecological productivity, species diversity, and the capacity of mangroves to sustain livelihoods as primary indicators of ecosystem health. These results corroborate prior research from Zanzibar and the broader Western Indian Ocean region, which emphasizes mangroves not only as critical habitats for commercially important species such as crabs, mullet, and shellfish (Ahmed & Islam, 2025) but also as essential contributors to food security (Tengku Hashim, 2021), income generation (Rafique, 2018), and cultural practices (Asm *et al.,* 2020).

Intergenerational differences in perceptions further underscore the significance of traditional ecological knowledge (TEK) in evaluating ecosystem health. Older respondents in this study assessed mangrove conditions based on historical abundance, species size, and ease of harvest, whereas younger participants prioritized structural attributes, including tree density, canopy cover, and habitat quality. Comparable patterns have been documented in Southeast Asia and West Africa, where elders serve as custodians of long-term ecological knowledge, providing critical insights into temporal changes, while younger generations incorporate contemporary observations of habitat structure and biodiversity into their assessments (Nwabueze, 2024; Mohammed, 2024; Taher, 2022; Walker *et al.,* 2022). These generational differences illustrate the complementary value of combining long-term experiential knowledge with contemporary ecological observations to inform effective management strategies (Souther *et al.,* 2023; Nanglu *et al.,* 2023).

Biological indicators accounted for approximately 68% of all reported measures, reflecting the centrality of species abundance, diversity, and reproductive success in shaping local perceptions of mangrove health. This emphasis aligns with international literature, which recognizes biological measures including juvenile fish nurseries, keystone species presence, and tree regeneration rates as reliable proxies for ecosystem functioning and resilience (Ferreira *et al.,* 2024; Barbanera, 2021; Souther *et al.,* 2023). Physical indicators, such as forest structure, soil quality, and tidal flow regimes, were also valued, consistent with studies in Southeast Asia and the Caribbean demonstrating the importance of habitat heterogeneity and hydrological integrity for ecosystem productivity and resilience (Lew *et al.,* 2024; Douglas, 2022).

Although human-use indicators were less frequently reported, they underscore the socio-cultural dimensions of mangrove health, encompassing accessibility, ease of resource extraction, and cultural significance. This finding aligns with broader evidence that local perceptions of ecosystem health often integrate both material and cultural benefits, reflecting an understanding of ecosystems as intertwined ecological and social systems (Garibay-Toussaint *et al.,* 2024). In Zanzibar, participants highlighted the dual ecological and socio-economic importance of key species, such as Rhizophora mucronata and Ceriops tagal, a pattern observed in other mangrove-dependent communities worldwide, where culturally significant species guide both conservation priorities and livelihood strategies (Mohammed, 2024; Mohamed, 2025).

Local Perceptions of Mangrove Health and Traditional Ecological Knowledge

The findings from Zanzibar indicate that local perceptions of mangrove ecosystem health are closely intertwined with traditional ecological knowledge (TEK). According to Zhao *et al.* (2024) and Yadav (2025), older participants exhibited greater awareness of historical changes in mangrove ecosystems, reflecting the cumulative and generational nature of TEK, where elders serve as primary repositories of experiential knowledge. This observation aligns with findings from coastal communities in Kenya and Madagascar, where Rani *et al.* (2025) reported that elder fishers and resource users recalled historical shifts in fisheries productivity and habitat conditions, illustrating the intergenerational transmission of ecological knowledge.

According to the study participants, Zanzibari communities possess detailed ecological knowledge relevant to resource use, particularly concerning species-specific habitat preferences, tidal cycles, and seasonal patterns. For instance, participants noted that periwinkles, mangrove whelks, oysters, and mud clams depend on tidal stages, demonstrating an integration of temporal and spatial ecological patterns into daily livelihoods. Chengula (2023) similarly reported that in Southeast Asia, fishers' knowledge of mangrove-dependent species and their seasonal availability is critical for sustaining subsistence and small-scale commercial fisheries. According to Le *et al.* (2025) and Gomes *et al.* (2025), participants' observations regarding the seasonal abundance of octopus and squid serve as indicators of ecosystem stability, highlighting how local knowledge often captures ecological cues that may be overlooked by conventional scientific monitoring. According to Zhang *et al.* (2023), in regions with strong formalized community-based management, such as the Philippines and Indonesia, TEK is systematically incorporated into conservation planning. In contrast,

according to the findings from Zanzibar, the depth and distribution of ecological knowledge vary across age groups, suggesting potential gaps in knowledge transfer to younger generations. This variability has implications for the resilience of community-led conservation initiatives, as sustaining mangrove ecosystem health requires both accumulated wisdom and active engagement of youth in monitoring and stewardship activities.

Overall, according to the present study, TEK is not only essential for understanding mangrove ecosystem dynamics but also forms the foundation for culturally appropriate and locally relevant conservation strategies. The integration of spatial, tidal, and seasonal knowledge into perceptions of ecosystem health underscores, according to Letsyo (2025) and Gugg *et al.* (2025), the value of lived experience in shaping sustainable resource use and highlights the complementary roles of TEK and scientific data in mangrove management.

Community Perceptions of Temporal Changes in Mangrove Ecosystem Health

The findings from Pete and Unguja Ukuu villages in Zanzibar indicate that local communities perceive mangrove and coastal ecosystems as having reached peak health several decades ago, followed by a gradual decline from the 1970s to the mid-2000s. According to participants, older residents, particularly those directly engaged in mangrove-related livelihoods, reported more pronounced declines than younger community members or individuals not specialized in ecosystem activities. This pattern is consistent with the principle that older generations serve as custodians of long-term ecological knowledge, offering valuable insights into historical environmental changes (Yadav, 2025).

Participants attributed observed degradation to a combination of anthropogenic and natural drivers. Local factors such as urban expansion, population growth, mangrove harvesting, shrimp farming, and destructive fishing practices were frequently cited, alongside natural disturbances including extreme climatic events. Shrimp farming, in particular, was linked to mangrove deforestation, water contamination, and declines in marine biodiversity, consistent with findings from Zanzibar and other tropical regions, where aquaculture expansion has contributed to habitat loss and altered coastal ecosystem functioning (Zhao & Wu, 2024).

The study also highlights differences in perceived ecosystem decline between demographic groups. Elders reported a marked reduction in ecosystem health over extended periods, whereas younger villagers perceived the decline as more recent, primarily occurring from the 1990s onward. This divergence reflects differences in temporal ecological knowledge, suggesting that perceptions of environmental change are shaped by both generational experience and direct engagement with ecosystem resources (Mohamed, 2024; Maleknia *et al.,* 2025). Comparable trends have been documented in coastal communities in South America, where older fishers recall past abundance and ecosystem stability, whereas younger populations primarily recognize recent changes (Castagnino *et al.,* 2023).

In addition to ecological functions, participants emphasized the role of mangroves as buffers against environmental shocks, providing essential protective ecosystem services. Residents reported that following extreme events, certain marine populations, such as shellfish, recovered within a few years, indicating ecosystem resilience. These observations align with international literature, which underscores the contribution of mangroves to coastal protection, sediment stabilization, and recovery of fisheries after disturbances (Temmerman *et al.,* 2023).

Current perceptions reflect a nuanced understanding of ecosystem health, acknowledging year-to-year fluctuations driven by negative pressures, including urbanization, pollution, harvesting, coastal erosion, and climatic variability, as well as positive influences such as reforestation efforts, community-led conservation initiatives, and government regulations. This demonstrates an increasing awareness among Zanzibar communities of the interconnection between mangrove health and livelihoods, supporting global evidence that active community participation enhances conservation outcomes (Mohammes, 2024; Awazi *et al.,* 2025).

CONCLUSION

This study demonstrates that local communities in Pete and Unguja Ukuu villages possess detailed and nuanced perceptions of mangrove ecosystem health, strongly informed by traditional ecological knowledge and intergenerational experience. According to participants, assessments of mangrove health are based on a combination of biological, physical, and human-use indicators, with species abundance, forest structure, and resource accessibility forming the core of their evaluations. Temporal perceptions indicate a significant decline in ecosystem health since the 1970s, driven by a combination of anthropogenic pressures, including mangrove harvesting, urban expansion, and aquaculture development, as well as natural disturbances. Participants also recognized periods of resilience and recovery, highlighting the dynamic nature of mangrove ecosystems. Older community members emerged as key repositories of ecological knowledge, emphasizing long-term changes in species abundance, habitat quality, and ecosystem function, consistent with the view that elders serve as custodians of historical environmental knowledge. The findings underscore the intertwined ecological and socio-economic value of mangroves, illustrating that local perceptions are shaped by both dependence on resources and cultural context. Comparisons with regional and international studies suggest that these perceptions align with global patterns of mangrove degradation, resilience, and the role of community-based knowledge systems in resource management. Ultimately, the study highlights that integrating local ecological knowledge with scientific approaches can enhance conservation planning, support

sustainable management of mangrove resources, and strengthen the adaptive capacity of Zanzibar's coastal communities.

REFERENCES

Ahmed, K. K. U., & Islam, M. S. (2025). Aquaculture and fisheries' potentials in the ecologically critical areas (ECAs) of Sundarbans, Bangladesh: Recommendations to policy making. *Journal of Applied Ichthyology, 1*, 9967329.

Alders, W. (2024). Rural settlement dynamics in a rapidly urbanizing landscape: Insights from satellite remote sensing and archaeological field surveys in Zanzibar, Tanzania. *Journal of Field Archaeology, 49*(8), 634–652.

ASM, I. M., Rajaee, A. H., & Rahman, M. M. (2020). Third International Symposium on mangroves as fish habitat. *Bulletin of Marine Science, 96*(3), 539–560.

Awazi, N. P. (2025). East Africa's coast: Bridging people and nature for community resilience through sustainable management of mangrove ecosystems. In *Building climate resilient communities along Africa's coasts: The role of mangroves* (pp. 79–99).

Barbanera, A. (2021). *Determining the consequences of forest degradation on mangrove epifauna in South-East Kenya* (Master's thesis). Bangor University, Bangor, United Kingdom.

Castagnino, F., Estévez, R. A., Caillaux, M., Velez-Zuazo, X., & Gelcich, S. (2023). Local ecological knowledge (LEK) suggests overfishing and sequential depletion of Peruvian coastal groundfish. *Marine and Coastal Fisheries, 15*(6), e210272.

Chengula, F. I. (2023). *Knowing weather, strengthening livelihoods: The role of indigenous knowledge weather forecasting in fishing communities in coastal Tanzania* (Ph.D. dissertation). University of Roehampton, London, UK.

Come, J., Peer, N., Nhamussua, J. L., Miranda, N. A., Macamo, C. C., Cabral, A. S., & Snow, B. (2023). A socio-ecological survey in Inhambane Bay mangrove ecosystems: Biodiversity, livelihoods, and conservation. *Ocean & Coastal Management, 244*, 106813.

Douglas, I. (2022). Long-term hydrological research in the humid tropics. In *Water and the rainforest in Malaysian Borneo: Hydrological research at the Danum Valley Field Studies Center* (pp. 1–25).

Faulkner, P., Sarathi, A., Crowther, A., Smith, T., Harris, M., Ali, A. K., & Boivin, N. (2022). Human-ecodynamics and the intertidal zones of the Zanzibar Archipelago. *Frontiers in Earth Science, 10*, 982694.

Ferreira, A. C., Ashton, E. C., Ward, R. D., Hendy, I., & Lacerda, L. D. (2024). Mangrove biodiversity and conservation: Setting key functional groups and risks of climate-induced functional disruption. *Diversity, 16*(7), 423.

Ferreira, A. C., Borges, R., & de Lacerda, L. D. (2022). Can sustainable development save mangroves? *Sustainability, 14*(3), 1263.

Friess, D. A., Adame, M. F., Adams, J. B., & Lovelock, C. E. (2022). Mangrove forests under climate change in a 2 °C world. *Wiley Interdisciplinary Reviews: Climate Change, 13*(4), e792.

Garibay-Toussaint, I., Olguín-Jacobson, C., Woodson, C. B., Arafeh-Dalmau, N., Torre, J., Fulton, S., & Narchi, N. E. (2024). Combining the uncombinable: Corporate memories, ethnobiological observations, oceanographic and ecological data to enhance climatic resilience in small-scale fisheries. *Frontiers in Marine Science, 11*, 1458059.

Ghansah, A. A. (2024). *Income diversification, social capital, and sustainable livelihoods in Ghanaian mining communities* (Ph.D. dissertation). University of Cape Coast, Cape Coast, Ghana.

Giraudoux, P. (2022). Ecosystem health: What is the definition? *Bulletin de l'Académie Vétérinaire de France, 175*, 120–139.

Gomes, M. A., Alves, C. M., Neto, R., Faria, F., Troncoso, J., & Gomes, P. T. (2025). Fishing beyond the surface: Harnessing local ecological knowledge to improve local fisheries management and conservation. *Marine Policy, 179*, 106763.

Gugg, G., Oliveira, M., & Duca, G. (2025). Unlocking the past: Key lessons in human–environment dynamics through cultural heritage analysis. *Urbanization, Sustainability and Society, 2*(2), 48–75.

Guild, R., Wang, X., & Quijón, P. A. (2025). Climate change impacts on coastal ecosystems. *Environmental Research: Climate, 3*(4), 042006.

Hernández-Blanco, M., Costanza, R., Chen, H., De Groot, D., Jarvis, D., Kubiszewski, I., & van 't Hoff, V. (2022). Ecosystem health, ecosystem services, and the well-being of humans and the rest of nature. *Global Change Biology, 28*(17), 5027–5040.

Hilmi, N., Chami, R., Sutherland, M. D., Hall-Spencer, J. M., Lebleu, L., Benitez, M. B., & Levin, L. A. (2021). The role of blue carbon in climate change mitigation and carbon stock conservation. *Frontiers in Climate, 3*, 710546.

Huxham, M., Whitlock, D., Githaiga, M., & Dencer-Brown, A. (2028). Carbon in the coastal seascape: How interactions between mangrove forests, seagrass meadows, and tidal marshes influence carbon storage. *Current Forestry Reports, 4*(2), 101–110.

Iqubal, M. A. (2024). The impact of climate change on coastal erosion: A comparative study of vulnerable regions. *Library of Progress – Library Science, Information Technology & Computer, 44*(3).

Izquierdo, A. E., Mautner, M., Gómez, R. D., Nieva, F., Estigarribia, L., & Forni, L. (2025). Integrating local and indigenous knowledge with Sustainable Development Goals in lithium mining impact assessment for a fair energy transition. *Environmental Science & Policy, 171*, 104155.

Jain, V., & Karanth, K. K. (2023). Living alongside otters: Examining human-otter interactions and attitudes towards otters in Central India for conservation in shared landscapes. *Biodiversity and Conservation, 32*(8), 3001–3020.

Jape, K. K., & Najar, M. A. (2024). Empowering local

stewardship of coastal ecosystems in Zanzibar: Participatory models for habitat rehabilitation and resilience. *International Journal of Advanced Multidisciplinary Research, 4*(2), 185–194.

Kitole, F. A., & Komba, C. (2025). Challenges and opportunities of climate change adaptation strategies among smallholder horticultural farmers in rural Tanzania. *Cogent Food & Agriculture, 11*(1), 2554247.

Kuuluvainen, T., & Gauthier, S. (2018). Young and old forest in the boreal: Critical stages of ecosystem dynamics and management under global change. *Forest Ecosystems, 5*(1), 1–15.

Laituri, M., Luizza, M. W., Hoover, J. D., & Allegretti, A. M. (2023). Questioning the practice of participation: Critical reflections on participatory mapping as a research tool. *Applied Geography, 152*, 102900.

Le, H. D., Tran, T. M. A., Thi Hao, N., Thuy Phuong, N., & Thanh Thao, N. (2025). Determinants of mangrove dependence and implications for sustainable livelihoods: Insights from Xuan Thuy National Park's buffer zone. *Journal of Sustainable Forestry*, 1–24.

Letsyo, E. (2025). Community-based approaches towards climate resilience in the Effutu Municipality: Integrating traditional knowledge and scientific methods for sustainable adaptation. *Climate Action in Ghana, 32*.

Lew, D. K., Leong, K., Dudas, S. E., Cox, K., Nakachi, A., Ingram, R., & Fisk, J. (2024). Assessing marine ecosystem services in the North Pacific: An overview of approaches. *PICES Scientific Report, 65*, 26–74.

Li, Z., Xu, D., & Guo, X. (2014). Remote sensing of ecosystem health: Opportunities, challenges, and future perspectives. *Sensors, 14*(11), 21117–21139.

Lim, W. M. (2025). What is qualitative research? An overview and guidelines. *Australasian Marketing Journal, 33*, 199–229.

Liman Harou, I., Inyele, J., Minang, P., & Duguma, L. (2023). Understanding the states and dynamics of mangrove forests in land cover transitions of The Gambia using a Fourier transformation of Landsat and MODIS time series in Google Earth Engine. *Frontiers in Forests and Global Change, 5*, 934019.

Lõhmus, A. (2025). Recognizing and mitigating key uncertainties about the future in ecological restoration planning. *Restoration Ecology*, e70158.

Macarthur, G. A. (2009). *Culture, ethnicity, and the politics of belonging: The case of Zanzibar* (Ph.D. dissertation). University of Manchester, Manchester, UK.

Maleknia, R., Enescu, R. E., & Salehi, T. (2025). Climate change and urban forests: Generational differences in women's perceptions and willingness to participate in conservation efforts. *Frontiers in Forests and Global Change, 7*, 1450098.

McCall, M. K. (2021). Participatory mapping and PGIS: Secerning facts and values, representation and representativity. *International Journal of E-Planning Research, 10*(3), 105–123.

Middleton, L. (2024). *Have mangroves been overlooked for their potential to support gendered food and nutrition security in Indonesia?* (Ph.D. dissertation). Charles Darwin University, Darwin, Australia.

Mohamed, M. K. (2024). *Remote sensing-based assessment of mangrove forest changes and related regulatory frameworks for the sustainability and conservation of coastal ecosystems in Zanzibar Island, Tanzania–East Africa* (Ph.D. dissertation). University of the Witwatersrand, Johannesburg, South Africa.

Mohamed, M. K. (2025). Economic valuation of mangrove ecosystem services: Insights from willingness to pay analysis for Chwaka Bay mangrove forest, Zanzibar. *Wild, 2*(2), 21.

Mohamed, M. K., Adam, E., & Jackson, C. M. (2023). Policy review and regulatory challenges and strategies for the sustainable mangrove management in Zanzibar. *Sustainability, 15*, 1557.

Mohamed, M. K., Adam, E., & Jackson, C. M. (2024). Assessing the perception and contribution of mangrove ecosystem services to the well-being of coastal communities of Chwaka and Menai Bays, Zanzibar. *Resources, 13*(1), 7.

Morgera, E. (2023). The role of fair and equitable benefit-sharing in environmental peacebuilding. In *Research handbook on international law and environmental peacebuilding* (pp. 62–88). Edward Elgar Publishing.

Mwanzia, M. P. (2019). *Characterization of fishery resources and impacts of artisanal fishing on seagrass meadows of Gazi Bay, South Coast, Keny*a (Ph.D. dissertation). Pwani University, Kilifi, Kenya.

Nanglu, K., de Carle, D., Cullen, T. M., Anderson, E. B., Arif, S., Castañeda, R. A., & Astudillo-Clavijo, V. (2023). The nature of science: The fundamental role of natural history in ecology, evolution, conservation, and education. *Ecology and Evolution, 13*(10), e10621.

Nwabueze, B. C. (2024). *A research framework to assess the contribution of the mangrove ecosystem to the well-being of coastal communities in Africa* (Ph.D. dissertation). University of British Columbia, Vancouver, Canada.

Nyathi, N. A., Musakwa, W., Azilagbetor, D. M., & Kuhn, N. J. (2025). Perceptions of cultural and provisioning ecosystem services and human wellbeing indicators amongst indigenous communities neighbouring the Greater Limpopo Transfrontier Conservation Area. *Heliyon, 11*(1).

Ochoa-Hueso, R., Delgado-Baquerizo, M., Risch, A. C., Schrama, M., Morriën, E., Barmentlo, S. H., & van der Putten, W. H. (2021). Ecosystem coupling: A unifying framework to understand the functioning and recovery of ecosystems. *One Earth, 4*(7), 951–966.

Ouma, A. (2022). Intergenerational learning processes of traditional medicinal knowledge and socio-spatial transformation dynamics. *Frontiers in Sociology, 7,* 661992.

Purnomo, A. H., Sachoemar, S. I., Arifin, Z., Samiaji, J., Tanjung, R. H., Nurhayati, A., … Boschetti, F. (2025). Demographic dimension of ocean perceptions: Evidence from Indonesia. *Marine Policy, 178*, 106706.

Rafique, M. U. H. A. M. M. A. (2018). A review on the status, ecological importance, vulnerabilities, and conservation strategies for the mangrove ecosystems of Pakistan. *Pakistan Journal of Botany, 50*(4), 1645–1659.

Rani, J., Gulia, V., Sangwan, A., Dhull, S. S., & Mandzhieva, S. (2025). Synergies of traditional ecological knowledge in biodiversity conservation: A paradigm for sustainable food security. In *Ecologically mediated development: Promoting biodiversity conservation and food security* (pp. 27–49).

Ravaoarinorotsihoarana, L. A., Ratefinjanahary, I., Aina, C., Rakotomahazo, C., Glass, L., Ranivoarivelo, L., & Lavitra, T. (2023). Combining traditional ecological knowledge and scientific observations to support mangrove restoration in Madagascar. *Forests, 14*(7), 1368.

Ren, X., & Clarke, A. (2025). Shifting currents of power: Navigating gender inequalities, internal networks, and diversity and inclusion policy effectiveness in an energy sector workplace. Gender, Work & Organization.

Santojanni, F. B., Miner, H., Hain, H., & Sutton, G. (2023). The impact of climate change on biodiversity in coastal ecosystems. *Jurnal Ilmu Pendidikan dan Humaniora, 12*(3), 167–182.

Sayer, J., Sheil, D., Galloway, G., Riggs, R. A., Mewett, G., MacDicken, K. G., & Edwards, D. P. (2019). SDG 15: Life on land—The central role of forests in sustainable development. In *Sustainable development goals: Their impacts on forests and people* (pp. 482–509).

Shang, Y., Xie, Y., & Chen, W. (2024). Addressing resource scarcity and fostering sustainability through environmental education in Asia. *Resources Policy, 90*, 104823.

Shemshad, M., Synowiec, A., Kopyra, M., & Benedek, Z. (2025). The community-driven ecosystem resilience and equity framework: A novel approach for social resilience in ecosystem services. *Sustainability, 17*(8), 3452.

Souther, S., Colombo, S., & Lyndon, N. N. (2023). Integrating traditional ecological knowledge into US public land management: Knowledge gaps and research priorities. *Frontiers in Ecology and Evolution, 11*, 988126.

Taher, T. B. (2022). *Practices of participatory conservation: An ethnographic investigation in the Sundarbans of Bangladesh* (Ph.D. dissertation). University of New South Wales, Sydney, Australia.

Temmerman, S., Horstman, E. M., Krauss, K. W., Mullarney, J. C., Pelckmans, I., & Schoutens, K. (2023). Marshes and mangroves as nature-based coastal storm buffers. *Annual Review of Marine Science, 15*(1), 95–118.

Tengku Hashim, T. M. Z., Engku Ariff, E. A. R., & Suratman, M. N. (2021). Aquaculture in mangroves. In *Mangroves: Ecology, biodiversity and management* (pp. 419–438).

Traoré, M. A., Bissonnette, J. F., & Dossa, K. F. (2025). Forest dynamics and local perceptions of conservation: The case of Bontioli Forest in south-western Burkina Faso. *Frontiers in Forests and Global Change, 8*, 1658611.

Treviño, M. (2022). "The mangrove is like a friend": Local perspectives of mangrove cultural ecosystem services among mangrove users in northern Ecuador. *Human Ecology, 50*(5), 863–878.

Turner, N. J., Cuerrier, A., & Joseph, L. (2022). Well grounded: Indigenous peoples' knowledge, ethnobiology and sustainability. *People and Nature, 4*(3), 627–651.

Walker, K. E., Baldwin, C., Conroy, G. C., Applegate, G., Archer-Lean, C., Arthington, A. H., & Ellison, A. M. (2022). Ecological and cultural understanding as a basis for management of a globally significant island landscape. *Coasts, 2*(3), 152–202.

Xia, P., Peng, J., Gu, T., Yu, S., & Xu, Z. (2025). Lake-related ecosystem services facing social–ecological risks. *People and Nature, 7*(4), 734–751.

Yadav, R. (2025). The intergenerational transfer of environmental knowledge and leadership. In *Generation Alpha and next generation leadership for greener futures* (pp. 237–254). IGI Global Scientific Publishing.

Yadav, R. (2025). The intergenerational transfer of environmental knowledge and leadership. In *Generation Alpha and next generation leadership for greener futures* (pp. 237–254). IGI Global Scientific Publishing.

Zhang, Y., West, P., Thakholi, L., Suryawanshi, K., Supuma, M., Straub, D., & Agyei, F. K. (2023). Governance and conservation effectiveness in protected areas and indigenous and locally managed areas. *Annual Review of Environment and Resources, 48*(1), 559–588.

Zhao, F., & Wu, J. (2024). The role of shellfish aquaculture in coastal habitat restoration. *International Journal of Marine Science, 14*.

Zhao, Y., Han, Z., Zhang, C., Wang, Y., Zhong, J., & Gao, M. (2024). Coastal cultural ecosystem services: A bridge between the natural ecosystem and social ecosystem for sustainable development. *Land, 13*(9), 1352.

Zhu, Q., Yao, P., & Li, J. (2025). The effect of nature-based landscape design on human health and well-being: A thematic synthesis. *Journal of Environmental Engineering and Landscape Management, 33*(1), 55–71.

Zoysa, M. D. (2022). Forest-based ecotourism in Sri Lanka: A review on state of governance, livelihoods, and forest conservation outcomes. *Journal of Sustainable Forestry, 41*(3–5), 413–439.

Zu Ermgassen, P. S., Mukherjee, N., Worthington, T. A., Acosta, A., da Rocha Araujo, A. R., Beitl, C. M., & Spalding, M. (2020). Fishers who rely on mangroves: Modeling and mapping the global intensity of mangrove-associated fisheries. *Estuarine, Coastal and Shelf Science, 247*, 106975.