Lakes & Reservoirs: Research & Management

WILEY

Lakes & Reservoirs
Science, Policy and Management for Sustainable Use

ORIGINAL ARTICLE

An Assessment of Local People's Knowledge and Management Practices of Freshwater Macrophytes in Three Kenyan Lakes

Rebeccah Kwamboka Onwong'a[1] | Ayub M. O. Oduor[2] | Lewis Sitoki[3] | Collins Handa[1]

[1]Department of Ecology and Conservation Biology, Technical University of Kenya, Nairobi, Kenya | [2]Department of Applied Biology, Technical University of Kenya, Nairobi, Kenya | [3]Department of Geosciences and the Environment, Technical University of Kenya, Nairobi, Kenya

Correspondence: Rebeccah Kwamboka Onwong'a (rebeccahonwonga@yahoo.com)

Received: 16 August 2023 | **Revised:** 9 February 2024 | **Accepted:** 13 April 2024

Funding: The author(s) received no specific funding for this work.

Keywords: freshwater macrophytes | Kenyan wetlands | local ecological knowledge | management | perceptions

ABSTRACT

It is increasingly being recognised that local people's knowledge can contribute to the ecological and socioeconomic goals of natural resource management programmes. Yet, few studies have examined local people's knowledge concerning freshwater macrophyte diversity. Consequently, the extent to which local people's knowledge can contribute to mitigating freshwater macrophyte degradation and supporting their management remains largely unknown. To contribute towards filling this knowledge gap, we investigated local people's knowledge, perceptions and management practices of freshwater macrophyte species. Data collection involved conducting face-to-face in-depth interviews and focus group discussions among local people who lived in areas adjacent to Lake Baringo, Nyanza Gulf of Lake Victoria and the Kenyan side of Lake Jipe. The sociodemographic characteristics of the respondents were summarised using descriptive statistics. Then, generalised linear mixed-effect models were used to test whether the respondent's sociodemographic characteristics were associated with their macrophyte species recognition skills, benefits and problems associated with macrophytes and management practices. Our respondents named a total of 35 macrophyte species, with each respondent naming an average of six species. Our results showed that respondents who were not involved in fishing and fish-related activities identified more macrophytes than those who participated in such activities. Additionally, individuals who frequently visited the lake named more macrophyte species compared to those who visited either daily or occasionally. While our respondents acknowledged various benefits and problems associated with macrophytes, there was a higher recognition rate for those that directly impacted humans. Regarding local management practices, it was observed that macrophytes were not conserved, with management efforts focusing solely on problematic species. Overall, macrophyte naming skills, knowledge on provisioning and supporting ecosystem services, direct adverse macrophyte impacts and management methods increased with age. We identified knowledge gaps regarding alien species and the indirect impacts of macrophytes. Addressing these gaps is crucial.

1 | Introduction

Historically, humans have had an intimate relationship with their environment and their observations, experiences and cultural practices have led to the formation of a body of knowledge known as local ecological knowledge (Warburton and Martin 1999; Olsson and Folke 2001). Local ecological knowledge accumulates overtime, adapts and evolves to address changing environmental conditions, can be passed from one generation to another and has enabled human communities to live in harmony with their environment (Warburton and Martin 1999; Olsson and Folke 2001). For a long time, the potential contribution of local people's knowledge towards sustainable management of natural resources had been greatly overlooked. But in 1987, the World Commission on Environment and Development formally recognised that local ecological knowledge could contribute to the desirable ecological, social and economic goals of natural resource management programmes (WCED 1987). Since then, there has been a growing global acceptance and implementation of approaches that actively involve local people and their ecological knowledge in natural resource management (Warburton and Martin 1999; Fernández-llamazares et al. 2022; Reyes-García 2023; Silvano et al. 2023).

Integration of local people and their local ecological knowledge into natural resource management has enabled many natural resource governance programmes to achieve their ecological, social and economic goals (Terer et al. 2012; Karnad 2022; Silas et al. 2023). The success of such programmes has often been linked to the attitudes, understanding and perceptions of local people towards natural resources (Polasky 2008; Bennett 2016; Hatty et al. 2022). In this context, attitude refers to actions or behaviour towards a resource, and these are often determined by an individual's observations, understanding, interpretation and evaluation of the resource (Bennett 2016). On the other hand, knowledge of a natural resource refers to the scientific or nonscientific collection of facts, information and skills about the resource (Bolisani and Bratianu 2018). Local ecological knowledge also includes species literacy—the species identification and in-depth awareness about species' geographical occurrences, life history traits and habitat preferences (Hooykaas et al. 2019, 2022). Generally, a person's attitude towards, understanding and knowledge of a natural resource are influenced by cultural practices, education, age, gender, livelihoods, motivations, persuasions, politics, preferences and religion (Bennett 2016; Truong 2021; Hatty et al. 2022). Additionally, a person's behaviour towards a natural resource depends on the ecosystem services they provide (i.e., the direct and indirect benefits derived from the resource), along with perceived or actual detrimental effects of natural resources on human well-being (i.e., ecosystem disservices) (Millenium Ecosystem Assessment 2005; Shackleton et al. 2016). Local ecological knowledge is not evenly distributed in a population. It varies with according to age (Owuor, Icely, and Newton 2019; Ahoyo et al. 2023), gender (Jubase, Shackleton, and Measey 2021; Randler and Heil 2021), level of education (Hooykaas et al. 2019; Ahoyo et al. 2023), occupation (Randler and Heil 2021; Ahoyo et al. 2023), frequency of engagement with nature (Cebrián-Piqueras et al. 2020; Szałkiewicz, Sucholas, and Grygoruk 2020) and proximity to the natural resource (Owuor, Icely, and Newton 2019; Cebrián-Piqueras et al. 2020). Therefore, investigation of attributes of local people that are associated with their local ecological knowledge of a resource can inform ecosystem managers on how to best adapt the body of knowledge into natural resource management.

Macrophytes are plants that grow in areas that are permanently or periodically inundated in water (Chambers et al. 2008). Macrophytes provide a variety of ecosystem (dis) services (Terer et al. 2012; Thomaz 2023). For instance, macrophytes stabilise shorelines and bottom sediments (Currin 2019), supply oxygen in water (Caraco et al. 2006), absorb pollutants (Wilkinson, Naeth, and Dhar 2023), influence the aquatic nutrient cycles (Reitsema, Meire, and Schoelynck 2018), drive aquatic food chains (He et al. 2021) and are habitats and breeding grounds for both aquatic and terrestrial animals (Fynn et al. 2015; Christie et al. 2022). Additionally, freshwater macrophytes provide a variety of socioeconomic benefits (e.g., food, fibre, fodder, medicine, construction material and a source of livelihood) to people in many parts of the world (Taran and Deb 2020; Buckley et al. 2023). While the benefits derived from macrophytes are undisputable, there is evidence that dense and extensive macrophytes mats reduce water quality and quantity (Pelella et al. 2023), alter an ecosystem's biodiversity (Desautels et al. 2022), harbour disease-causing parasites (Angoh et al. 2021) and interfere with ecosystem use activities such as navigation, fishing activities and water use (Enyew, Assefa, and Gezie 2020).

Since the start of industrial revolution, anthropogenic activities have had disproportionately large and contrasting effects on macrophyte communities (Arthington 2021). In some regions of the Earth, macrophyte management practices defined by national governments and implemented by either government agencies acting alone or in collaboration with other stakeholders has led to sustainable management of freshwater macrophytes (McGregor et al. 2010; Terer et al. 2012). For instance, in Australia's Kakadu National Park, co-management between the government and the Aboriginal people, along with the application of management strategies from both conventional science and traditional ecological knowledge has enhanced biodiversity in the park's floodplains and provided the local people with a variety of socioeconomic benefits (McGregor et al. 2010). Similarly, co-management of Loboi swamp in Baringo County, Kenya, has led to sustainable management of macrophytes in the wetland (Terer et al. 2012). In other regions, however, the impacts of anthropogenic activities such as introduction of alien species, overexploitation of macrophytes, diversion of water inflows, eutrophication, pollution, sand harvesting and the conversion of wetlands into other land uses have caused degradation and species losses in macrophyte assemblages (Salgado et al. 2019; Kassa et al. 2021; Maua et al. 2022). Due to the variable impacts of human activities on macrophytes, an understanding of how local people living near freshwater ecosystems perceive, comprehend and manage macrophytes can provide valuable insights for improving macrophyte management (Bennett 2016; Government of Kenya 2021).

Macrophytes are a key feature of Kenyan freshwater lakes, providing a diverse range of ecosystem services to local communities (Omondi and Gichuki 2000; Raburu, Okeyo-Owuor, and Kwena 2012). For example, local communities utilise the macrophytes as construction materials, fodder, fuel, medicine and for crafting artefacts (Gichuki et al. 2001; Morrison et al. 2012; Terer et al. 2012). In Kenya, sustainable management and conservation of freshwater macrophytes follow the general natural resource management directives outlined in the Integrated National Land Use Guidelines (NEMA 2011). At the grassroots level, these guidelines are implemented by several government agencies and nongovernmental organisations with conflicting priorities and mandates (Raburu, Okeyo-Owuor, and Kwena 2012). None of these organisations is directly involved in the sustainable management of macrophytes. Despite the top-down approach of natural resource management, local wetland users have historically served as the *de facto* custodians of macrophytes and other wetland resources (Government of Kenya (GoK) 2021), a role that has a legal backing by the Environmental Management and Co-ordination Act of 1999 (act no. 8 of 1999) and the Constitution of Kenya 2010 (GoK 2010). Currently, freshwater macrophytes in Kenyan wetlands are experiencing increased degradation, primarily due to anthropogenic activities (Maua et al. 2022; Morrison et al. 2012). However, most of the studies that have documented how local people's attitudes, perceptions and management practices drive degradation or conservation of macrophytes in Kenya have largely focused on species that are either iconic (have high economic value) or problematic (noxious weeds) while ignoring the less prominent species (Morrison et al. 2012; Terer et al. 2012; Waithaka 2013; Maua et al. 2022). Thus, the ecological knowledge of macrophytes among local people in Kenya, in general, remains unclear.

The aim of this study was to assess local people's ecological knowledge of, and management practices towards, freshwater macrophytes in freshwater lakes in Kenya. Specifically, we (1) tested the local people's macrophyte species literacy (i.e., macrophyte species identification skills, knowledge of alien macrophyte species and macrophyte dynamics), (2) examined local peoples' attitudes and perceptions towards macrophyte species that occurred in their ecosystem and (3) documented local people's macrophyte management practices.

2 | Methodology

2.1 | Study Areas

Kenya's major freshwater bodies occur in the Lake Victoria, Rift Valley and Athi drainage basins (Nyingi, Gichuki, and Ogada 2013). Lakes in the drainage basins have distinct climatic conditions, variable anthropogenic pressures, diverse compositions of animal, plant and microbial species, as well as differing conservation statuses (see Ndetei 2006; Odada, Onyando, and Obudho 2006; Simiyu et al. 2022; Omondi et al. 2016). Moreover, different human communities with unique cultural practices inhabit the areas surrounding the lakes (Awange and Ong'ang'a 2006; Ndetei 2006; Odada, Onyando, and Obudho 2006). These communities derive a variety of provisioning, supporting, regulatory and cultural ecosystem services from the lakes (Awange and Ong'ang'a 2006; Ndetei 2006; Odada, Onyando, and Obudho 2006). To assess local people's ecological knowledge of, and management practices towards freshwater macrophytes, we focused our study on Lake Baringo, Nyanza Gulf of Lake Victoria and the Kenyan side of Lake Jipe (Figure 1), which occur within the three drainage basins above.

2.1.1 | Lake Baringo

Lake Baringo (Figure 1a) is a Ramsar site located between latitudes 0°30′–0°45′ N and longitudes 36°00′–36°10′ E, and at an altitude of *ca*. 900 m above sea level. The Lake has a surface area of approximately 130 km^2, a mean depth of 4.7 m (Odada, Onyando, and Obudho 2006; Omondi et al. 2016). This Ramsar lake is fed by the perennial rivers Molo and Perkerra and the seasonal rivers Ol Arabel, Makutan, Endao and Chemeron (Odada, Onyando, and Obudho 2006; Omondi et al. 2016). The land surrounding the Lake is arid and semi-arid and is inhabited by the Ilchamus, Tugen and Pokot ethnic communities (Omondi et al. 2016). The communities derive their livelihoods from pastoralism, irrigated agriculture, fishing, tourism-related activities and conservation of wild animals (Odada, Onyando, and Obudho 2006).

2.1.2 | The Nyanza Gulf of Lake Victoria

The Nyanza Gulf of Lake Victoria is located at the north-eastern corner of Lake Victoria (Figure 1b). It lies between 0°6′ S–0°32′ S and 34°13′ E–34°52′ E and at an altitude of 1134 m above sea level (Awange and Ong'ang'a 2006). The Gulf has a surface area of approximately 1400 km^2, a mean depth of 10 m, and its major inflows are from the rivers Nyando, Sondu, Awach, Kibos and Oluch (Awange and Ong'ang'a 2006). The local communities living in the arid and semi-arid areas surrounding the Gulf majorly consist of the Luhya, Luo, Kisii, Kuria, Maasai, Suba, Kalenjin and Teso ethnic communities (UNEP 2006). The communities primarily derive their livelihoods from fishing and fish-related activities, such as fish processing and fish mongering (Awange and Ong'ang'a 2006).

2.1.3 | Lake Jipe

Lake Jipe is a transboundary ecosystem that lies between 3°37′–3°33′ S and 37°44′–37°47′ E and at an altitude of *ca*. 700 m above sea level (Ndetei 2006). The lake has a surface area of about 30 km^2, a maximum depth of 3 m and is fed by River Lumi and drained by River Ruvu (Ndetei 2006). The land adjacent to the Kenyan side of Lake Jipe is semi-arid and is predominantly inhabited by the Taita and Taveta ethnic communities (Ndalilo, Kirui, and Maranga 2020). Fishing and farming are the primary livelihood activities for the communities (Ndetei 2006; Ndalilo, Kirui, and Maranga 2020).

2.2 | Data Collection

To assess local people's perceptions, species literacy and management practices of freshwater macrophytes, we defined several indicators for each objective (Table 1). We then used the indicators to design questionnaires and topic guides. The questions contained in both questionnaires and topic guides are shown in Table 1. Regular engagement with a resource enhances one's understanding of it (Cebrián-Piqueras et al. 2020; Szałkiewicz, Sucholas, and Grygoruk 2020) therefore, we narrowed our study to wetland users who frequently interacted with macrophytes. In a reconnaissance survey, we found that most of the local people utilising macrophytes lived within 2 km of the lake's shoreline. Therefore, we conducted individual household interviews and focus group discussions among local people who resided within a 2 km distance from the lake shores. According to the 2019

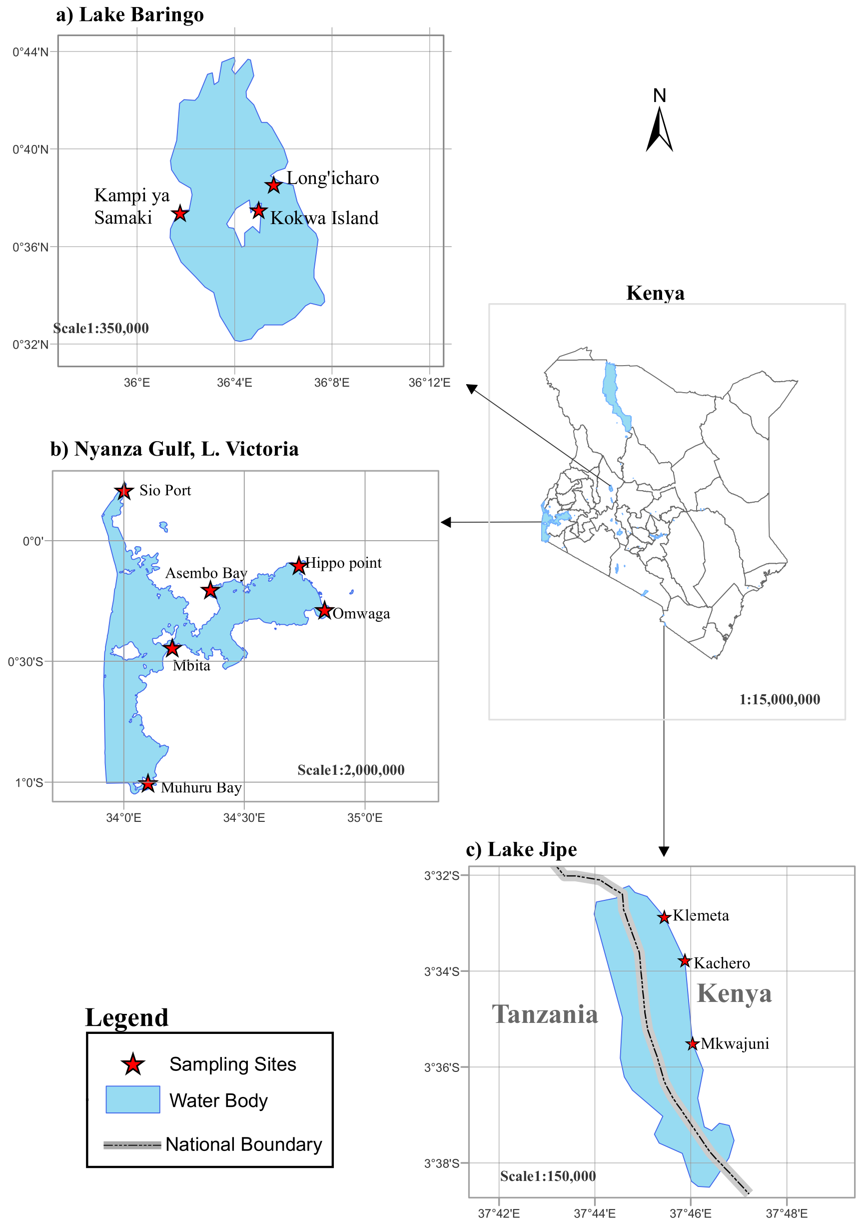

FIGURE 1 | Map showing the sampling sites in Lake Baringo (a), Nyanza Gulf of Lake Victoria (b) and the Kenyan side of Lake Jipe (c).

Kenya population census, about 928, 78 and 136 households live within 2 km from the shores of Nyanza Gulf of Lake Victoria, Lake Baringo and the Kenyan side of Lake Jipe, respectively (KNBS 2019). Five counties namely: Migori, Homabay, Kisumu, Siaya and Busia counties border the Nyanza Gulf of Lake Victoria. To ensure the representativeness of the sample, data were collected from one administrative ward in each county: Muhuru, Kasgunga, Omwaga, East Asembo and Busijo wards in Migori, Homabay, Kisumu, Siaya and Busia counties, respectively. Additionally, to include both rural and urban residents of Kisumu, Hippo Point, a major recreational area within the urban parts of the county, was also selected as a sampling point. In Lake Baringo, security reasons limited our data collection to Kampi ya Samaki, Kokwa Island and Long'icharo villages. At the Kenyan side of Lake Victoria, Tsavo West National Park that borders the southern portion of the lake restricted our data collection to three villages outside the protected area.

Respondents for the individual household interviews were obtained by randomly selecting 49, 52 and 44 households in the Nyanza Gulf of Lake Victoria, Lake Baringo and the Kenyan Side of Lake Jipe. The questions asked during the individual household interviews are shown in Table 1. In all study locations, we treated a household as a basic sampling unit and therefore interviewed only one adult member (≥18 years old) of a household. Focus group discussion enabled us to obtain broad perspectives concerning our research objectives and verify the information that was obtained from individual household interviews (DiCicco-Bloom and Crabtree 2006; Nyumba et al. 2018). Participants for the eight focus group discussions were recruited through convenience, purposive and snowballing sampling methods. The number of participants in the focus group discussions ranged from 6 to 10 (an average of 8 per focus group). The focus groups discussions were conducted using a topic guide with questions shown in Table 1. We moderated the discussions to ensure that each participant had an equal chance to participate in the discussion of each question. We audio-recorded the discussions with the permission of the participants and these recordings were later transcribed and translated into English. Because of power imbalance between men and women among the study communities, seven out of the eight focus group discussions were made up of participants of one gender only (four and three focus group discussions with exclusively male and female participants, respectively). However, at Kokwa Island of Lake Baringo, we conducted a mixed-gender focus group discussion as the community's gatekeepers demanded. In both methods of data collection, we adopted a two-step method of testing macrophyte species literacy to avoid species misidentification and control for any bias in macrophyte identification (Bogner and Landrock 2016). First, the respondents were asked to name the macrophytes species they knew. We then listed the names that they mentioned, and in the second step, we gave them a set of printed images of unnamed macrophyte species to match with the macrophytes that they had named.

To help with data collection, village chiefs aided in the recruitment of local research assistants who were proficient with the local languages and the national language *Swahili*. Prior to conducting the household interviews and focus group discussions, the respondents were informed that their participation in the study was voluntary and that no incentive would be provided to them, they had a right to withdraw from the study at any time, and their identity would not be revealed in any communication. Thereafter, they voluntarily signed consent forms. We obtained ethical clearance for data collection from Kabarak University Research Ethics Committee (approval number KUREC-010122).

2.3 | Data Analyses

We summarised the demographic statuses (i.e., age, gender, residence, level of education, occupation and frequency of weekly visits to the lake) of the 145 respondents who participated in the face-to-face interviews using descriptive statistics. Although our respondents had diverse livelihoods, some occupations had very few individuals. To avoid errors during statistical analyses, we broadly categorised occupations into two levels—fish handlers and other occupations. For binary responses (yes vs. no), a 'yes' response was coded as 1 and a 'no' response as 0. For each question that generated quantitative data, we used generalised linear mixed-effect models with the *glmer* function in the *lme4* package (Bates et al. 2020) to test for correlations between the sociodemographic characteristics of the respondents and the responses obtained. In the models, responses to the questions were treated as the dependent variables, the sociodemographic characteristics of the respondents as fixed-effect independent variables (age, gender, residence, level of education, occupation and frequency of weekly visits to the lake) and lakes as a random-effect independent variable. Models that analysed binary responses were fitted with a binomial (link = 'logit') error distribution using the *bobyqa* optimiser. On the other hand, models that handled count data were fitted with a *Poisson* (link = 'log') error distribution. After running the models, we used the 'drop1' function to determine the statistical significance of the independent variables at $\alpha < 0.05$. In the cases when fixed-effect independent variables with two or more categories were statistically significant, we performed Tukey's HSD post hoc tests through the *glht* command to check for differences among the categories. All statistical analyses were performed with R v 4.0.2 (R Core Team). For qualitative data, we used direct quotes from the respondents to back up the information obtained from in-depth interviews. We preferred using direct quotes because they are known to highlight particular features of the data and give explanations of processes, observations and perspectives (Nyumba et al. 2018; Eldh, Årestedt, and Berterö 2020). The method of selecting quotes involved sifting through the translated data and arranging the data points according to the various indicators shown in Table 1.

3 | Results

3.1 | Sociodemographic Characteristics of the Respondents

A total of 145 respondents participated in the face-to-face interviews; a summary of their social and demographic profiles is provided in Table 2. The respondents' ages ranged from 18 to 79 years, and their mean residence time (years lived in the study location) was 29.73 ± 15.95 (SD). Most of the respondents (97%; $n = 145$) had attained some form of formal education. The respondents made various trips to the lake for multiple reasons, including to work (e.g., as fishermen, fish cleaners, small-scale traders, tour guides and sand harvesters), to obtain water for domestic use, to extract food and nonfood items and for recreation and transportation purposes. Fishing and fish-related secondary activities, such as gutting, cleaning and sale of fish, constituted the primary livelihood activities for nearly a half of the respondents.

3.2 | Macrophyte Species Literacy

3.2.1 | Macrophyte Species Recognised

Respondents from the three study lakes recognised a total of 53 macrophyte species (named 35 macrophyte species by free listing [i.e., asking respondents to list all macrophyte species they can think of] and 18 more using picture aids). The 10 most frequently identified macrophyte species by free listing are shown in Table 3, while the 35 macrophyte species named by free listing are shown in Table 4. The mean number of macrophytes species named by the respondents through free listing was 5.98 ± 2.73 (SD) macrophyte species. However, none of the respondents from the three study locations could tell apart macrophyte species that closely resembled each other. We observed that bladderworts (*Utricularia* sp.) were often erroneously referred to as immature hornworts (*Ceratophyllum demersum* L.), while duckweeds (*Lemna* sp.) were mistaken for juvenile water lettuce (*Pistia stratiotes* L.). Moreover, most grasses were lumped together and referred to using local common names (*suswa*/*seret* in Lake Baringo, *ongago* in the Nyanza Gulf and *nyasi* on the Kenyan side of Lake Jipe). The naming of macrophyte species was significantly correlated with occupation, with respondents who did not engage in

TABLE 1 | Indicators and questions that were used to evaluate local people's perceptions, species literacy and management practices towards macrophytes in Lake Baringo, Nyanza Gulf of Lake Victoria and the Kenyan side of Lake Jipe.

Specific objective	Rationale	Indicator	Questions used in individual household interviews	Type of data	Topic guide questions for focus group discussions
1 To test local people's macrophyte species literacy	Species literacy indicates (dis)connection with nature (Hooykaas et al. 2019, 2022)	The average number of macrophyte species that a person can recognise	Can you name macrophyte species that occur in your ecosystem?	Quantitative (count data)	Do you know macrophytes species that are present in the lake?
		Knowledge of alien and native species in their ecosystem	Do you know of any alien macrophyte species in your ecosystem?	Quantitative (binary data)	Are there foreign macrophyte species in the lake?
			If yes, can you name them?	Quantitative (count data)	
		Perceived change in the abundance and diversity of macrophyte species	Do you perceive any changes in the diversity and abundance of macrophyte species?	Quantitative (binary)	In terms of richness and abundance, are there any macrophyte changes in the lake?
			If yes, can you describe the macrophyte changes?	Qualitative.	
2 To examine local people's attitudes and perceptions towards. macrophytes	Perceived ecosystem (dis) services shapes people's attitudes and perceptions towards the resource (Terer et al. 2012; Maua et al. 2022)	Provisioning, supporting, regulatory and cultural ecosystem services macrophytes offer (Millenium Ecosystem Assessment 2005)	Are macrophytes beneficial?	Quantitative (binary)	What benefits do you derive from macrophytes?
			If yes, how are they beneficial?	Qualitative	
		Macrophyte functions, processes and attributes that result in perceived or actual detrimental effects on human well-being including diminished or loss of provisional, supporting, regulatory and cultural ecosystem services (Shackleton et al. 2016)	Do macrophytes cause problems?	Quantitative (binary)	Do macrophytes cause problems?
			If yes, how are macrophytes problematic?	Qualitative	

(Continues)

TABLE 1 | (Continued)

Specific objective	Rationale	Indicator	Questions used in individual household interviews	Type of data	Topic guide questions for focus group discussions
3 Document local people's macrophyte management practices	The management practices can include methods of controlling problematic macrophyte species while fostering and propagating beneficial ones (Terer et al. 2012; Enyew, Assefa, and Gezie 2020). Their management and harvesting practices tacitly or directly reveal local people's attitudes and perceptions towards macrophytes Bennett (2016)	Macrophyte conservation practices	Are macrophytes harvested?	Quantitative (binary)	Do you harvest macrophytes?
			If yes, how are they harvested?	Qualitative	
			How frequently are they harvested?	Quantitative (count)	
			Are macrophytes propagated or fostered?	Quantitative (binary)	Do you propagate/ foster macrophytes?
			If yes, can you describe the process of propagating and or fostering macrophytes?	Qualitative	
			Do the local people conserve macrophytes?	Quantitative (binary)	Does your community conserve macrophytes?
			If yes, how are macrophytes conserved?	Qualitative	
		Methods of manipulating diversity and abundance of macrophyte species	Are macrophyte species controlled?	Quantitative (binary)	
			If yes, do the control programmes target specific species or entire macrophyte communities?	Quantitative (binary) or qualitative	
			How are the macrophytes controlled?	Qualitative	

TABLE 2 | Sociodemographic characteristics of the respondents ($n = 145$) (sample size obtained by pooling individuals sampled from Lake Baringo, Nyanza Gulf of Lake Victoria and the Kenyan side of Lake Jipe).

Characteristic	Category	Sample size (n)	Proportion of overall sample size (%)
Age (18–79)	Continuous (not categorised)	145	—
Gender	Female	30	20.67
	Male	115	79.31
Residence	Short term (≤10 years)	19	13.10
	Long term (>10 years)	126	86.90
Level of formal education	None	11	7.59
	Primary school	71	48.97
	Secondary school	46	31.72
	Postsecondary school	17	11.72
Occupation	Fish handlers (fishing and fish-related activities)	71	48.97
	Others (farming, hoteliers, mechanics, motorcycle taxi riders, small-scale traders)	74	51.03
Weekly visits to the lake	Occasionally (≤3 times a week)	16	11.03
	Frequently (four to six times a week)	97	66.90
	Daily	32	22.07

fish-related activities naming more macrophyte species than respondents whose livelihoods depended on fishing and fish-related activities (Table 5 and Figure 2A). The frequency with which a respondent visited the lake was also significantly associated with macrophyte naming, as those who visited the lake frequently (≥four–six times a week) named more macrophyte species than their counterparts who either visited occasionally (≤three times a week) or daily (Table 5 and Figure 2B). Additionally, age was significantly positively associated with knowledge of macrophyte species (Table 5 and Figure 3A). The ability to identify macrophyte species was not significantly associated with gender, education and residence time of the respondents (Table 5).

3.2.2 | Knowledge of Alien Macrophytes Species

Some respondents from Lake Baringo and Nyanza Gulf of Lake Victoria perceived that some macrophyte species in their ecosystems were alien. In Lake Baringo, 37 out of the 52 respondents perceived water lettuce (*P. stratiotes*) and water hyacinth (*Eichhornia crassipes*) as alien macrophyte species:

> Water lettuce appeared in Lake Baringo in 1997… I started seeing water hyacinth in 2016, and after a year, the macrophyte had covered most parts of the Lake. We believe that water hyacinth came into the Lake from seeds attached to tourists' boats or nets of fishermen who had relocated from Lake Victoria.

(Respondent number 70, male, Kampi Samaki, Lake Baringo)

Water hyacinth was also identified as an alien macrophyte in the Nyanza Gulf by 5 out of the 49 respondents:

> I started noticing water hyacinth in the Lake in 1989. I do not know who brought it.

(Respondent number 145, male, Sangorota, the Nyanza Gulf of Lake Victoria)

The respondents' knowledge of alien macrophyte species was not significantly correlated with any of their sociodemographic characteristics (Table 5).

3.2.3 | Perceived Changes in Macrophyte Species Diversity and Abundance

Local people's perceptions about macrophyte changes that had occurred in their lakes were attributed to invasive alien or range-expanding macrophyte species. These perceptions, however, did not significantly correlate with the sociodemographic characteristics of the respondents (Table 5). In Lake Baringo, 32 out of the 52 respondents perceived that short-term changes in the diversity and abundance of macrophytes were brought about by intense selective macrophyte harvesting during dry seasons and minimal macrophyte harvesting during wet seasons. Only four respondents linked the changes in diversity and abundance of macrophyte species to variation in environmental conditions. On the other hand, the respondents perceived that long-term changes in the diversity and abundance of macrophyte species such as the common hornwort (*C. demersum*) and water lettuce (*Pistia statiotes*) were caused by presence of water hyacinth (*E. crassipes*) in Lake Baringo. Perceptions that water hyacinth (*E. crassipes*) decimated other macrophyte species were also noted by 40 out of the 49 respondents from Nyanza Gulf of Lake Victoria. Additionally, the respondents perceived those strong winds that redistributed water hyacinth throughout the gulf, causing erratic changes in the diversity and abundance of native macrophyte species. At the Kenyan side of Lake Jipe, 23 out of the 44 respondents perceived that the ever-increasing densities of the cattails *Typha domingensis* Pers decimated 'good macrophytes such as water lilies (*Nymphaea* spp.) and water lettuce (*P. stratiotes*).

TABLE 3 | Ten most frequently identified macrophyte species by respondents through free listing at the shores of Nyanza Gulf of Lake Victoria, Lake Baringo and the Kenyan side of Lake Jipe.

Nyanza Gulf of Lake Victoria		Lake Baringo		Kenyan side of Lake Jipe	
Species	**Respondents (%)**	**Species**	**Respondents (%)**	**Species**	**Respondents (%)**
Eichhornia crassipes (Mart.) Solms	94.23	*Eichhornia crassipes*	94.23	*Typha domingensis* Pers.	100.00
Nymphaea spp.	80.77	*Nymphaea* spp.	80.77	*Cyperus papyrus* L.	93.18
Typha domingensis	69.23	*Typha domingensis*	69.23	*Pistia stratiotes* L.	63.64
Aeschynomene elaphroxylon (Guill. and Perr.) Taub	63.46	*Aeschynomene elaphroxylon.*	63.46	*Schoenoplectus spp.*	34.09
Pistia stratiotes	53.85	*Pistia stratiotes*	53.85	*Ceratophyllum demersum* L.	27.27
Vossia cuspidata (Roxb.) Griff.	51.92	*Vossia cuspidata*	51.92	*Azolla spp*	20.45
Cyperus esculentus L.	23.08	*Cyperus esculentus*	23.08	*Vossia cuspidata*	18.18
Ceratophyllum demersum	21.15	*Ceratophyllum demersum*	21.15	*Hydrilla verticillata* (L.f.) Royle	13.64
Prosopis juliflora (Sw.) DC.	21.15	*Prosopis juliflora*	21.15	*Ipomea aquatica* Forssk.	13.64
Phragmites spp.	15.38	*Phragmites* spp.	15.38	*Vigna nilotica* (Delile) Hook.f.	9.09
				Trapa natans L.	9.09

3.3 | Local People's Perceptions Towards Freshwater Macrophytes

3.3.1 | Macrophyte Ecosystem Services

Our respondents mentioned a variety of benefits derived from various macrophyte species, and we broadly classified these benefits into various ecosystem services. Overall, the respondents identified 13 provisioning, 4 supporting, 3 regulatory and 1 cultural macrophyte ecosystem services. The species-specific services are shown in Table 4.

3.3.1.1 | Provisioning Ecosystem Services. In all study locations, the material benefits that the local people obtained from various macrophyte species were the most frequently identified ecosystem service (Figure 4A). According to our respondents, macrophytes served as food, fodder, chicken feed, fibre to make artefacts, fuel, fish baits, medicine, manure and construction material for animal shades, houses and canoes (Table 4). Some local people from the Nyanza Gulf of Lake Victoria used water lettuce to rear fish in ponds and to purify borehole water. These material benefits generated some income for some local people:

> Owning an iron sheet-roofed house is a sign of modernization but I prefer using the cattails [*T. domingensis*] and papyrus [*C. papyrus*] to roof my house. This is because the inside of a thatched house is cooler compared to that of iron sheet-roofed house. During dry seasons, we harvest macrophytes to feed livestock and we also eat bulbs and seeds from water lilies [*Nymphaea* sp.] and the rhizomes from the cattails. Macrophytes are freely accessible to everyone, but you can pay someone to harvest them for you. Other people make and sell artifacts made from macrophytes, but these artisans make very little money because people prefer modern baskets, chairs, mattresses....

(Respondent number 66, male, Kampi Samaki, Lake Baringo)

TABLE 4 | Macrophyte species and their ecosystem services as identified by respondents.

Scientific name	Common name	Local name	Location where identified	Provisioning ecosystem services	Supporting ecosystem services	Regulatory ecosystem services	Cultural ecosystem services
Aeschynomene cristata Vatke	Malagasy joint vetch	Amarindi•	Nyanza Gulf, Lake Baringo	Constructing houses			
Aeschynomene elaphroxylon Taub.	Balsa wood	Longaran♦/kosykosia♦/ sipei♦/subei♦	Lake Baringo	Making canoes, feeding livestock			
Alternanthera sessilis R.Br.	Sessile joy weed	Nasigumba•	Sio Port, Nyanza Gulf, Lake Baringo	Vegetable			
Azolla spp		Malongolongo*	Lake Jipe, Nyanza Gulf, Lake Baringo		Food for fish, habitat for snails		
Ceratophyllum demersum L.	Coontail	Kinyanguo♦ /amalasi•/ obwaka•/majani ya kondoo*	Lake Jipe, Nyanza Gulf, Lake Baringo	Chicken feed, used as medicine	Food both fish and birds, refugia for fish	Purifies water by trapping silt	
Cynodon dactylon (L.) Pers.	Bermuda grass	Suswa♦/ongago•/lum•/nyasi*	Lake Jipe, Nyanza Gulf, Lake Baringo	Fodder		Prevent siltation	
Cyperus articulans L.	Jointed flatsedge	Seret♦/suswa♦/amasamba•/ esamba•/ondago•/ndago*	Lake Jipe, Nyanza Gulf, Lake Baringo	Fodder, making artefacts	Habitat and breeding sites for fish, food for wild animals		
Cyperus esculentus L.	Yellow nutsedge	Meigut♦/seret♦/suswa♦/ eseme•/ngage*	Lake Jipe, Nyanza Gulf, Lake Baringo	Medicine, fodder, knives, making ropes and fish traps	Habitats and breeding sites for fish, food for fish and other wild animals		
Cyperus papyrus L.	Papyrus	Amadutu•/vidutu•/ oluvembe•/mabura*	Lake Jipe, Nyanza Gulf, Lake Baringo	Constructing houses and making artefacts	Breeding sites for fish		Decorations during cultural ceremonies
Echinochloa scabra (Lam.) Roem. & Schult.		Suswa♦/ongago•/lum• /nyasi*	Lake Jipe, Nyanza Gulf, Lake Baringo	Fodder		Prevent siltation	
Eichhornia crassipes Solms	Water hyacinth	Gugumaji♦/labarsian♦/ achandra•/anyuongi•/ ebichankore•/ford•	Nyanza Gulf, Lake Baringo	Making artefacts, manure, biofuel, fodder	Breeding sites for fish, food for birds and other wild animals		
Eleusine indica (L.) Gaertn.	Yard-grass	Suswa♦/ongago•/lum• /nyasi*	Lake Jipe, Nyanza Gulf, Lake Baringo	Fodder		Prevent siltation	

(Continues)

TABLE 4 | (Continued)

Scientific name	Common name	Local name	Location where identified	Provisioning ecosystem services	Supporting ecosystem services	Regulatory ecosystem services	Cultural ecosystem services
Euphorbia tirucalli L.	African milk bush	Asao•	Nyanza Gulf, Lake Baringo	Medicine			
Hydrilla verticillata (L.f.) Royle	Florida elodea	Iraki*	Lake Jipe	Fishing bait, aerate ponds	Food for fish		
Ipomea aquatica Forssk.	Morning glory	Majani ya viazi*	Lake Jipe, Nyanza Gulf, Lake Baringo	Vegetable, fodder			
Leersia hexandra Sw.	Cut grass	Suswa◆/ongago•/lum• /nyasi*	Lake Jipe, Nyanza Gulf, Lake Baringo	Fodder		Prevent siltation	
Lemna perpusilla Torr.	Minute duckweed	Watoto wa maboga*	Lake Jipe, Nyanza Gulf, Lake Baringo		Food for fish		
Ludwigia stolonifera Forssk.	Water primrose		Lake Jipe, Nyanza Gulf, Lake Baringo	Rearing fish in hatcheries	Food for fish		
Melanthera scandens (Schumach and Thonn.) Roberty			Nyanza Gulf, Lake Baringo	Cooking stick			
Myriophyllum spicatum L.	Eurasian water-milfoil	Amalasi•/obwaka•	Lake Jipe, Nyanza Gulf, Lake Baringo	Chicken feed	Food for fish		
Nymphaea lotus L.	Egyptian lotus	Ndorok◆/riyombeyombe•/oyungu•/mabaiskeli*	Nyanza Gulf, Lake Baringo	Drinking straw, food for both humans and livestock, fish preservation	Refugia and food for fish and insects	Purifies water	
Paspalum vaginatum Sw.	Biscuit grass	Suswa◆/ongago•/lum•/nyasi*	Lake Jipe, Nyanza Gulf, Lake Baringo	Fodder		Prevent siltation	
Phragmites spp.	Common reed	Sampuma◆/samuli◆/amasare•/amakada•/ipodo*/magugu*	Lake Jipe, Nyanza Gulf, Lake Baringo	Constructing houses and livestock shades, making fishing rods and lamp holders	Refugia and breeding sites for fish	Windbreaker	
Pistia stratiotes L.	Water lettuce	Nkaparsian◆/ngabarasian◆/amayombeyombe•/kabeji*/maboga ya baharini*	Lake Jipe, Nyanza Gulf, Lake Baringo	Vegetable, purifying borehole water, rearing fish	Food and refugia for fish, nesting sites for birds	Purifies water	

(Continues)

TABLE 4 | (Continued)

Scientific name	Common name	Local name	Location where identified	Provisioning ecosystem services	Supporting ecosystem services	Regulatory ecosystem services	Cultural ecosystem services
Potamogeton schweinfurthii A.Benn			Nyanza Gulf		Refugia and breeding sites for fish		
Prosopis juliflora (Sw.) D.C.		Mesquite◆	Lake Jipe, Lake Baringo	Fuel (firewood and charcoal), constructing houses, fencing, fodder		Prevents siltation	
Schoenoplectus sp.		Seret◆/suswa◆/seret◆/esamba•/ondago•/ndago*	Lake Jipe, Nyanza Gulf, Lake Baringo	Making artefacts, manure	Breeding sites for fish		
Sesbania sesban (L.) Merr.	Common Sesban	Asawo•/enjago•	Nyanza Gulf, Lake Baringo	Constructing houses, cleaning boats, making soap		Windbreaker	
Spirogyra sp.		Kurungurwa◆	Lake Baringo		Food for fish		
Triumfetta macrophylla K.Schum.	Burbark	Obalandagwa•	Nyanza Gulf	Firewood, medicine		Windbreaker	
Typha domingensis Pers.	Cattail	Larau◆/eseberi• /togo•/makuruvia*/ makuruvira* /masekete*/magugu*	Lake Jipe, Nyanza Gulf, Lake Baringo	Roofing, making mats and charcoal, food for both humans and animals	Food, breeding sites, and habitat for fish and other wild animals	Windbreaker, prevent siltation	
Utricularia inflexa Forssk.		Amalasi•/obwaka•/majani ya kondoo*	Lake Jipe, Nyanza Gulf, Lake Baringo	Chicken feed, aerate fish ponds			
Vallisneria spiralis L.	Tape grass	Amalaslas•/malasi•	Nyanza Gulf		Refugia and food for fish		
Vigna nilotica (Delile) Hook.f.	Wild cowpea	Dindi•/ majani ya kunde*	Lake Jipe, Nyanza Gulf, Lake Baringo	Vegetable, fodder			Decorations during religious activities
Vossia cuspidata (Roxb.) Griff	Hippo grass	Nketiketi◆/sapong'wa◆/sapung'wa◆/saka•/magugu*	Nyanza Gulf, Lake Baringo	Fodder	Breeding sites for fish		

Note: The symbols *, ● and ◆ denote local species names at the Kenyan side of Lake Jipe, Nyanza Gulf of Lake Victoria and Lake Baringo, respectively.

TABLE 5 | Results of the generalised linear mixed-effect models that tested for associations between the sociodemographic characteristics of respondents and various aspects of macrophyte species literacy.

Factor	Number of macrophyte species identified		Observed macrophyte changes		Alien species	
	F	*p*	*F*	*p*	*F*	*p*
Gender	1.37	0.13	0.00	0.64	0.73	0.26
Education	0.06	0.92	0.85	0.50	1.88	0.10
Occupation	2.24	**0.02**	0.02	0.82	0.49	0.73
Frequency of lake visits	4.65	**0.007**	0.38	0.66	0.44	0.64
Residence time	1.97	0.74	0.45	0.27	0.51	0.72
Age	4.25	**0.04**	0.72	0.39	0.04	0.84

Note: Statistically significant factors ($p < 0.05$) are highlighted in bold print.

Knowledge of provisioning ecosystem services that macrophytes offered was significantly correlated with gender (Table 6), with more males (96.52%; $n = 115$) than females (83.33%; $n = 30$) identifying this category of ecosystem service. Knowledge of provisioning services was not associated with level of education, occupation, frequency of visiting the lake, residence time and age.

3.3.1.2 | Supporting Ecosystem Services. The supporting ecosystem services that macrophytes provided were the second most frequently identified ecosystem service (Figure 4A). According to 49.66% of the 144 respondents, macrophytes were food, habitat, refugia and breeding sites for fish and other wild animals (Table 4):

> Fish feed on macrophyte and during the cold season, they hide among the macrophytes and come out when water becomes warmer.
>
> (Respondent number 22, male, Kachero, Lake Jipe)

Gender significantly correlated with the respondents' knowledge of the various supporting ecosystem services (Table 6), as more males (55.65%; $n = 115$) than females (26.67%; $n = 30$) identified at least one ecosystem service. Additionally, age showed a positive correlation with the respondent's knowledge of the various supporting ecosystem services that macrophytes offered (Table 6 and Figure 3B). Supporting ecosystem services were not associated with level of education, occupation, lake visits and residence time.

3.3.1.3 | Regulatory Ecosystem Services. The regulatory ecosystem services that macrophytes offered were the third most frequently identified ecosystem services. According to 13.19% of the 144 respondents, macrophytes purified water, regulated lake siltation and sheltered local people from strong winds (Table 4):

> …… If you lift common hornwort [*C. demersum*] from water, you will see that it has trapped a lot of sediments. This is an indication that macrophytes purify water.
>
> (Respondent number 84, Male, Kampi Samaki, Lake Baringo)

Age showed a positive association with the respondent's knowledge of the various regulatory services that macrophytes offered but correlation was not significant (Table 6 and Figure 3C). Regulatory ecosystem services were not associated with gender, level of education, occupation, lake visits and residence time.

3.3.1.4 | Cultural Ecosystem Services. The cultural services were the least identified ecosystem service (recognised by 6 out of the 145 respondents). In Lake Baringo, five respondents noted that the Tugen, Pokot and Njemps ethnic groups used the umbels of the paper reed (*Cyperus papyrus*) as decorations during traditional ceremonies. Additionally, one respondent from the Nyanza Gulf of Lake Victoria noted that some religious groups used the hairy cowpea (*Vigna nilotica*) as decorations during religious functions (Table 4). None of the independent variables correlated with knowledge of the cultural services macrophytes offered.

3.3.2 | Macrophyte Ecosystem Disservices

3.3.2.1 | Impacts on Aquatic Organisms. Combined data showed that 33.33% of 144 respondents perceived that some macrophyte species negatively affected other aquatic organisms (Figure 4B). In this regard, 29 of 49 the respondents from Lake Baringo and 14 of the 48 respondents from Nyanza Gulf of Lake Victoria, perceived that water hyacinth decimated 'good' macrophytes such as water lettuce and altered the richness and abundance of fish species:

> When strong winds push water hyacinth to our location, the macrophyte brings some rare fishes such as the Elephant-snout fish [Mormyrus kannume Forssakål, 1775]. However, presence of dense water hyacinth mats reduces the abundance of the tilapiines.
>
> (Respondent number 126, male, Muhuru Bay, Nyanza Gulf of Lake Victoria)

At the Kenyan side of Lake Jipe, 4 of 37 respondents associated reduced tilapiines' sizes and abundance to diminishing water quality, an occurrence that had been brought about by dense

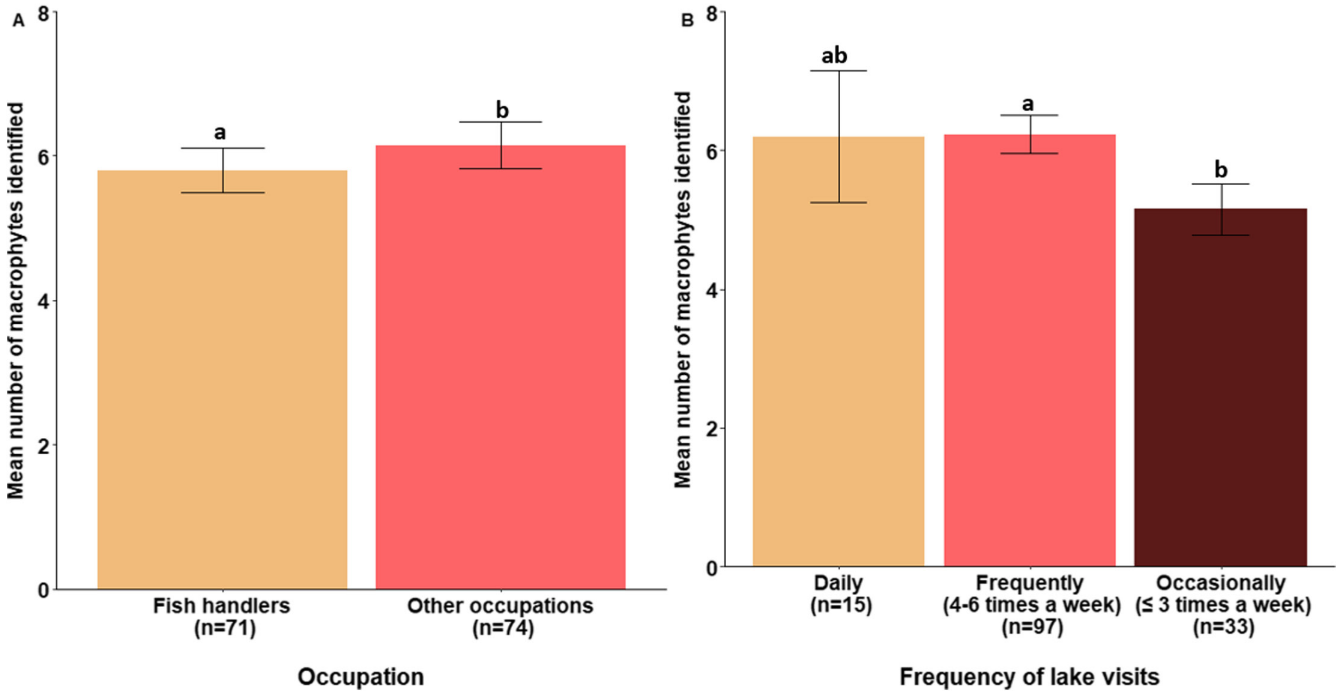

FIGURE 2 | Knowledge of macrophyte species according occupation (A) and frequency of weekly visits to the lake (B).

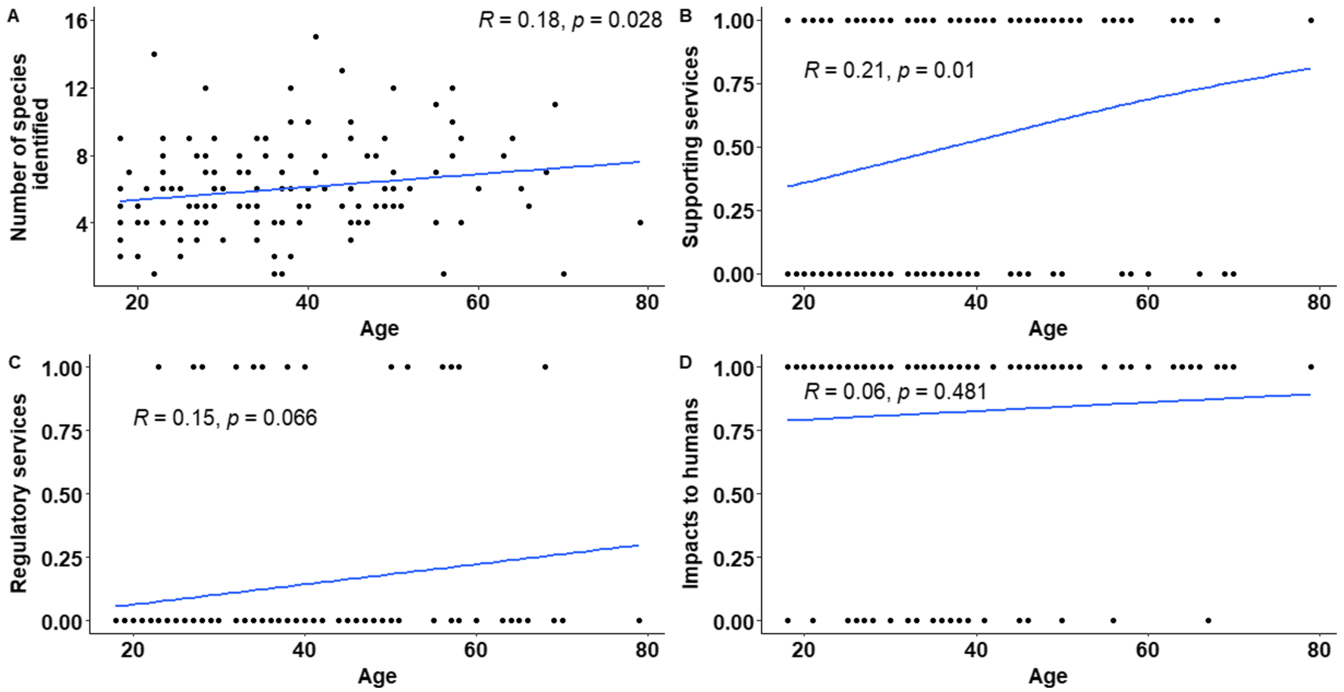

FIGURE 3 | Logistic regression curves showing correlations between respondent's age and knowledge of macrophyte species (A), supporting ecosystem services (B), regulating ecosystem services (C) and direct impacts to humans (D).

cattails stands that had blocked mouth of River Lumi causing it to divert its course. Additionally, the respondents perceived that aggressive expansion of the cattails also reduced the population of the 'good macrophytes':

> The cattails blocked the mouth of River Lumi and caused it to divert its course. Since then, water quality has greatly diminished, leading to a decline in the size and abundance of the tilapias.
>
> (Respondent number 22, male, Mkwajuni, Lake Jipe)

None of the independent variables correlated with knowledge of how macrophyte species negatively impacted aquatic organisms (Table 6).

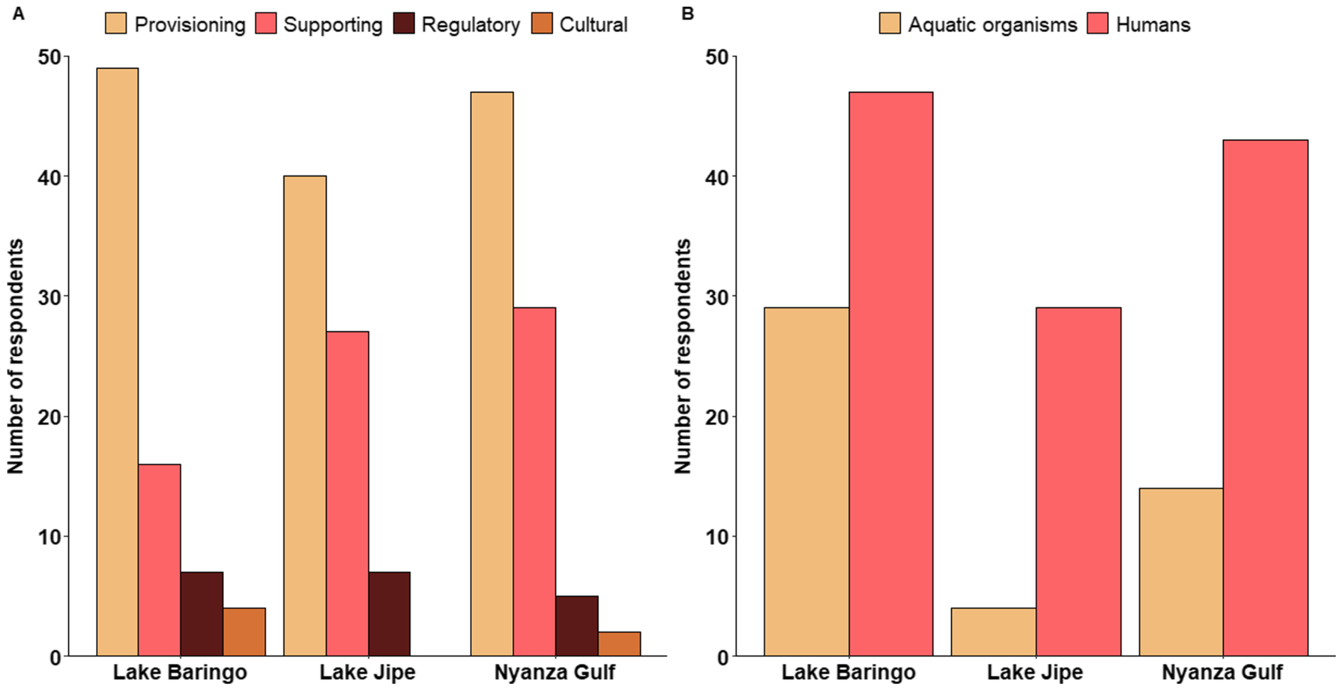

FIGURE 4 | Proportion of respondents with the knowledge of various ecosystem services (A) and disservices (B) of macrophytes.

3.3.2.2 | Direct Impacts on Humans. Pooled data showed that most respondents (82.07% of the 145 respondents) perceived that macrophytes directly affected their well-being (Figure 4B). In this context, 47 of the 52 respondents from Lake Baringo and 43 of the 49 respondents from Nyanza Gulf of Lake Victoria perceived that dense water hyacinth mats made it difficult for the locals to fetch water for domestic use, blocked landing sites for boats, destroyed fishing gears, interfered with navigation, reduced water quality, changed the diversity and abundance of fish, harboured disease-causing parasites and were hideouts for dangerous animals such as snakes and crocodiles. Overall, these impacts increased their costs of living:

> When water hyacinth covers this part of the Gulf, we shift our fishing base to other less invaded locations. Moving to other locations means incurring extra fishing costs which are often passed to the consumer. Dense water hyacinth mats also make the water dirty, so we must look for alternative sources of water.

(Respondent number 108, male, Asembo, Nyanza Gulf)

At the Kenyan side of Lake Jipe, 29 of the 44 respondents perceived that the dense cattail stands negatively impacted their well-being. The impacts they mentioned are similar those caused by water hyacinth. Additionally, the respondents mentioned that the rhizomatous roots of the cattails (*T. domingensis*) attracted elephants to the lake, often causing human–wildlife conflicts:

> The cattails have covered most of the lake's shoreline, and Mkwajuni beach is the only place with an open landing site. In other areas, we access the open lake through pathways created by hippopotamuses and elephants. Some villagers have been attacked by elephants that come to the lake to eat makuruvira (the cattails) roots.

(Respondent number 16, male, Kachero, Lake Jipe)

In all study locations, respondents pointed out that floating macrophyte islands, which had detached from the shores, destroyed fishing gears and translocated domestic and wild animals. Age negatively correlated with knowledge of how macrophytes directly affected human well-being, but the correlation was not significant (Table 6 and Figure 3D). Gender, level of education, occupation, frequency of lake visits and residence time did not associate with knowledge of how macrophytes negatively impacted humans.

3.3.3 | Local people's Macrophyte Management Practices

3.3.3.1 | Harvesting and Propagation of Macrophyte Species. Majority of the respondents (86.90% of the 145 respondents) were aware that some members of their community harvested macrophytes either for sale or personal use. According to these respondents, their harvesting practices involved taking what they only needed and leaving behind the roots, rhizomes and stumps. On the other hand, only a handful of respondents (4 out of the 133 respondents) had information about macrophyte propagation in their locality. These respondents, who were from the Nyanza Gulf of Lake Victoria, mentioned that small densities of water lettuce were cultivated in small dams to purify water. These respondents also noted that some fishpond owners cultivated water lettuce in their ponds to diversify the fish diet, serve as breeding sites for fish and shelter the fish from strong sunlight:

TABLE 6 | Results of the generalised linear mixed-effect models that tested for associations between the sociodemographic characteristics of the respondents and their knowledge of various ecosystem (dis)services and management practices of freshwater macrophyte species.

	Ecosystem service						Ecosystem disservices				Management practices					
	Provisioning		Supporting		Regulatory		Direct impacts on human		Effects on aquatic biodiversity		Harvesting practices		Propagation		Control methods	
Factor	*F*	*p*	*F*	*p*	*F*	*p*	*F*	*p*	*F*	*p*	*F*	*p*	*F*	*p*	*F*	*p*
Gender	3.32	**0.04**	7.02	**0.01**	0.15	0.6	0.62	0.3	3.34	0.11	0.03	0.54	0	0.3	0.01	0.57
Education	0.72	0.62	0.61	0.1	0.06	0.63	0.66	0.25	0.57	0.43	1.51	0.16	0.29	0.81	0.49	0.28
Occupation	0.13	0.6	0	0.78	0.09	0.97	0.01	0.83	0.75	0.38	0.24	0.57	0.07	0.59	3.86	0.11
Lake visits	1.25	0.34	0.85	0.39	0.45	0.64	0.15	0.89	0.22	0.75	3	0.07	0.42	0.66	0.18	0.68
Residence	0.28	0.59	5.71	0.54	0.24	0.31	0.59	0.85	0.93	0.92	2.26	0.06	0	0.09	1.06	0.66
Age	0.03	0.86	4.14	**0.04**	4.77	**0.03**	5.08	**0.02**	1.33	0.26	1.17	0.3	0	0.14	3.78	0.05

Note: The p values highlighted in bold print are significant ($p < 0.05$).

> Macrophytes regenerate quickly after harvesting so there is no need to propagate them. But we leave the roots, rhizomes, and stumps on the ground so that they can grow back. Also, we do not store macrophytes. We just harvest what is enough at that time.
>
> (Respondent number 93, Male, Kokwa Island, Lake Baringo)

None of the social demographic characteristics significantly associated with knowledge of macrophyte harvesting and propagation practices (Table 6).

3.3.3.2 | Methods of Manipulating Diversity and Abundance of Macrophyte Species. Out of the 144 respondents, 50.69% of them mentioned that they only controlled macrophyte species that they perceived to be problematic. In Lake Jipe, the cattails were either burned, manually uprooted, slashed or sprayed with herbicides:

> Slash and burn are the main methods of controlling the cattails. Other methods include spraying the cattails with Round-Up [a herbicide] or manually digging them up. These methods only open small spaces so that we can access water or clear paths to the open lake. Previously, we manually dug up the cattails that had blocked the mouth of River Lumi and the river started emptying into the Lake again. However, the macrophyte grew back and caused the river to divert its course.
>
> (Respondent number 4, male, Kachero, Lake Jipe)

In both Lake Baringo and Nyanza Gulf of Lake Victoria, water hyacinth was manually harvested, dumped on land to dry up and later buried or burnt:

> When water hyacinth covered this area [Kampi Samaki], we organized ourselves [worked as a team] and manually harvested the macrophyte. Later, the County Government of Baringo facilitated the manual harvesting exercise by offering food for work incentives and providing boats, gloves, rakes, and wheelbarrows. This method significantly reduced the water hyacinth density.
>
> (Respondent number 94, male, Kampi Samaki, Lake Baringo)

In addition to manual harvesting, residents from Nyanza Gulf of Lake Victoria were aware that biological and mechanical methods were also being used to control water hyacinth:

> The Government of Kenya set up a rearing unit for water hyacinth weevils [*Neochetina eichhorniae* Warner], trained us how to rear them, and facilitated weevil distribution to various parts of the Lake. Although the project stalled, the weevils are still on the plants. I am also aware of a water hyacinth harvester

in Kisumu. Unfortunately, these methods have not controlled the macrophyte. Only strong winds can control the macrophyte [by blowing them away].

(Respondent number 108: male, Asembo Bay, Nyanza Gulf)

None of the respondents' characteristics were significantly correlated with their knowledge of macrophyte management practices (Table 6).

4 | Discussion

How people comprehend biodiversity and its related issues often determine whether they support conservation activities (Hooykaas et al. 2019, 2022). Therefore, examining local people's species literacy levels, understanding and perceptions of freshwater macrophytes might provide insights into the people's relationships with the resources. Such information can assist ecosystem managers in making education and conservation programmes for freshwater macrophytes. In this regard, the current study examined how local people living adjacent to Lake Baringo, Nyanza Gulf of Lake Victoria and the Kenyan side of Lake Jipe understood macrophyte species that occurred in their ecosystem.

4.1 | Macrophyte Species Literacy

Our respondents recognised an average of six macrophyte species, which accounts for approximately 20% and 15% of the macrophyte species previously inventoried in Lake Baringo and Nyanza Gulf of Lake Victoria, respectively (Omondi and Gichuki 2000; Ondiba et al. 2018). Although there is no preexisting macrophyte species inventory for Lake Jipe to compare our result with, this result implies low macrophyte species recognition skills among the local people. This observation is consistent with other studies that have demonstrated that local people's species identification rates are often less than 50% of those identified by scientists (Berkström et al. 2019; Braga-Pereira et al. 2022). Evaluation of macrophyte recognition skills in the context of the respondents' sociodemographic characteristics revealed that respondents who derived their livelihoods from nonfishing activities named more macrophytes than their counterparts who derived their livelihoods from fishing and fish-related activities. Our results also showed that frequent visitors to the lake (four to six times a week) named more macrophyte species than fellow respondents who visited the lake either daily or occasionally (≤3 times a week). These two observations suggest that personal interests or lack of it might have played a role in local people's macrophyte recognition skills (Hooykaas et al. 2019; Randler and Heil 2021). Macrophyte recognition skills also varied according to age, with older respondents identifying more macrophyte species than the younger ones, a result that reinforces the belief that local knowledge accumulates over time (Warburton and Martin 1999; Olsson and Folke 2001). Overall, diminishing reliance on wetlands, possibly due to access to modern alternatives for some of the ecosystem services that wetlands provide and apathy towards macrophytes (see Ferreira Júnior et al. 2016; Aswani, Lemahieu, and Sauer 2018; Gómez-Baggethun 2022) could have contributed to low macrophyte naming skills among younger respondents.

Our results also showed that most local people were aware of changes in macrophyte species' abundance, an indication that local people living close to freshwater lakes can be an invaluable source of information about macrophyte trends in their ecosystem. This finding corroborates the results of other studies that have shown that local people can be important sources of information about various abiotic and biotic changes that have occurred in their ecosystems (Braga-Pereira et al. 2022; Nunes et al. 2023). Concerning alien macrophyte species, most respondents from Lake Baringo (75.15%) perceived *E. crassipes* as alien in their ecosystem. This perception may be attributed to the fact that the species' rapid proliferation along with its associated negative impacts only became evident in the recent decade (<10 years ago), prompting many locals to take notice. On the other hand, only 10.23% of the respondents from Nyanza Gulf of Lake Victoria identified water hyacinth as an alien species. This result may be attributed to the macrophyte's extensive historical presence in Lake Victoria (more than 30 years) (Witt and Quentin 2017), leading to assumptions that the macrophyte is native. Moreover, we noticed that our respondents failed to recognise other known alien macrophyte species (e.g., *A. sessilis*, *L. perpusilla* and *P. stratiotes*), possibly because these species occurred in small populations hence unnoticeable, limited awareness on the alien species concept and apathy towards such species (Jubase, Shackleton, and Measey 2021). Generally, macrophyte species literacy skills were skewed towards species that the respondents perceived to be either beneficial or problematic to the local people, which is consistent with findings from other studies that have shown that people are more likely to be knowledgeable of natural resources that directly impact them (Warburton and Martin 1999; Ouko et al. 2018; Kimpouni et al. 2021; Jubase, Shackleton, and Measey 2021). We infer that the local people's low macrophyte naming skills, their inability to distinguish species with similar morphology, as well as their limited capacity to recognise alien macrophyte species, indicate gaps in macrophyte species literacy among wetland users in these three ecosystems.

4.2 | Local people's Perceptions of Freshwater Macrophytes

4.2.1 | Macrophyte Ecosystem Services

The material benefits that local people derived from macrophytes were the most frequently identified ecosystem service, a result consistent with findings from other studies that have shown that local people are more knowledgeable of the provisioning services they obtain from a natural resource (Ouko et al. 2018; Kimpouni et al. 2021). The material benefits the respondents mentioned are synonymous with those reported in studies conducted in Lake Victoria's Lower Sondu Miriu wetland (Gichuki et al. 2001) and Loboi wetland in Baringo County (Terer et al. 2012). However, we observed three use patterns unique to each study location. Firstly, using macrophytes as food and fodder was more pronounced in Lake Baringo, and this can be attributed to frequent droughts in the area (Terer et al. 2012; Omondi et al. 2016). Because of the cyclic nature of the droughts, gathering seeds and tubers of water lilies and the cattails' rhizomes usually starts long before the dry season begins. Secondly, we noted that the residents of Lake Jipe did not use macrophytes for fuel, possibly because the locals could get firewood from Tsavo West National Park. Moreover, abundant mesquite (*Prosopis juliflora*) offered alternative fuel sources to the locals. Thirdly, the usage of macrophytes to rear fish in ponds and to purify borehole water was unique to the locals of the Nyanza Gulf of Lake Victoria, where water pollution (Simiyu et al. 2022; van den Broek 2019), eutrophication (Simiyu et al. 2022) and dense mats of invasive *E. crassipes* (Gichuki et al. 2001) and overfishing (Awange and Ong'ang'a 2006; van den Broek 2019) have altered the Gulf's ecosystem.

The supporting and regulatory ecosystem services identified by the respondents align closely with those documented in prior studies conducted in various locations, including Nyando Wetland (Raburu, Okeyo-Owuor, and Kwena 2012), Sudan (Ali 2009), Ethiopia (Desta 2021) and Ghana (Abobi et al. 2015). However, the identification rates for these two ecosystem services was quite low, a result that is comparable to preceding studies that have shown that local people have low identification rates for supporting and regulating ecosystem services (see Ouko et al. 2018; Gouwakinnou et al. 2019; Kimpouni et al. 2021). Interestingly, most people could not identify the role that macrophytes played in ensuring continuity of fish populations, a major source of protein and livelihood for local people living adjacent to these lakes (Ndetei 2006; Omondi et al. 2014; Etiegni, Irvine, and Kooy 2020). Similarly, most respondents could not identify the role of macrophytes in reducing silt deposition into the lakes, which is a leading cause of poor water quality in all three study locations (Awange and Ong'ang'a 2006; Ngugi, Ogindo, and Ertsen 2015; Omondi et al., 2016). Our results showed that more males than females knew the various provisioning and supporting ecosystem services that macrophytes offered, and this could be because men in the study areas played a greater role in utilising wetland resources (Raburu, Okeyo-Owuor, and Kwena 2012). Additionally, older respondents appeared to be more knowledgeable about the various supporting and regulatory ecosystem services that macrophytes offered, and this could be because their macrophyte experiences had accumulated over time (Olsson and Folke 2001).

Information that the Njemps, Pokots and Ilchamus ethnic groups living around Lake Baringo used papyrus umbels as decorations during cultural ceremonies has been previously documented among the Endorois people of the Loboi area, Baringo County (Terer et al. 2012). On the other hand, no previous study had documented that a section of locals living around Nyanza Gulf of Lake Victoria used wild cowpeas for decorations during religious festivals.

4.2.2 | Macrophyte Ecosystem Disservices

Our respondents identified a variety of macrophyte ecosystem disservices, similar to those reported by wetland users in the Hadejia-Nguru Wetlands in Nigeria (Ringim, Sabo, and Harry 2015), Lake Naivasha in Kenya (Waithaka 2013) and Lake Tana in Ethiopia (Enyew, Assefa, and Gezie 2020). Their primary attribution of these disservices to alien or range-expanding macrophyte species aligns with findings from earlier studies (van den Broek 2019; Desta 2021). Moreover, we observed high recognition rates for macrophyte ecosystem disservices that directly affected human well-being but lower identification rates for those that either indirectly affected well-being or negatively impacted other components of the lakes. Notably, responses regarding the impacts of macrophytes on biodiversity were biased towards the negative effects of invasive alien or range-expanding macrophyte species on fish populations, which are valuable resources among wetland users (Awange and Ong'ang'a 2006; Ndetei 2006; Odada, Onyando, and Obudho 2006). This result is consistent with findings from similar studies (Waithaka 2013; Ringim, Sabo, and Harry 2015; Enyew, Assefa, and Gezie 2020), and it reinforces the belief that local people are more knowledgeable of species that directly impact them (Millenium Ecosystem Assessment 2005; Shackleton et al. 2016). From the focus group discussions, we found out that these ecosystem disservices increased the local people's cost of living, as locals had to incur extra fishing costs, purchase water for domestic use, seek treatment for malaria and bilharziasis (diseases associated with dense macrophyte communities) and seek alternative modes of transportation, which often were costlier than water transportation. Knowledge of the macrophyte ecosystem disservices was associated with age, possibly due to accumulation of macrophyte experiences (Olsson and Folke 2001).

4.3 | Local people's Macrophyte Management Practices

The local people's macrophyte management practices documented here have also been reported as those adopted by other communities living close to Lake Naivasha in Kenya (Waithaka 2013) and Lake Tana in Ethiopia (Enyew, Assefa, and Gezie 2020). While the success rates of these management practices varied from one lake to another, it was interesting to note that respondents from the Nyanza Gulf of Lake Victoria perceived that only strong winds could control water hyacinth in the Gulf. This perception contradicts science-based monitoring studies that attributed the decline of water hyacinth in the Gulf to the 1997/1998 El Niño event and biological control agents (Wilson et al. 2007). In all our study locations, the local people's macrophyte management methods focused on reducing the ecosystem disservices caused by alien or range-expanding macrophyte species, a result that supports views by Shackleton et al. (2016) and Blanco et al. (2019) that people's actions towards a natural resource are often driven by their perceptions of ecosystem disservices rather than ecosystem services. Although macrophytes provided various benefits to the local people, there were no management practices aimed at conserving macrophytes, which may indicate that the locals had little regard for these resources, did not use macrophytes or did not perceive that the macrophytes were under threat. However, we noted that their practice of harvesting what they needed and leaving behind the stumps, roots and rhizomes indirectly ensured continuity of macrophyte communities.

4.4 | Implications of the Current Study on the Sustainable use and Management of Freshwater Macrophytes

Our respondents noted that dense and extensive mats of *T. domingensis* and *E. crassipes* on the Kenyan side of Lake Jipe and Nyanza Gulf of Lake Victoria, respectively, caused a variety of ecological and socioeconomic problems. Therefore, we recommend controlling these macrophyte species. Our study also revealed that local people in our study locations had neglected macrophytes, highlighting a wetland management shortfall. This issue is further aggravated by limited institutional involvement in macrophyte conservation, along with the absence of direct policies and clear frameworks for addressing the sustainable management of freshwater macrophytes. Considering that ongoing climate change (IPCC 2023) might interact with ever-increasing anthropogenic stressors, impacting the richness, abundance and distribution of macrophyte species (Short et al. 2016; Lozano 2021), addressing this neglect is imperative. In this regard, we recommend raising awareness about the ecological importance of freshwater macrophytes, developing policies that directly address sustainable macrophyte management and integrating macrophyte management into broader lake resource management strategies. Integrating local people into these management programmes will not only leverage local people's macrophyte knowledge and expertise but also enable them to assist in monitoring macrophyte changes as well as implementing conservation programme.

4.5 | Future Research Considerations

In Kenya, freshwater macrophytes have been scantily studied, resulting in a limited understanding of their richness, diversity, ecology, drivers of degradation, as well as their socioeconomic importance. This limitation makes it difficult to advise policymaking and design and implement ecosystem-specific sustainable macrophyte management practices. Therefore, multifaceted collaborative research, employing both local knowledge and conventional scientific methods, can fill the existing knowledge gaps regarding freshwater macrophytes. Considering that some local people generate income from macrophytes, there is a possibility that livelihood diversification through the commercialisation of provisioning ecosystem services can alleviate pressure on the already declining fish stocks in these lakes—the primary livelihood for wetland communities (Ndetei 2006; Nyakeya et al. 2020; Nyamweya et al. 2022). However, studies that quantify and value the provisioning ecosystem services macrophytes offer, evaluate the factors that support or hinder the commercialisation of freshwater macrophyte use and predict the ecological implications of such commercialisation can provide insights into the feasibility of such ventures These studies should be extended to neighbouring countries that share a transboundary water body.

4.6 | Conclusion

Our results showed that local people had some form of knowledge concerning the macrophyte species present in their wetlands, the ecosystem (dis)services that the macrophytes offered and management practices for problematic macrophyte species. The respondents' macrophyte recognition skills were significantly correlated with their occupation and frequency of visits to the lake, while knowledge of provisioning and supporting services, ecosystem disservices that directly affected humans, and macrophyte control methods were all associated with age. Although future research with larger sample sizes can validate and strengthen these correlations, our results give insights into how local people perceive and understand freshwater macrophyte and this information can be used to guide macrophyte conservation activities at the grassroot levels. However, there is need to fill the knowledge gaps concerning macrophyte species literacy, the indirect (dis)services provided by macrophytes and the importance of conserving these resources. Filling these knowledge gaps may increase positive attitudes towards freshwater macrophytes and cause local people to support macrophyte management programmes.

Acknowledgements

We thank our field assistant Sarah Bitengo Atera, local guides, village elders and respondents in Lake Baringo, the Nyanza Gulf of Lake Victoria and Lake Jipe. We are grateful to Dr Evance Omondi Mbao who provided useful comments on the manuscript. Approval for the study was granted by National Commission for Science, Technology, and Innovation of Kenya (NACOSTI) (permit number NACOSTI/P/22/15279).

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

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

References

Abobi, S. M., T. A. Kpodonu, E. H. Alhassan, et al. 2015. "Socio-Ecological Importance of Aquatic Macrophytes to Some Fishing Communities in the Northern Region of Ghana." *Elixir Bio Diver* 79: 30432–30437.

Ahoyo, C. C., K. V. Salako, T. D. Houéhanou, I. Montcho, R. L. Glèlè Kakaï, and M. R. B. Houinato. 2023. "Sociodemographic, Environmental and Biological Factors Affecting Uses of Plants From Open Ecosystems: Insights for Improved Livelihoods and Biodiversity Conservation." *Frontiers in Conservation Science* 4: 1127567. https://doi.org/10.3389/fcosc.2023.1127567.

Ali, O. M. M. 2009. "Aquatic Plants of The Sudan." In *The Nile: Origin, Environments, Limnology, and Human Use*, edited by H. J. Dumont, 479–494. Netherlands: Springer Science+Business Media. https://doi.org/10.1007/978-1-4020-9726-3_23.

Angoh, S. Y. J., J. Freeland, J. Paterson, P. A. Rupasinghe, and C. M. Davy. 2021. "Effects of Invasive Wetland Macrophytes on Habitat Selection and Movement by Freshwater Turtles." *Biological Invasions* 23, no. 7: 2271–2288. https://doi.org/10.1007/s10530-021-02505-8.

Arthington, A. H. 2021. "Grand Challenges to Support the Freshwater Biodiversity Emergency Recovery Plan." *Frontiers in Environmental Science* 9: 664313. https://doi.org/10.3389/fenvs.2021.664313.

Aswani, S., A. Lemahieu, and W. H. H. Sauer. 2018. "Global Trends of Local Ecological Knowledge and Future Implications." *PLoS One* 13, no. 4: e0195440. https://doi.org/10.1371/journal.pone.0195440.

Awange, J. L., and O. Ong'ang'a. 2006. *Lake Victoria: Ecology, Resources, and Environment*. Netherlands: Springer Berlin Heidelberg.

Bates, D., M. Maechler, B. Bolker, et al. 2020. *Linear Mixed-Effects Model Using "Eigen" and S4*. The R Development Core Team. The Comprehensive R Archive Network. https://cran.r-project.org/web/packages/lme4/lme4.pdf.

Bennett, N. J. 2016. "Using Perceptions as Evidence to Improve Conservation and Environmental Management." *Conservation Biology* 30, no. 3: 582–592. https://doi.org/10.1111/cobi.12681.

Berkström, C., M. Papadopoulos, N. S. Jiddawi, and L. M. Nordlund. 2019. "Fishers' Local Ecological Knowledge (LEK) on Connectivity and Seascape Management." *Frontiers in Marine Science* 6: 130. https://doi.org/10.3389/fmars.2019.00130.

Blanco, J., N. Dendoncker, C. Barnaud, and C. Sirami. 2019. "Ecosystem Disservices Matter: Towards Their Systematic Integration Within Ecosystem Service Research and Policy." *Ecosystem Services* 36: 100913. https://doi.org/10.1016/j.ecoser.2019.100913.

Bogner, C., and K. Landrock. 2016. "Response Biases in Standardised Surveys." In *GESIS Survey Guidelines*. Mannheim, Germany: GESIS–Leibniz Institute for the Social Sciences. https://doi.org/10.15465/gesis-sg_en_016.

Bolisani, E., and C. Bratianu. 2018. "The Elusive Definition of Knowledge." In *Emergent Knowledge Strategies. Knowledge Management and Organizational Learning*, edited by E. Bolisani and C. Bratianu, 1–22. Switzerland: Springer Cham. https://doi.org/10.1007/978-3-319-60657-6_1.

Braga-Pereira, F., T. Q. Morcatty, H. R. El Bizri, et al. 2022. "Congruence of Local Ecological Knowledge (LEK)-Based Methods and Line-Transect Surveys in Estimating Wildlife Abundance in Tropical Forests." *Methods in Ecology and Evolution* 13, no. 3: 743–756. https://doi.org/10.1111/2041-210X.13773.

Buckley, S., K. Hardy, F. Hallgren, et al. 2023. "Human Consumption of Seaweed and Freshwater Aquatic Plants in Ancient Europe." *Nature Communications* 14: 6192. https://doi.org/10.1038/s41467-023-41671-2.

Caraco, N., J. Cole, S. Findlay, and C. Wigand. 2006. "Vascular Plants as Engineers of Oxygen in Aquatic Systems." *Bioscience* 56, no. 3: 219–225. https://doi.org/10.1641/0006-3568(2006)056[0219:VPAEOO]2.0.CO;2.

Cebrián-Piqueras, M. A., A. Filyushkina, D. N. Johnson, et al. 2020. "Scientific and Local Ecological Knowledge, Shaping Perceptions Towards Protected Areas and Related Ecosystem Services." *Landscape Ecology* 35, no. 11: 2549–2567. https://doi.org/10.1007/s10980-020-01107-4.

Chambers, P., P. Lacoul, K. J. Murphy, and S. M. Thomaz. 2008. "Global Diversity of Aquatic Macrophytes in Freshwater." *Hydrobiologia* 595: 9–26. https://doi.org/10.1007/s10750-007-9154-6.

Christie, H., G. S. Andersen, L. A. Tveiten, and F. E. Moy. 2022. "Macrophytes as Habitat for Fish." *ICES Journal of Marine Science* 79, no. 2: 435–444. https://doi.org/10.1093/icesjms/fsac008.

Currin, C. 2019. "Living Shorelines for Coastal Resilience." In *Coastal Wetlands*, edited by G. M. E. Perillo, E. Wolanski, D. R. Cahoon, and C. S. Hopkinson, 2nd ed., 1023–1053. Netherlands, United Kingdom, United States of America: Elsevier. https://doi.org/10.1016/B978-0-444-63893-9.00030-7.

Desautels, D. J., R. B. Hartman, K. E. Shaw, S. Maduraiveeran, and D. J. Civitello. 2022. "Divergent Effects of Invasive Macrophytes on Population Dynamics of a Snail Intermediate Host of *Schistosoma mansoni*." *Acta Tropica* 225: 106226. https://doi.org/10.1016/j.actatropica.2021.106226.

Desta, H. 2021. "Local Perceptions of Ecosystem Services and Human-Induced Degradation of Lake Ziway in the Rift Valley Region of Ethiopia." *Ecological Indicators* 127: 107786. https://doi.org/10.1016/j.ecolind.2021.107786.

DiCicco-Bloom, B., and B. F. Crabtree. 2006. "The Qualitative Research Interview." *Medical Education* 40, no. 4: 314–321. https://doi.org/10.1111/j.1365-2929.2006.02418.x.

Eldh, A. C., L. Årestedt, and C. Berterö. 2020. "Quotations in Qualitative Studies: Reflections on Constituents, Custom, and Purpose." *International Journal of Qualitative Methods* 19: 1–6. https://doi.org/10.1177/1609406920969268.

Enyew, B. G., W. W. Assefa, and A. Gezie. 2020. "Socioeconomic Effects of Water Hyacinth (*Eichhornia crassipes*) in Lake Tana, North Western Ethiopia." *PLoS One* 15, no. 9: e023766. https://doi.org/10.1371/journal.pone.0237668.

Etiegni, C. A., K. Irvine, and M. Kooy. 2020. "Participatory Governance in Lake Victoria (Kenya) Fisheries: Whose Voices Are Heard?" *Maritime Studies* 19, no. 4: 489–507. https://doi.org/10.1007/s40152-020-00195-x.

Fernández-llamazares, A., C. Geralda, S. Eduardo, et al. 2022. "Scientists' Warning to Humanity on Threats to Indigenous and Local Knowledge Systems." *Journal of Ethnobiology* 41, no. 2: 144–169. https://doi.org/10.2993/0278-0771-41.2.144.

Ferreira Júnior, W. S., F. R. Santoro, I. Vandebroek, and U. P. Albuquerque. 2016. "Urbanization, Modernization, and Nature Knowledge." In *Introduction to Ethnobiology*, edited by R. Albuquerque and U. Nóbrega Alves, 1–310. Switzerland: Springer Cham. https://doi.org/10.1007/978-3-319-28155-1.

Fynn, R. W. S., M. Murray-Hudson, M. Dhliwayo, and P. Scholte. 2015. "African Wetlands and Their Seasonal Use by Wild and Domestic Herbivores." *Wetlands Ecology and Management* 23, no. 4: 559–581. https://doi.org/10.1007/s11273-015-9430-6.

Gichuki, J., F. D. Guebas, J. Mugo, C. O. Rabuor, L. Triest, and F. Dehairs. 2001. "Species Inventory and the Local Uses of the Plants and Fishes of the Lower Sondu Miriu Wetland of Lake Victoria, Kenya." *Hydrobiologia* 458: 99–106. https://doi.org/10.1023/A:1013192330498.

Gómez-Baggethun, E. 2022. "Is There a Future for Indigenous and Local Knowledge?" *Journal of Peasant Studies* 49, no. 6: 1139–1157. https://doi.org/10.1080/03066150.2021.1926994.

Gouwakinnou, G. N., S. Biaou, F. G. Vodouhe, M. S. Tovihessi, B. K. Awessou, and H. S. S. Biaou. 2019. "Local Perceptions and Factors Determining Ecosystem Services Identification Around Two Forest Reserves in Northern Benin." *Journal of Ethnobiology and Ethnomedicine* 15, no. 1: 61. https://doi.org/10.1186/s13002-019-0343-y.

Government of Kenya. 2010. *The Constitution of Kenya, 2010*. Nairobi, Kenya: National Council for Law Reporting.

Government of Kenya. 2021. Kenya State of Environment Report 2019–2021 Nairobi, Kenya.

Hatty, M., D. Goodwin, L. Smith, and F. Mavondo. 2022. "Speaking of Nature: Relationships Between How People Think About, Connect With, and Act to Protect Nature." *Ecology and Society* 27, no. 3: 17. https://doi.org/10.5751/ES-13369-270317.

He, Y., K. Zhao, H. Zhang, et al. 2021. "Linking Macrophyte Community Structure With Food Chain Length: A Case Study in the Largest Freshwater Lake in China and Ecological Restoration Implications." *Ecological Indicators* 123: 107363. https://doi.org/10.1016/j.ecolind.2021.107363.

Hooykaas, M. J. D., M. Schilthuizen, C. J. Albers, and I. Smeets. 2022. "Species Identification Skills Predict in-Depth Knowledge About Species." *PLoS One* 17, no. 4: e0266972. https://doi.org/10.1371/journal.pone.0266972.

Hooykaas, M. J. D., M. Schilthuizen, C. Aten, E. M. Hemelaar, C. J. Albers, and I. Smeets. 2019. "Identification Skills in Biodiversity Professionals and Laypeople: A Gap in Species Literacy." *Biological Conservation* 238: 108202. https://doi.org/10.1016/j.biocon.2019.108202.

IPCC. 2023. "Summary for Policymakers." In *Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, edited by T. Core Writing, H. Lee, and J. Romero, 1–34. Geneva, Switzerland: IPCC. https://doi.org/10.59327/IPCC/AR6-9789291691647.001.

Jubase, N., R. T. Shackleton, and J. Measey. 2021. "Public Awareness and Perceptions of Invasive Alien Species in Small Towns." *Biology* 10: 1322. https://doi.org/10.3390/biology10121322.

Karnad, D. 2022. "Incorporating Local Ecological Knowledge Aids Participatory Mapping for Marine Conservation and Customary Fishing Management." *Marine Policy* 135: 104841. https://doi.org/10.1016/j.marpol.2021.104841.

Kassa, Y., S. Mengistu, A. Wondie, and D. Tibebe. 2021. "Distribution of Macrophytes in Relation to Physico-Chemical Characters in the South Western Littoral Zone of Lake Tana, Ethiopia." *Aquatic Botany* 170: 103351. https://doi.org/10.1016/j.aquabot.2020.103351.

Kenya National Bureau of Statistics. 2019. 2019 Kenya Population and Housing Census. In Population by County and Sub-County: Vol. I. https://www.knbs.or.ke/?wpdmpro=2019-kenya-population-and-housing-census-volume-i-population-by-county-and-sub-county.

Kimpouni, V., J. D. D. Nzila, N. Watha-Ndoudy, M. I. Madzella-Mbiemo, S. Yallo Mouhamed, and J. P. Kampe. 2021. "Exploring Local people's Perception of Ecosystem Services in Djoumouna Periurban Forest, Brazzaville, Congo." *International Journal of Forestry Research* 2021: 6612649. https://doi.org/10.1155/2021/6612649.

Lozano, V. 2021. "Distribution of Five Aquatic Plants Native to South America and Invasive Elsewhere Under Current Climate." *Ecologies* 2: 27–42. https://doi.org/10.3390/ecologies2010003.

Maua, J. O., M. T. E. Mbuvi, P. Matiku, S. Munguti, E. Mateche, and M. Owili. 2022. "The Difficult Choice–To Conserve the Living Filters or Utilizing the Full Potential of Wetlands: Insights From the Yala Swamp, Kenya." *Environmental Challenges* 6: 100427. https://doi.org/10.1016/j.envc.2021.100427.

McGregor, S., V. Lawson, P. Christophersen, et al. 2010. "Indigenous Wetland Burning: Conserving Natural and Cultural Resources in Australia's World Heritage-Listed Kakadu National Park." *Human Ecology* 38: 721–729. https://doi.org/10.1007/s10745-010-9362-y.

Millenium Ecosystem Assessment. 2005. *Ecosystems and Human Well-Being: Current State and Trend*, edited by H. Rashid, S. Robert, and A. Neville, vol. 1. Washington: Island Press.

Morrison, E. H. J., C. Upton, K. Odhiambo-K'oyooh, and D. M. Harper. 2012. "Managing the Natural Capital of Papyrus Within Riparian Zones of Lake Victoria, Kenya." *Hydrobiologia* 692: 5–17. https://doi.org/10.1007/s10750-011-0839-5.

National Environment Management Authority (NEMA). 2011. *Integrated National Land use Guidelines: For a Sustained Societal Attributes-Infrastructure, Environmental Resources and Public Safety*. Nairobi, Kenya: NEMA. ISBN: 9966-7460-2-1.

Ndalilo, L. A., B. K. Kirui, and E. K. Maranga. 2020. "Socio-Economic Drivers of Degradation and Their Implication on Conservation of River Lumi Riparian Ecosystem in Kenya." *Open Journal of Forestry* 10: 307–319. https://doi.org/10.4236/ojf.2020.103020.

Ndetei, R. 2006. "The Role of Wetlands in Lake Ecological Functions and Sustainable Livelihoods in Lake Environment: A Case Study on Cross Border Lake Jipe - Kenya/Tanzania." In *Proceedings of the 11th World Lakes Conference*, edited by D. O. Odada and Eric & Olago, vol. 2, 162–168. Nairobi, Kenya: Kenyan Ministry of Water and Irrigation and The International Lake Environment Committee. http://hdl.handle.net/1834/1492.

Ngugi, K., H. Ogindo, and M. Ertsen. 2015. "Impact of Land use Changes on Hydrology of Mt. Kilimanjaro: The Case of Lake Jipe Catchment." *Geophysical Research Abstracts* 17: EGU201. https://ui.adsabs.harvard.edu/abs/2015EGUGA..17.4526N/abstract.

Nunes, C. B., K. C. Vieira, P. E. Pereyra, G. Hallwass, C. V. Cunha, and R. A. Silvano. 2023. "'From the Sky to the Ground': Fishers' Knowledge, Landscape Analysis and Hydrological Data Indicate Long-Term Environmental Changes in Amazonian Clear Water Rivers." *Science of the Total Environment* 904: 166763. https://doi.org/10.1016/j.scitotenv.2023.166763.

Nyakeya, K., E. Chemoiwa, J. M. Nyamora, et al. 2020. "Endemic Lake Baringo *Oreochromis niloticus* Fishery on Verge of Collapse: Review of Causes and Strategies Directed to Its Recovery, Conservation and Management for Sustainable Exploitation." *Lakes & Reservoirs: Science, Policy and Management for Sustainable Use* 25, no. 4: 423–438. https://doi.org/10.1111/lre.12344.

Nyamweya, C. S., H. M. Nyaboke, C. M. Aura, et al. 2022. "Lake Victoria's Bounty: A Case for Riparian countries' Blue Economic Investment." *Frontiers in Environmental Science* 10: 952654. https://doi.org/10.3389/fenvs.2022.952654.

Nyingi, D. W., N. Gichuki, and M. O. Ogada. 2013. "Freshwater Ecology of Kenyan Highlands and Lowlands." In *Developments in Earth Surface Processes*, edited by P. Paron, D. O. Olago, and C. T. Omuto, vol. 16, 1st ed., 199–218. Oxford and Amsterdam: Elsevier B.V. https://doi.org/10.1016/B978-0-444-59559-1.00016-5.

Nyumba, T. O., K. Wilson, C. J. Derrick, and N. Mukherjee. 2018. "The Use of Focus Group Discussion Methodology: Insights From Two Decades of Application in Conservation." *Methods in Ecology and Evolution* 9, no. 1: 20–32. https://doi.org/10.1111/2041-210X.12860.

Odada, E. O., J. O. Onyando, and P. A. Obudho. 2006. "Lake Baringo: Addressing Threatened Biodiversity and Livelihoods." *Lakes & Reservoirs: Research and Management* 11: 287–299. https://doi.org/10.1111/j.1440-1770.2006.00309.x.

Olsson, P., and C. Folke. 2001. "Local Ecological Knowledge and Institutional Dynamics for Ecosystem Management: A Study of Lake Racken Watershed, Sweden." *Ecosystems* 4: 85–104. https://doi.org/10.1007/s100210000061.

Omondi, R., and J. Gichuki. 2000. *Importance of Indeginous Macrophytes in Control of Water Hyacinth in the Nyanza Gulf of Lake Victoria, Kenya*. Kenya Marine and Fisheries Research Institute. https://aquadocs.org/handle/1834/6909.

Omondi, R., E. Kembenya, C. Nyamweya, H. Ouma, S. K. Machua, and Z. Ogari. 2014. "Recent Limnological Changes and Their Implication on Fisheries in Lake Baringo, Kenya." *Journal of Ecology and the Natural Environment* 6, no. 5: 154–163. https://doi.org/10.5897/jene2014.0438.

Omondi, R., W. Ojwang, C. Olilo, J. Mugo, S. Agembe, and J. E. Ojuok. 2016. "Lakes Baringo and Naivasha: Endorheic Freshwater Lakes of the Rift Valley Lakes (Kenya)." In *The Wetland Book*, edited by C. M. Finlayson et al. Dordrecht, Netherlands: Springer. https://doi.org/10.1007/978-94-007-6173-5.

Ondiba, R., R. Omondi, K. Nyakeya, J. Abwao, and E. Oyoo-okoth. 2018. "Environmental Constraints on Macrophyte Distribution and Diversity in a Tropical Endorheic Freshwater Lake." *International Journal of Fisheries and Aquatic Studies* 6, no. 3: 251–259.

Ouko, C. A., R. Mulwa, R. Kibugi, M. A. Owuor, J. G. Zaehringer, and N. O. Oguge. 2018. "Community Perceptions of Ecosystem Services and the Management of Mt. Marsabit Forest in Northern Kenya." *Environments–MDPI* 5, no. 11: 121. https://doi.org/10.3390/environments5110121.

Owuor, M. A., J. Icely, and A. Newton. 2019. "Community Perceptions of the Status and Threats Facing Mangroves of Mida Creek, Kenya: Implications for Community Based Management." *Ocean and Coastal Management* 175: 172–179. https://doi.org/10.1016/j.ocecoaman.2019.03.027.

Pelella, E., B. Questino, B. Luzi, F. Mariani, and S. Ceschin. 2023. "Impact of the Invasive Alien Macrophyte *Ludwigia hexapetala* on Freshwater Ecosystems: Evidence From Field Data." *Biology* 12, no. 794: 1–13. https://doi.org/10.3390/biology12060794.

Polasky, S. 2008. "Why Conservation Planning Needs Socioeconomic Data." *Proceedings of the National Academy of Sciences of the United*

States of America 105, no. 18: 6505–6506. https://doi.org/10.1073/pnas.0802815105.

Raburu, P. O., J. B. Okeyo-Owuor, and F. Kwena. 2012. *Community Based Approach to the Management of Nyando Wetland, Lake Victoria Basin, Kenya*. 1 ed. Nairobi, Kenya: KDC–VIRED–UNDP.

Randler, C., and F. Heil. 2021. "Determinants of Bird Species Literacy—Activity/Interest and Specialization Are More Important Than Socio-Demographic Variables." *Animals* 11: 1595. https://doi.org/10.3390/ani11061595.

Reitsema, R. E., P. Meire, and J. Schoelynck. 2018. "The Future of Freshwater Macrophytes in a Changing World: Dissolved Organic Carbon Quantity and Quality and Its Interactions With Macrophytes." *Frontiers in Plant Science Sec Functional Plant Ecology* 9, no. 629: 1–15. https://doi.org/10.3389/fpls.2018.00629.

Reyes-García, V. 2023. "Indigenous and Local Knowledge Contributions to Social-Ecological Systems' Management." In *The Barcelona School of Ecological Economics and Political Ecology, Studies in Ecological Economics*, edited by S. Villamayor-Tomas and R. S. Muradian, vol. 8, 71–81. Switzerland: Springer Cham. https://doi.org/10.1007/978-3-031-22566-6_7.

Ringim, A., B. B. Sabo, and H. Harry. 2015. "Implication of Invasive Plant *Typha domingensis* on Biodiversity: An Ecological Study of the Hadejia-Nguru wWetlands, Nigeria." *Journal of Biological Science* 4, no. 5: 40–46.

Salgado, J., M. I. Vélez, L. C. Cáceres-Torres, et al. 2019. "Long-Term Habitat Degradation Drives Tropical Macrophyte Species Loss While Assist the Spread of Invasive Plant Species." *Frontiers in Ecology and Evolution Sec Paleoecology* 7: 140. https://doi.org/10.3389/fevo.2019.00140.

Shackleton, C. M., S. Ruwanza, G. K. Sinasson Sanni, et al. 2016. "Unpacking Pandora's Box: Understanding and Categorising Ecosystem Disservices for Environmental Management and Human Wellbeing." *Ecosystems* 19, no. 4: 587–600. https://doi.org/10.1007/s10021-015-9952-z.

Short, F. T., S. Kosten, P. A. Morgan, S. Malone, and G. E. Moore. 2016. "Impacts of Climate Change on Submerged and Emergent Wetland Plants." *Aquatic Botany* 135: 3–17. https://doi.org/10.1016/j.aquabot.2016.06.006.

Silas, M. O., M. L. Semba, S. S. Mgeleka, L. Van Well, H. W. Linderholm, and M. Gullström. 2023. "Using Fishers' Local Ecological Knowledge for Management of Small-Scale Fisheries in Data-Poor Regions: Comparing Seasonal Interview and Field Observation Records in East Africa." *Fisheries Research* 264: 106721. https://doi.org/10.1016/j.fishres.2023.106721.

Silvano, R. A. M., I. G. Baird, A. Begossi, et al. 2023. "Fishers' Multidimensional Knowledge Advances Fisheries and Aquatic Science." *Trends in Ecology & Evolution* 38, no. 1: 8–12. https://doi.org/10.1016/j.tree.2022.10.002.

Simiyu, B. M., H. S. Amukhuma, L. Sitoki, W. Okello, and R. Kurmayer. 2022. "Interannual Variability of Water Quality Conditions in the Nyanza Gulf of Lake Victoria, Kenya." *Journal of Great Lakes Research* 48, no. 1: 97–109. https://doi.org/10.1016/j.jglr.2021.10.017.

Szałkiewicz, E., J. Sucholas, and M. Grygoruk. 2020. "Feeding the Future With the Past: Incorporating Local Ecological Knowledge in River Restoration." *Resources* 9: 47. https://doi.org/10.3390/resources9040047.

Taran, M., and S. Deb. 2020. "Utilization Pattern of Macrophytes in Rudrasagar Lake, a Ramsar Site in India." *Applied Ecology and Environmental Sciences* 8, no. 4: 179–186. https://doi.org/10.12691/aees-8-4-6.

Terer, T., A. M. Muasya, F. Dahdouh-Guebas, G. Ndiritu, and L. Triest. 2012. "Integrating Local Ecological Knowledge and Management Practices of an Isolated Semi-Arid Papyrus Swamp (Loboi, Kenya) into a Wider Conservation Framework." *Journal of Environmental Management* 93: 71–84. https://doi.org/10.1016/j.jenvman.2011.08.005.

Thomaz, S. M. 2023. "Ecosystem Services Provided by Freshwater Macrophytes." *Hydrobiologia* 850: 2757–2777. https://doi.org/10.1007/s10750-021-04739-y.

Truong, D. D. 2021. "Villagers' Perception and Attitude Toward Wetland Values and Conservation in Vietnam: A Case Study of Xuan Thuy Ramsar National Park." *Frontiers in Sociology* 6: 763743. https://doi.org/10.3389/fsoc.2021.763743.

United Nations Environmental Programme (UNEP). 2006. *Lake Voctoria Basin Environment Outlook: Environment and Development*. Nairobi, Kenya: UNEP.

van den Broek, K. L. 2019. "Stakeholders' Perceptions of the Socio-Economic and Environmental Challenges at Lake Victoria." *Lakes & Reservoirs: Research and Management* 24, no. 3: 239–245. https://doi.org/10.1111/lre.12275.

Waithaka, E. 2013. "Impacts of Water Hyacinth (*Eichhornia crassipes*) on the Fishing Communities." *Journal of Biodivers Endanger Species* 1, no. 2. https://doi.org/10.4172/.1000108.

Warburton, H., and A. Martin. 1999. "Local people's Knowledge in Natural Resources Research." In *Socio~Economic Methodologies for Natural Resources Research*. Chatham, United Kingdom: Natural Resources Institute.

Wilkinson, S. R., M. A. Naeth, and A. Dhar. 2023. "Potential of Macrophytes for Wastewater Remediation With Constructed Floating Wetlands in Cold Climates." *Watermark* 15: 2479. https://doi.org/10.3390/w15132479.

Wilson, J. R. U., O. Ajuonu, T. D. Center, et al. 2007. "The Decline of Water Hyacinth on Lake Victoria Was due to Biological Control by *Neochetina* spp." *Aquatic Botany* 87, no. 1: 90–93. https://doi.org/10.1016/j.aquabot.2006.06.006.

Witt, A., and L. Quentin. 2017. *Guide to the Naturalized and Invasive Plants of Eastern Africa*. Boston, MA: CABI.

World Commission on Environment and Development (WCED). 1987. Our Common Future. In Report of the World Commission on Environment and Development. https://doi.org/10.9774/gleaf.978-1-907643-44-6_12.