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Research article

Willingness to pay for the ecological restoration of an inland freshwater shallow lake: case of Lake Malombe, Malawi

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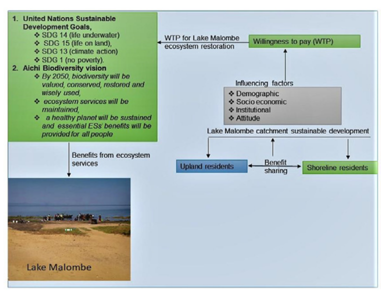
HIGHLIGHTS

- 420 WTP questionnaires were analyzed.
- Mean WTP was $28.42/yr.
- Many factors influenced WTP.

GRAPHICAL ABSTRACT



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ABSTRACT

Lake Malombe is ranked among the most vulnerable inland freshwater shallow lakes in Malawi. The lake has lost over US$79.83 million ecosystem service values from 1999 to 2019 due to rapid population growth, increased poverty, landscape transformation, and over exploitation-hampering the effort to achieve United Nations (UN) Sustainable Development Goals (SDGs), in particular, life underwater (SDG 14), life on land (SDG 15), climate action (SDG 13), and no poverty (SDG 1) and Aichi Biodiversity Targets. In line with the 2021–2030 United Nations' Declaration on massive upscaling of the ecosystems restoration effort, this study applied the contingent valuation method (CVM) and binary logistic regression model to determine the public's willingness to pay (WTP) for ecosystem restoration and the influencing factors. The aim was to integrate science into policy framework to achieve a sustainable flow of ecosystem services (ESs). Qualitative data were collected by employing focus group discussion, key informant interviews, and field observation. Quantitative data were collected using structured questionnaires covering 420 households. The results revealed that 56% of the respondents were willing to pay an average of US$28.42/household/year. These respondents believed that the initiative would improve lake ESs, fish biodiversity, income level, water quality and mitigate climate change impact. Age, gender, literacy, income, social trust, institutional trust, access to extension services, period stay in the area, household distance from the lake, lake ecological dynamics impact, having the hope of reviving the lake health ecological status, perception of having lake ecological restoration program, participation in lake restoration program, access to food from the

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lake, involved in fishing and Lake Malombe primary livelihood sources significantly ($p < 0.05$) influenced WTP. This study provides a reference point to policymakers to undertake cost-benefit analysis and develop a practical policy response framework to reverse the situation and achieve United Nations Sustainable Development Goals and Aichi Biodiversity Targets.

1. Introduction

The inland freshwater shallow lakes offer various ecosystem services (ESs) such as provisioning, regulating, supporting, cultural, and aesthetic services (Sterner et al., 2020; Makwinja et al., 2021a). The biodiversity and economic value of freshwater shallow lakes ecosystems are more important than many terrestrial ecosystems (Sterner et al., 2020). Lakes, rivers, streams, wetlands, and flood plains supply goods and services critical to humankind's survival (MEA 2005; Deffner and Haase 2018). They contribute US$12, 512 $\times 10^{12}$/year and US$25,681 $\times 10^{12}$ $/year compared to US$313-4166 $\times 10^{12}$/year for temperate forests and grasslands (Costanza et al., 2014; Vári et al., 2021). Various researchers have demonstrated the critical contribution of inland freshwater shallow lakes ESs to the local population. For example, Ga Mampa freshwater shallow lake in South Africa contributes US$211/year/household (Adekola et al., 2012), Ghodaghodi Lake, Western Nepal, contribute US$63/household/year (Lamsal et al., 2015), Njhum Dwip, Bangladesh, contribute between US$625 and US$937/household/year (Rahman et al., 2012), Lake Chiuta and Lake Malombe in Malawi contribute US$248/household/year and US$1943.08/household/year (Zuze 2013; Makwinja et al., 2021a). Despite these significant contributions, inland freshwater shallow lakes are threatened globally, with global declines in their area by 64% from 1977 to 2011 (Costanza et al., 2014; IPBES 2018). The rapid human population growth, coupled with climate change, rising demand for food, and economic development (Venkatachalam 2004; IPBES 2018; Nkwanda et al., 2021; Makwinja et al., 2021b), have exceeded the capacity at which these lakes can support the local and global communities in terms of providing improved ESs. The rate of biodiversity loss is more significant in freshwater than terrestrial ecosystems, and freshwater vertebrates such as fishes and amphibians are the most affected (Moorhouse and Macdonald 2014; IPBES 2018; Albert et al., 2021). More than 56% of amphibians from global freshwater ecosystems are threatened (Darwall et al., 2011). Approximately 0.9 billion global population experiences freshwater shortages, more than 40% lack clean water, a 1.5 million children die every year due to contaminated water (WHO/UNICEF 2008), and about €78 billion is lost due to policy inaction (Chiabai et al., 2009). The human exploitation of freshwater resources for food production shows a persistent linear increase (Boretti and Rosa 2019). Much aquatic flora and fauna are under threat by a range of human-induced drivers such as landscape dynamics, habitat alteration, over-harvesting, poaching, and pollution (Bani and Damnyag 2017; IPBES 2018). Climate-related risks, landscape degradation, loss of habitat for migratory and other species, loss of soil fertility, productivity, and economic opportunities further threaten freshwater ecosystems with severe negative impacts on livelihoods, and futures projections indicate the worst (Makwinja et al., 2014; Hernández-Delgado 2015; IPBES 2018).

In Malawi, rapid population growth, infrastructure developments (increased inflow from human settlements and industries), agricultural activities (unsustainable farming systems and heavy use of fertilizers in the upland catchments of the lakes), and climate change have been linked to freshwater ecosystems degradation (Njaya et al., 2011; Jamu et al., 2011; FISH 2015; Kanyika-Mbewe et al., 2020; Makwinja et al., 2021b). Malawi has lost about 30,000–40,000 ha of forest land to agriculture and charcoal production, making it the highest in the Southern African Development Community (SADC) (Ngwira and Watanabe 2019; Nkwanda et al., 2021). Lake Malombe catchment alone has lost about 87.3% of the forest land from 1989 to 2019 to agriculture (Makwinja et al., 2021c). The average net loss of ESs from 1989 to 2019 in the catchment is estimated at US$45.58 million and US$8.63 million from the fishery (Makwinja et al., 2021c). The open-access nature of Lake Malombe, coupled with climate change, unselective and unregulated fishing, have led to the worst depletion of fish stocks from the lake, with severe consequences on the lake ecosystem (Hara 2011; Kolding et al., 2016; Makwinja et al., 2021d). Currently, the human population in the lake catchment is increasing exponentially, and the local population that always depends on the lake's ESs live under extreme poverty and have limited alternative livelihood options (FISH 2015; Makwinja et al., 2021e). Faced with the great challenge of limited alternative livelihood options, some native inhabitants are increasingly expanding agricultural activities in the lake's landscape (Makwinja et al., 2021c), while fishing effort is also increasing exponentially (Makwinja et al., 2021f), resulting in a further collapse of the lake ecosystem.

Malawi needs inland freshwater shallow lakes' ecosystem restoration projects to achieve United Nations Sustainable Development Goals, mainly no poverty (SDG 1), zero hunger (SDG 2), good health and well-being (SDG 3), clean water and sanitation (SDG 6), responsible consumption and production (SDG 12), climate action (SDG 13), life below water (SDG 14), and life on land (SDG 15) (IPBES 2019; UN 2019), and the Aichi Biodiversity Targets which state: "*By 2050, biodiversity will be valued, conserved, restored and wisely used, ecosystem services will be maintained, a healthy planet will be sustained and essential ESs' benefits will be provided for all people*" (CBD 2010). Ecosystem restoration involves activities that aim to recover the degraded ESs to halt biodiversity loss, ensure ecosystem resilience, continue provisioning essential ESs, improve human health and well-being, and eradicate poverty (Aasetre et al., 2021). Lake Malombe inhabits rich biological diversity, contributes US$ 124.36 million/year-about 1.97% of Malawi's Gross domestic product (GDP), and supports 97.74% of the local population's livelihoods (Makwinja et al., 2021a). However, the lake has lost over US$79.83 million ecosystem service values from 1999 to 2019 due to rapid population growth, increased poverty, landscape transformation, and over exploitation-hampering the effort to achieve UN SDGs, in particular, life underwater (SDG 14), life on land (SDG 15), climate action (SDG 13), and no poverty (SDG 1) and Aichi Biodiversity Targets. Limited knowledge and experience with the restoration concept among the various stakeholders hamper the effort to manage these lake ESs (Makwinja et al., 2019). If the problem remains unaddressed, the lake ecosystem degradation will inevitably worsen and negatively affect local communities that predominately depend on it for their sustenance. In line with the 2021–2030 United Nations Declaration on massive upscaling of the ecosystem's restoration effort (NEP 2020), the following objectives form the foundation of this study: (i) to estimate the public WTP amount for the Lake Malombe ecosystem restoration program, and (ii) to determine factors influencing the local communities' willingness to pay towards the proposed Lake Malombe restoration program. This study provides insight into how the local communities embrace the local governance system to manage the inland freshwater shallow lakes' ecosystem effectively. It further demonstrates how science and policy frameworks can be integrated to achieve a sustainable ecosystem services (ESs) flow and help policymakers develop practical and relevant policies and make science-based decisions to respond to the local challenges.

2. Materials and methods

2.1. Study area

Laying (14°40′0″S and 35°15′0″E) within the Southern Section of Great Rift Valley system (Afro-Arabian Rift Valley-the most extensive rift valley on Earth's surface, extending from Jordan in southwestern Asia through eastern Africa to Mozambique) in the South East Arm of Lake Malawi/Nyasa (the third-deepest freshwater lake in the world-located in the southern part of Great African Rift Valley complex-, 560km long, 75km width and 706m depth and drain into the Zambezi River through Shire River basin), Lake Malombe (420 km^2) in Figure 1 is the second-largest inland freshwater shallow lake (average depth of around 2–2.5m and a maximum depth of 7m) in Malawi after Lake Chilwa (an endorheic lake lying within a northeast-southwest-tectonic depression of Southern Malawi, with water depth ranging from 1 to 5m and total area of 683km^2) (FISH 2015). The lake is fed by a 19km stretch of the Shire River, extending from Lake Malawi to the Zambezi through a 520 km stretch of basin catchment (Makwinja et al., 2021g). Its catchment depicts unique natural beauty with the rugged landscapes rich with unique habitats for terrestrial biodiversity. The lake is home to many cichlids and shares unique characteristics of Lake Malawi's aquatic ecology, including a high level of fish biodiversity, genetic plasticity, and endemism (FISH 2015). The hippopotamus and crocodiles are prevalent around the lake, while native and migrant birds such as waterfowl, cormorants, kingfishers, and others form part of the lake ecology. An inflowing network of rivers enriches the lake from its highly populated catchment and nutrient recycling in the sediments (Jury 2014). Except for submerged vegetations, Typha swamps, marshes, and seasonally inundated flood plain grasslands are found around the lake's eastern part, in-, and outflow. Lake Malombe is thoroughly mixed and fairy turbid with average transparency of 2.4m. Like other African inland freshwater shallow lakes such as Lake Chilwa, Rukwa, Kyoga, Baringo, Chiuta, Mweru Wa Ntipa, Naivasha, Awassa, Langano, and Victoria, Lake Malombe is a climate-sensitive lake. The lake disappeared entirely between 1915 and 1924, after the water connection between Lake Malawi and Lake Malombe was cut off (Shela 2000). In the 1980s, the average annual water levels in the Upper Shire River decreased by 1.5m, peaked in 1988, and continued to decline since then by 21 cm per year, reaching its lowest (2.5m) in 1997, with an overall drop in an average of 3.5 m over 17 years (Shela 2000). Lake Malombe seasonal fluctuations vary around 90 cm per year, with the highest levels in April–May and lowest in November–December. The temperature ranges from 13 °C to 35 °C, and the average annual rainfall ranges from 600mm on the rift valley floor to 1600mm in the mountainous areas (Makwinja et al., 2021g).

Lake Malombe is bordered by Mangochi and Machinga (Dulanya et al., 2014). The catchment area lies in Machinga district is declared Protected Area. Most of the villages and communities are situated within the Mangochi district. The west bank side of the lake is bordered by the Mpiri Piri hills, which lie within 3–7km from the lake, while on the east side, it is bordered by the Mangochi hills (Owen et al., 1990). Liwonde National Park is located on the Southeast of the Lake. The fishing villages are thus confined within narrow strips of land along the lake on both sides, making the population densities very high with significantly small landholding capacity. The main road from Lake Malawi lies on the west bank passing through Mangochi township to Zomba and Blantyre cities. The population distribution around the lake is indicated by a census conducted by the Ministry of Agriculture in 1998. The 1998 census showed that 8,396 farming households existed in the villages on the west bank while another 2,657 households on the eastern part. Lake Malombe is increasingly threatened by rapid encroachment of subsistence farming, upland deforestation, settlements, invasive alien species, over-exploitation, and climate change.

2.2. Data collection design and application

The data collection began with exploratory surveys to contextualize the study area in which the research was conducted. The lake ESs' primary beneficiaries were carefully selected, and all ESs were contextualized, taking direct and indirect use values into account. The exploratory survey was conducted in the three Traditional Authorities (Chowe, Mponda, and Chimwala) from April to September 2019. The results from the exploratory survey helped to frame qualitative and quantitative questionnaires. The qualitative techniques included focus group discussion (FGD), in-depth key informant interviews, and direct observations. The quantitative technique comprised a structured contingent valuation questionnaire survey.

2.3. Qualitative data collection techniques

Four focus group discussions (FGDs) per traditional authority were organized, with 10–12 villagers representing different socio-economic and demographic backgrounds. The FGDs targeted fishers, farmers, hunters, traders, women, fish crew members, and youth and were

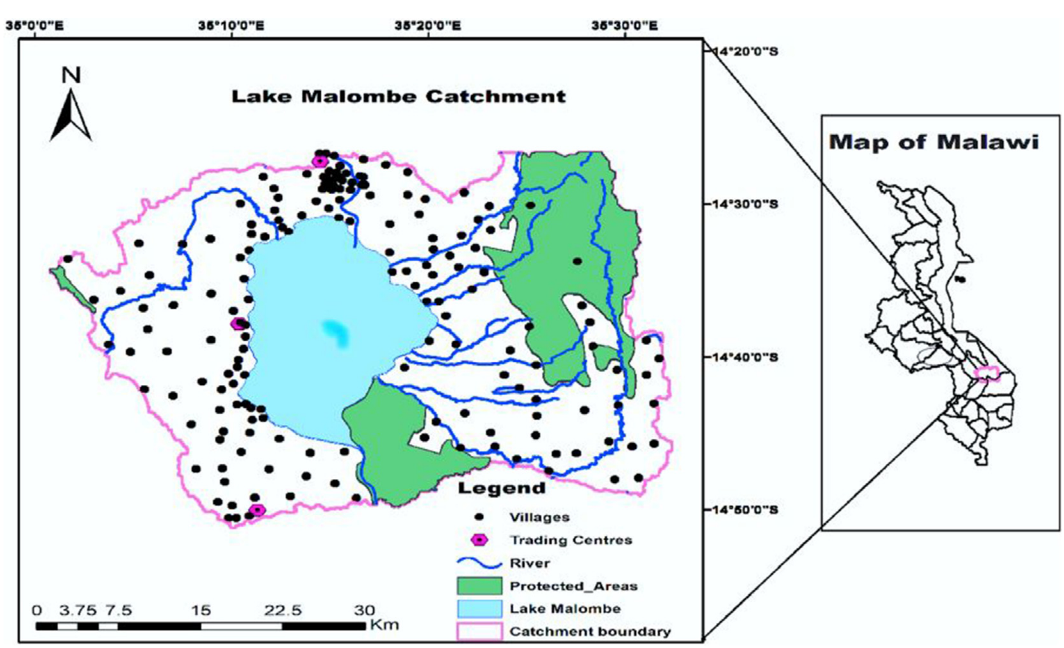

Figure 1. Map of Lake Malombe catchment (Makwinja et al., 2021b).

conducted in the western part, eastern part, Upper Shire, and southern part of the lake catchment. The interviews were audio-recorded with participants' consent and transcribed for fundamental content analysis. The key participatory approaches such as institutional analysis, resource mapping, cause-effect analysis, seasonality, and well-being analysis were employed. Men and women were interviewed separately to facilitate openness. On the flip chart paper, the local communities recorded the ESs and ranked them using a Likert scale of 1–5 (one means less degraded while five means highly degraded). The participatory maps sketched by the local communities were used to rank the indicators for ESs degradation. Anecdotal information on ESs change was gathered during the FGDs in which historical change from the community's memory was obtained with specific years mentioned (approximately 10–30 years). The FGDs generated a more profound knowledge of Lake Malombe's ecological changes, its implication on ESs, local livelihood, and common challenges that local communities face due to ecological changes of the lake. The FGDs further explored the perception of the local communities' vulnerability due to ecological changes, future threats, and opportunities. The FGDs were conducted along with the in-depth key informant interviews. About 30 elderly residents in the Lake Malombe catchment were interviewed. A 'snowball' sampling technique was employed to select the informants, where each informant was used to select another possible informant through networks. The number of informants increased with additional of subsequent informants until the sample size became saturated, where no critical data was gathered. Several transect walk accompanied by villagers were also undertaken every morning to the local markets, fish landings sites, and farmlands for over two months, to understand the lake ecosystem, socio-economic activities, livelihood strategies, governance issues, and interpret the deeper meanings of local communities' responses to the lake ESs changes. The FGDs, key informant interviews and field observation were conducted from April to September 2019. The researcher's personal experience working directly with the Government of Malawi, Fisheries Department within the study area further provided supplementary qualitative data. The goal of the qualitative data collection technique was to provide a contextualized understanding of some aspects of human perception towards the lake ecosystem restoration (Mills et al., 2010).

2.4. Quantitative data collection approach

The three Traditional Authorities (Chowe, Mponda, and Chimwala) were delineated into clusters (the group village headmen). The 30 × 12 cluster sampling technique was used to select twelve clusters (Makwinja et al., 2021a). The face-to-face interviews at the respondents' houses, fishing landing sites, or fields were facilitated by highly trained research assistants from Mzuzu University and Lilongwe University of Agriculture and Natural Resources. A detailed survey was organized among the randomly selected respondents in the catchment. Eq. (1) was used to determine the sample size (Islam 2018).

$$\mathbf{n_r} = \mathbf{P}(1-\mathbf{p})\left(\frac{\mathbf{z}}{\boldsymbol{\varepsilon}}\right)^2 \quad (1)$$

where n_r = sample size and z = value calculated from the standard normal distribution (z = 1.96 for 95% confidence), p is the population proportion (p = 0.5), ε is a marginal of error (4.8%). According to central limit theory, the distribution p followed the approximately normal distribution under the assumption that the Poisson error was constrained by the specific confidence level (Cameron 2011). The 0.5 in this study was selected to represent the likelihood function of the actual value selected based on the probability theory of the normal distribution curve of the underlying population proportion, given a specific confidence interval (Grover and Kaur 2020). In order to statistically generalize the findings of this study, the calculated sample size from the above formula was 420 households. The sample size was large enough to achieve a high degree of precision and representativeness. The probability sampling technique, where every member of the population had an equal chance to be included in the study, was applied to address the drawback of generalization (Polit and Beck 2010). The contingent valuation (CV) questionnaire was framed following the National Oceanic and Atmospheric Administration (NOAA) guidelines (Arrow et al., 1993) and was divided into three sections. The first section focused on socio-economic characteristics, the lake's current status, indicators for ecological dynamics, threats, and opportunities associated with the dynamics. The second section detected specific socio-economic, demographic, and institutional characteristics influencing the individual perception of WTP for the proposed program. The third section focused on digging information on the WTP values of the respondents. The questionnaire was pretested first in a different area before administering it to the 420 respondents selected based on the catalog obtained from the clustered village head. Pretesting was done to standardize the structure, the number of questions, the duration of the interviews, verify whether it was readable and clear, and reduce the rejection rate from respondents. The questionnaire was designed in English, an official language in Malawi, and translated into Chichewa or Yao (the native language of the study area). The questionnaire was administered to the respondents after seeking consent. The CV household survey was conducted between October and December 2020.

2.5. Non-market valuation techniques

Several techniques have been proposed to estimate WTP for improved ESs (Ward 2007). These techniques include direct methods such as Travel Cost Method (TCM), Hedonic Pricing Method (HPM), and Advertising Behaviour (AB), and indirect techniques such as Contingent Valuation Method, Conjoint Analysis (CA), Choice Experiments (CE), Choice Ranking and Contingent rating. The HPM has been applied in environmental economics since the 1970s (Rather et al., 2015). The technique is based on market goods often traded at prices where amenities are internalized (Ndebele 2009). This method assumes that a difference in environmental quality can be valued through property prices. The method assesses the differentials in property prices and wages between locations and isolates the proportion attributed to the existence or quality of the goods and services offered by the lake ecosystem. However, this technique cannot determine non-use values of the lake ESs because its validity is questionable, and the shape of the hedonic price function is unknown (Chumpitaz et al., 2010).

The TCM received attention in the Australasian context as the best valuation technique (Bennett 2005). It assumed that people make repeated trips to recreational sites until the marginal utility derived from a trip equals the marginal costs of a trip. The marginal costs are travel costs in terms of time and transportation costs (Stynes 1990). These travel costs can be regarded as a directly revealed preference for recreation and an indirectly revealed preference for nature. The travel cost method assumes that the demand for trips to a specific site is dependent on travel costs, income, characteristics of the site, prices of substitutes, etc (Stynes 1990). Travel costs are, however, related to distance. In order to determine the visitors' willingness to pay for various distances, distance circles are drawn in the service area of a site. However, the challenge with this technique is that it requires a relatively large amount of data. The CE is the best in estimating the marginal value of individual ES that sums up the overall ESs (Polizzi et al., 2015). However, choosing individual ES from the extensive set of ESs is a significant drawback (Marcot 2012).

On the other hand, CVM is a well-established technique for valuing environmentally sensitive areas. It is based on a survey in which respondents are asked WTP amount to use or conserve natural goods. The stated preferences of CVM are assumed to be contingent upon the alternative goods offered in a 'hypothetical market.' Essential elements of the survey are a description of the natural goods to be valued, the payment vehicle, and the hypothetical market. The technique is regarded as one of the most promising methods for valuing public goods such as freshwater and has made a significant contribution to the environmental science field by demonstrating that an explicit link between non-market goods and market prices is unnecessary. The method is flexible because it allows social research to categorize the exact scenario valued and measure ecosystem goods and services (Bani and Damnyag 2017). This study considered CVM a highly suitable technique for estimating households' WTP for ecosystem restoration in Lake Malombe.

2.6. Contingent valuation model

The first part of this paper focused on understanding the respondents' perception regarding the lake ecosystem restoration program. It was achieved by probing the individual's attitude towards WTP (Makwinja et al., 2019). This question emphasized the honesty of the respondents. Therefore, the respondents were requested to be truthful in their answer, considering their limited level of income which can also be used to purchase other essential items (Makwinja et al., 2019). Based on the response from the first question, the respondents were desegregated into two categories (positive or negative). The questions were simplified considering the high illiteracy in the study area, currently estimated at 89 % of the population (Makwinja et al., 2021d). The willingness to pay questions formulated were: *Assuming the proposal is drafted to restore Lake Malombe's ecological status. The main goal is to improve the ecosystem services, increase biodiversity, improve resilience, reduce exposure to climate change, increase fish production, reduce the risk of your household being affected by food and nutritional insecurity, water-borne diseases, climate-related disasters such as frequent floods, prolonged droughts, and ensure that everyone in the community benefits from various ESs provided by the improved lake. The proposal will need* funds *to* support *various restoration activities. The option available is to pay annually for the ecosystem service benefits derived from the lake: Q1 Would you agree to the proposed program? Yes or No (If no, go to question 3 or 4); Q2 If you agree, can you explain the reasons?; Q3 If you disagree, what could be the reasons?; Q4 If you are not sure, would you explain the reasons?*

If the response was positive, the respondents were asked about their WTP single annual lump-sum amount of about US$35/household/year–the value proposed by Florio et al. (2016), who did a meta-analytical CV study across the globe on the current value of public goods, particularly ecological, health and cultural goods. Three possible answers were expected 'yes,' 'no,' and 'do not know.' The following bids of *US$1, US$ 5, US$ 10, US$ 20, US$ 40, US$100, US$200,* and above were presented. The single annual lump-sum amount of about US$35/household/year was used as a benchmark. If the response to this bid was negative, the subsequent biddings were lower. However, if the response to the proposed bid was positive, the subsequent biddings were higher. The 20 years was proposed as the lake ecosystem restoration program period. The Double bound dichotomous choice (DBDC) was used in this study in which the respondents were asked a second follow up WTP question after the first WTP questions (Khan et al., 2014) as expressed in Eqs. (2) and (3):

$$\mathbf{WTP}_i^1 = \mathbf{x}_i'\boldsymbol{\beta} + \varepsilon_i \tag{2}$$

$$\boldsymbol{WTP}_i^2 = (1-\boldsymbol{\gamma})\mathbf{WTP}_i^1 + \boldsymbol{Y}\boldsymbol{\beta}_1 + \boldsymbol{\delta} \tag{3}$$

where γ is the parameter reflecting on the starting bid β_i and δ is a shifting parameter. Data on WTP intervals was obtained based on the DBDC CVM. $WTP \geq \beta^2$ accept both initial bids (B) and follow up a bid (β^2); $\beta^1 \leq WTP < \beta^2$ accept the initial bid (β^1) and reject the follow-up bid (β^2) ; $\beta^2 \leq WTP < \beta^1$ reject the initial bid (β^1) and accept the follow-up bid (β^2); $WTP < \beta^2$ Reject both initial bids (β^1) and subsequent bid (β^2). Eqs. (4), (5), (6), and (7) express the probability of observing each possible choice:

$$\boldsymbol{L}_i\left(\frac{\boldsymbol{WTP}_i}{\boldsymbol{\beta}^1}\middle|\boldsymbol{\beta}^i\right) = \boldsymbol{P}_r\left(\boldsymbol{WTP}_1 + \boldsymbol{\varepsilon}_{ij} > \boldsymbol{\beta}^1, \boldsymbol{WTP}_2 + \boldsymbol{\varepsilon}_{2j} \geq \boldsymbol{\beta}^2\right)^{\boldsymbol{YY}} \tag{4}$$

$$\text{x } \boldsymbol{P}_r\left(\boldsymbol{WTP}_1 + \boldsymbol{\varepsilon}_{ij} \geq \boldsymbol{\beta}^1, \boldsymbol{WTP}_2 + \boldsymbol{\varepsilon}_{2j} < \boldsymbol{\beta}^2\right)^{\boldsymbol{YN}} \tag{5}$$

$$\boldsymbol{xP}_r\left(\boldsymbol{WTP}_1 + \boldsymbol{\varepsilon}_{ij} < \boldsymbol{\beta}^1, \boldsymbol{WTP}_2 + \boldsymbol{\varepsilon}_{2j} > \boldsymbol{\beta}^2\right)^{\boldsymbol{NY}} \tag{6}$$

$$\boldsymbol{xP}_r\left(\boldsymbol{WTP}_1 + \boldsymbol{\varepsilon}_{ij} < \boldsymbol{\beta}^1, \boldsymbol{WTP}_2 + \boldsymbol{\varepsilon}_{2j} < \boldsymbol{\beta}^2\right)^{\boldsymbol{NN}} \tag{7}$$

WTP_i and WTP_2 represent the first and second bid response and YY = yes and YN = yes-no answer, NY = no-yes answer, and NN = no-no answer. This likelihood function was estimated using the probit model shown in Eq. (8).

$$\boldsymbol{L}_i\left(\boldsymbol{WTP}_1|\boldsymbol{\beta}^i\right) = \varnothing_{\frac{\varepsilon}{\varepsilon_2}}\left(\boldsymbol{d}_{1j}\left(\frac{\boldsymbol{\beta}^1 - \boldsymbol{WTP}_1}{\boldsymbol{\sigma}^1}\right), \boldsymbol{d}_{2j}\left(\frac{\boldsymbol{\beta}^2 - \boldsymbol{WTP}_2}{\boldsymbol{\sigma}^2}\right), \boldsymbol{d}_{1j}\boldsymbol{d}_{2j}\boldsymbol{\rho}\right) \tag{8}$$

where $WTP_{1j} = 1$ means positive response or otherwise, $\mathrm{WTP_{1j}} = 1$ means the second question has a positive response or otherwise, $\mathrm{WTP_{2j}} = 1$ means the second question has a positive response; or otherwise, $\mathrm{d_{1j}} = 2$ $\mathrm{WTP_{1j}} = 1$ and $\mathrm{d_{1j}} = 2\,\mathrm{WTP_{2j}} = 1$. Mean, and median WTP was derived as shown in Eqs. (9) and (10):

$$\textbf{Mean WTP} = \textbf{exp}\left(\frac{\overline{\mathbf{X}}\widehat{\boldsymbol{\beta}}'}{\widehat{\boldsymbol{\beta}}_0} + 0.5\widehat{\boldsymbol{\sigma}}^2\right) \tag{9}$$

$$\textbf{Median WTP} = \textbf{exp}\left(\frac{\overline{\mathbf{X}}\widehat{\boldsymbol{\beta}}'}{\widehat{\boldsymbol{\beta}}_0}\right) \tag{10}$$

$\overline{\mathrm{x}}$ is a k+1 which means a row vector of the mean value of the explanatory variable, including 1 for constant term, $\widehat{\beta}'$ is a-1 column vector of estimated coefficient and $\widehat{\sigma}$ is the estimated variance (Krinsky and Robb 1986).

2.7. Logistic regression model

Two factors that influenced the CV techniques were: (a) the tendency of the individual to consider a group of goods, rather than one specific good, as the basis for utility maximization; and (b) the fact that CVM provided both use and non-use values for environmental assets. A use-value is the value experienced by people who use the environmental asset. A non-use or passive value is the sum of simply knowing that an asset exists and the values associated with potential future use. Non -use values are related to the sustainability of an ecosystem. The individual's attitudes and perceptions regarding ecosystem degradation are often linked to the beneficiaries' spatial distribution and the degree to which an individual has been exposed to vulnerability due to ESs dynamics. In equilibrium, economic theory predicts that individuals equate the marginal utility of expected avoided disutility with marginal costs, subject to budget constraints, dynamic ecological indicators, and factors such as demographic, socio-economic, institutional, attitude, etc. Hence, considering that the identified Lake Malombe ecological indicators of ecosystem degradation and factors affecting WTP responses were dichotomous and were distributed between 0 and 1, the logistic regression model shown in Eq. (11) was applied (Gujurati 1999).

$$\mathbf{WTP}_i = \ln\left(\frac{\mathbf{P}}{1-\mathbf{P}}\right) = \boldsymbol{\beta}_0 + \boldsymbol{\beta}_1\mathbf{X}_1 + \boldsymbol{\beta}_2\boldsymbol{\beta}_2 + \boldsymbol{\beta}_3\boldsymbol{\beta}_3 + \ldots\boldsymbol{\beta}_n\mathbf{X}_n + \boldsymbol{\varepsilon}_i \tag{11}$$

$\mathrm{WTP_i}$ represent a dummy variable (where 0 = positive WTP and 1 = negative WTP), P as a dependent variable of probability 1, the parameter β_0 is constant and estimates (β_n) is the regression coefficient, and $\mathrm{X_n}$ is both the endogenous and exogenous factors, $\boldsymbol{\varepsilon}_i$ means a random error term assumed to be normally distributed with zero mean and variance δ^2. The logistic regression model for indicators of lake ecosystem degradation was assessed, and the model showed the -2 log likelihood =

59.1, Cox & Snell R square = 0.54, Nagelkerke R square = 0.73, Hosmer and Lemeshow Chi-square = 5.44, and sig = 0.695, suggesting the suitability and overall good fit to the data. On the other hand, logistic regression model for factors affecting WTP showed Hosmer and Lemeshow test, Chi-square = 8.22, p = 0.69, -2log likelihood = 66.8%, Nagelkerke R Square = 0.84, Cox & Snell R Square = 0.39, suggesting that the selected model was overall good fit.

2.8. Ethical approval

The authorities who approved the study were from the Mangochi District Council, Malawi. All the participants were fully informed about the purpose of the study in their native language. Before the interview, consent was sought from each participant, and no personal identification was registered. The consent was proposed verbally since the study's cross-section nature required descriptive data, and the response had no personal, social, political, or significant risks. The data's confidentiality was guaranteed, and access to raw data was acceptable after a shared agreement by the researchers involved in designing, conducting, and funding the study.

2.9. Data analysis

Qualitative data were analyzed using critical discourse, content analysis and iterative approaches. Dominant themes were isolated from the data and link them to the research questions. Field recordings were decoded, and notes were scanned to identify, classify and group various stakeholders' ideas and concepts. Quantitative data analysis involves descriptive and inferential statistics. Descriptive statistics were done in Microsoft Excel (2016), while inferential statistics were done in Econometric software Stata 20.0.

3. Results

3.1. Socio-economic profile and the current Lake Malombe status

Table 1 shows that 89% of the households interviewed in the Lake Malombe catchment were locals who stayed in the area for not less than ten years. Most of them (69.1%) were males, average younger (39 years old), 74.1% married, and 52.2% had a family size of more than six. Regarding literacy, 62.2% of the respondents had primary education, 25.9% had no education, 11.2% had secondary education, and 4% had tertiary education. The average daily income (US$1.77) was less than US$2/day, with the majority (44%) of the households employed in the fisheries industry as crew members. The landholding capacity was significantly low, and the majority (87.5%) of the respondents had only 1 acre of land for crop production (38.8%) and settlement (58.7%). Figure 2 depicts the current status of the Lake Malombe ecosystem. Households were asked about the changes in the Lake Malombe catchment over the past decades. The rate of respondents in Figure 3 shows that the majority (46%) of the respondents ranked the rate of carbon sequestration poor, with 23% describing it as worse while 11% suggested that it is the worst. In terms of water quality, 38% of the respondents ranked it as poor, 29% worse, and 29% worst. The rate of scenic view is also decreasing, with the majority (22%) of the respondents ranking it as poor, 18% worse, and 20% worst. Lake Malombe has been a source of pride to the local population. Some crucial rivers, forests, and wetlands found in the catchment had cultural and aesthetic values to the local communities. They were given special attention, and some of them were referred to as sacred places due to their rich aquatic biodiversity, thickest forest, and vegetation. However, the current status indicates otherwise. The majority of the respondents (30%) described the situation as the worst. Similarly, the lake ecosystem has lost its ability to control flooding, with the majority (26%) describing the situation as the worst.

Table 1. Demographic and socio-economic characteristics of the respondents.

Explanatory Variables	Information Category	Value	Percent	Mean ± STD Error	Min-Max
AGH	<20	420	-	39 ± **0.01**	17–86
	20–24	4.62	1.1	-	-
	25–29	58.8	14	-	
	30–34	64.26	15.3	-	-
	35–39	118.86	28.3	-	-
	40–44	79.38	18.9	-	-
	45–49	42	10	-	-
	50–54	26.88	6.4	-	-
	55–59	25.2	6	-	-
LU	crop production	162.96	38.8	-	-
	settlements	246.54	58.7	-	-
	fallow	1.68	0.4	-	-
	rent	2.94	0.7	-	-
	livestock production	7.56	1.8	-	-
MS	Married	311	74.1	-	-
	Single	109	25.9	-	-
HLSC	More than 10 yrs	374	89	-	-
	Less than 10 years	46	11	-	-
GHH	Male	290	69.1	-	-
	Female	130	30.9	-	-
HFS	1 person	6	1.1	-	-
	2-3 persons	85	15.9	-	-
	4-5 persons	162	30.4	-	-
	6 above	280	52.5	-	-
HLE	No Education	136	25.9	-	-
	Primary	327	62.2	-	-
	Secondary	59	11.2	-	-
	Tertiary	4	0.8	-	-
HLS	1 acre	86.4	87.5	-	-
	1 ha	11.8	11.8	-	-
	3 acres	0.4	0.4	-	-
	4 acre	0.4	0.3	-	-
ADLI		420		1.77 ± **0.02**	0–17.6
HC	Farmer	8	2	-	-
	Fishermen	55	13	-	-
	Farmer and Fishermen	143	34	-	-
	Business owner	3	0.6	-	-
	formally employed	0	0.1	-	-
	Traders	1	0.3	-	-
	Crew members	185	44	-	-
	firewood/ charcoal seller	25	6	-	-

Note: AGH means age of the household, MS means Marital status, HLI means the household level of income, HS means household size, GHH means gender of household, HFS means household family size, HLE means the household level of education, HLS means household land size, ADLI means an average daily level of income, HC means household occupation, LU means land use.

3.2. Lake Malombe ecological dynamics indicators, threats, and opportunities

Lake Malombe's ecological dynamics are too complex. Many human-induced, ecological, and climatic indicators explain how the lake ecosystem has changed. Table 2 shows some of the identified indicators and the results of a binary logistic regression model. Prolonged dry spell, droughts, floods, water scarcity, and disease outbreak had positive regression coefficient (R^2 = 0.67, 0.53, 0.82, 1.25, 0.34) and

Note: Rodgers Makwinja took a picture (a) at the Western Part of Lake Malombe and (c) at Lake Malombe Upper Shire River. Picture (b) was taken by Emmanuel Chisesa, while (d) was accessed from the Mangochi District State of Environment and Outlook report (Government of Malawi , 2014). *Picture (a) shows one of the dry rivers that drain into Lake Malombe. Picture (b) shows the receding part of Lake Malombe. Picture (c) shows the water hyacinth driven into Lake Malombe, and picture (d) shows charcoal production in Mangochi hills, the eastern part of Lake Malombe.*

Figure 2. The current status of Lake Malombe and its catchment.

significant (p = 0.03, 0.02, 0.03, 0.03, 0.04). The soil productivity, agricultural yields, mangroves population, reeds population, rivers' flow, invasion of alien spp, water levels, biodiversity status, water clarity had negative regression coefficients (R2 = -0.55, -0.63, -0.25, -0.80, -0.49, -0.22, -1.35, -0.49, -0.22) and significant (p = 0.04, 0.03, 0.03, 0.02,0.01, 0.02, 0.01, 0.02, 0.04). The poor households that make up a significant proportion of affected households identified these indicators as threats that expose them to vulnerability while their counterparts saw them as opportunities. For example, Figure 4a shows that 28% of the respondents suggested increased loss of income as a significant threat to their sustainability. Other threats suggested were food insecurity (24%), fish biodiversity loss (18%), increased poverty (12%), water-borne diseases (8%), increased diseases and pest outbreak (6%), crop damage (2%), livestock loss and natural resources degradation (1%). On the contrary, Figure 4b shows that 44% of the respondents suggested that the current lake ecological dynamics offer opportunities such as wetland farming, winter cropping (23%), irrigation (18%), creating fish breeding grounds (6%), income diversification (5%), and fast fish drying (4%).

3.3. The mean WTP and the determinants

Table 3 shows that 235 respondents of 420 sampled households were willing to pay (WTP>0), accounting for 56% of the total sample. The mean WTP was US$28.42/household/year, median US$4.62/household/year, and mode US$ 0.92/household/year. The minimum WTP was US$0.88/household/year, while the maximum was US$321.18/household/year. Figure 5 summarized the final WTP using iterative bidding. The linear regression coefficient (R^2) was 0.80, suggesting that the WTP bid amount influenced 80% of the variations in the rate of responses. The fitted linear trend line shows that the rate of responses decreases with an increase in the level of WTP bid amount, which conforms to the principles of demand. The rate of responses decreased from 28% to 13.3%, with an increase in WTP bid amount from US$0.88/household/year to US$4.41/household/year, and further decreased from 20% to the lowest level of 3.3% as the bid WTP amount increased from US$8.82/household/year to US$321.18/household/year. Factors such as the age of the household (AGH), gender (GH), literacy level (LL), level of income (LI), social trust (ST), institutional trust (IT), access to extension services (AES), knowledge of the lake ecosystem degradation such as aware of Lake Malombe ecosystem degradation (ALMED), period stay in the area (PSA), a distance of the household from the lake (DHL), and household affected by the lake ecological dynamics (HALED), attitudes such as having the hope of reviving the lake health ecological status (HRLHES), perception of having a lake ecological restoration program (PHLEP), participation in lake restoration program (PLRP), and the benefits derived from the lake ecosystem, such as fishing (IF) and other livelihood sources (LMLS), were positive and significant ($p < 0.05$), suggesting that these factors positively influenced the WTP (see Table 4).

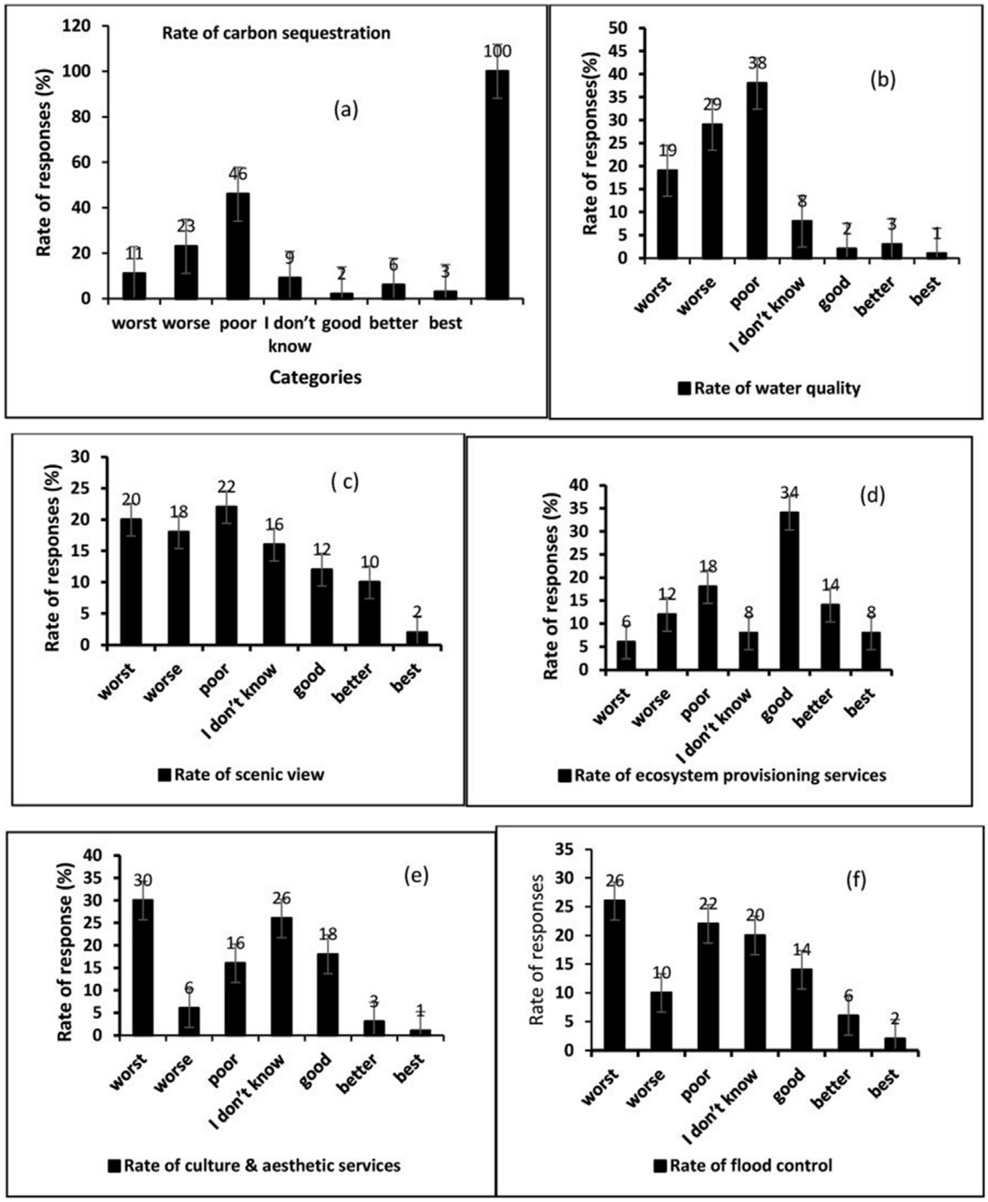

Figure 3. The rate of carbon sequestration(a), rate of water quality(b), rate of scenic view(c), rate of ecosystem provisioning services(d), rate of culture and aesthetic services (e), rate of flood control(f).

4. Discussion

Lake Malombe ESs' dynamics have been extensively discussed in the literature (Jamu et al., 2011; Dulanya et al., 2014; FISH 2015; Hara and Njaya 2016; Makwinja et al., 2021c). The consensus is that the lake has been susceptible to human-induced factors and climatic variability (Makwinja et al., 2021c). Increased ecological indicators such as prolonged dry spells, droughts, floods, water scarcity, disease outbreaks, decreased soil productivity, agricultural yields, mangroves population, reeds population, rivers' flow, invasion of alien species, water levels, biodiversity status, and water clarity suggest that the lake ecosystem has increasingly degraded over the past decade. A similar situation has been depicted across the globe. For example, Guo et al. (2008) reported a similar situation in the Poyang Lake basin, China, Li et al. (2007) in Lake Chad Basin, West Africa, Elias et al. (2019) in Ethiopia Central Rift Valley, Kafumbata et al. (2014) in Lake Chilwa basin, Malawi, Talbot et al. (2018) in Tonle Sap Lake in Cambodia, and DasGupta and Shaw (2013) in Southern Part of Andaman Island in India, Tennessee and Cumberland River Basins and Portneuf River catchment in the United States of America (USA) (Thieme et al., 2016; Huang et al., 2019).

National and regional policy frameworks have acknowledged the effort to restore the degraded inland freshwater shallow lake ecosystem as a crucial activity towards achieving United Nations Sustainable Development Goals (IPBES, 2019) such as no poverty (SDG 1), zero hunger (SDG 2), good health and well-being (SDG 3), clean water (SDG 6), clean energy (SDG 7), responsible consumption and production (SDG 8), climate action (SDG 13), life below water (SDG 14) and life on land (SDG 15) (UN 2019; Aasetre et al., 2021). In the 1990s, FAO formulated the management plan to restore the depleted Chambo species in Lake Malombe in line with SDG 14 (Banda et al., 2005). Nevertheless, the initiative failed due to a lack of an action plan. The management plan was further not supported by an enabling environment and focused on technical aspects overlooking the integration of economic and ecological models into the policy framework. In 1994, participatory fisheries management was also initiated to recover the depleted Chambo stock in the lake (Banda et al., 2005). Unfortunately, the status of Chambo

Table 2. The best fitted logistic regression models of indicators for Lake Malombe Lake ecosystem degradation.

Indicator variables	Hypothesis	B	S. E	Wald	Sig. level
Prolonged dry spell	+	0.67	0.08	0.60	0.03**
droughts	+	0.53	0.01	0.96	0.02*
Floods	+	0.82	0.09	0.38	0.03*
Heavy rain	+	0.01	0.06	0.06	0.54^{ns}
Erratic rain	+	0.25	0.02	0..23	0.32^{ns}
Late-onset rain	+	0.29	0.07	0.07	0.14^{ns}
Early-onset rains	+	2.66	0.02	0.98	0.10^{ns}
Water scarcity	+	1.25	0.02	0.26	0.02*
Disease outbreak	+	0.34	0.01	0.05	0.03*
Soil productivity	-	-0.55	0.02	3.54	0.04*
Agricultural yields	-	-0.63	0.04	0.97	0.03*
Crop damage	+	0.18	0.00	0.47	0.12^{ns}
Mangroves population	-	-0.25	0.03	0.39	0.03*
Reeds population	-	-0.80	0.07	0.17	0.02*
Rivers' flow	-	-0.49	0.02	0.22	0.01*
Invasion of alien spp	+	0.22	0.03	0.14	0.02*
Water levels	-	-1.35	0.01	0.97	0.01*
Biodiversity status	-	-0.49	0.00	0.44	0.02*
Water clarity	+	-0.22	0.01	0.23	0.04*

Note: response variable is lake Malombe ecosystem degradation and is a dummy variable (where 0 = positive suggesting that as indicator increases, the lake ecosystem degradation also increases, 1 = negative suggesting that as indicator decreases, the lake ecosystem degradation increase). Hosmer and Lemeshow test, Chi-square = 5.44 (df = 8), P = 0.71. -2 log likelihood = 59.1%. Note: Nagelkerke R Square = 0.73, Cox & Snell R Square = 0.54, Sig = 0.695. ns indicates not significant while ** and * indicate significance at 0.01 and 0.05 probability level of Confidence, negative hypothesis (-) means decrease, positive hypothesis (+) means increase assuming that these indicators were not static.

continued declining. The initiative also overlooked the existence of theoretical conflicts between utilization and conservation among the local communities. In Lake Malombe, forests, fishery, and subsistence farming support the livelihood of the local communities, as demonstrated by the following anecdote: "*The current state of the lake ecosystem is beneficial. When the catches are good, I generate enough income from fishing. When the catches are bad, and the lake level recedes, I switch to winter farming,*" said a man at Sili beach, Oct 2019-a typical scenario depicted in Lake Chilwa, Chia lagoon, Elephant Marsh, and Lake Chiuta (Jamu et al., 2003; Kosamu et al., 2012; Zuze 2013; Wood 2013; Makwinja et al., 2019). An older woman at Chimwala beach also expressed the following anecdote: "*Farming practices used to take place in the upland areas* 15km *away from the shoreline. However, the current situation indicates otherwise. Increasing population pressure, decreasing land holding capacity, and the collapse of the lake fishery have pushed the local population to cultivate areas around the shorelines and river banks*." Hara (2011), Ngochera et al. (2018), and Makwinja et al. (2021c) also pointed out that unsustainable livelihood activities such as brick-making, sand mining, small scale irrigations, use of destructive fishing gears, charcoal production, poaching, burning of macrophytes and mangroves for farming are the major drivers accelerating the rate of lake ecosystem degradation -a situation also depicted in African freshwater shallow lakes (Schuyt 2005; Mvula and Haller 2009; Harter 2009; Nagoli et al., 2016; Dejen et al., 2017; Chiotha et al., 2018).

Different individuals expressed different perceptions towards the proposed lake ecosystem restoration program. These varying perceptions were linked to the marginal utilities derived from the improved lake ecosystem, and the results were reflected in varying WTP responses and

Table 3. Analysis of WTP amount (US$/year).

Parameter	Number of positive responses	Percent	Mean	Median	Mode	Min-Max
WTP/year	235	56	28.42	4.62	0.88	0.88–321.18

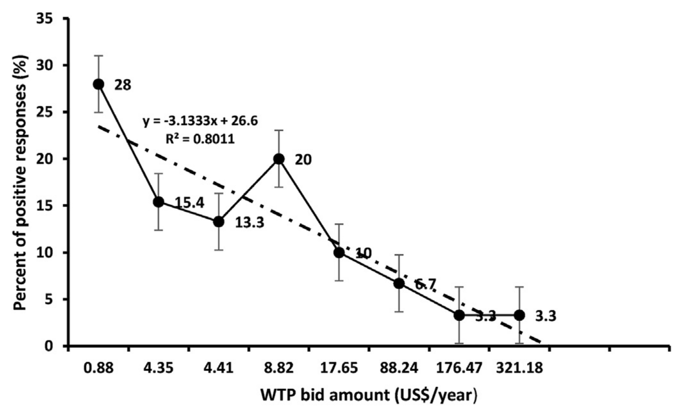

Figure 5. The analysis of WTP bid amount (US$/yr).

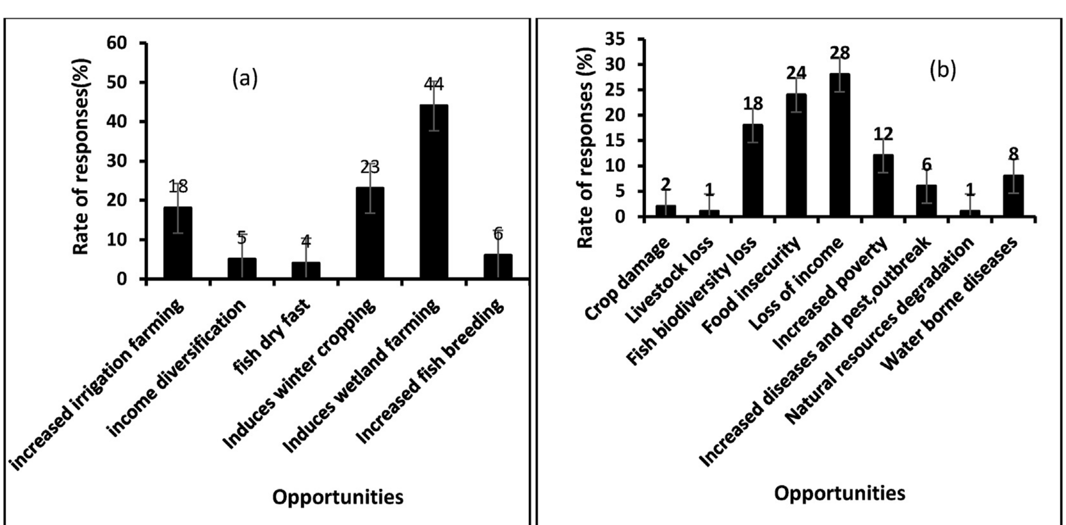

Figure 4. Lake Malombe ecosystem opportunities (a) and threats (b).

Table 4. The best fitted logistic regression model of factors influencing household' WTP.

Parameters	Description of Variable	B	S. E	Wald	Sig
Socioeconomic					
AGH	Dummy variable where 45 years below = 0 and 46 above = 1	2.90	3.15	0.84	0.02*
GH	Dummy variable where male = and female = 1	5.29	2.72	3.77	0.04*
HS	Dummy variable where 4 below = 0 and 5 above = 1	1.24	3.17	3.86	0.05^{ns}
LL	Dummy variables where literate = 0 and illiterate = 1	3.46	3.28	0.02	0.01*
LI	Dummy variable where US$2/day above = 0 and less than US$2/day = 1	2.80	2.87	0.95	0.03*
LO	Dummy variable where own land = 0 and doesn't own the land = 1	-1.17	3.45	0.12	0.74^{ns}
MS	Dummy variable where married = 0 and single = 1	-1.26	2.81	0.20	0.65^{ns}
Institutional factors					
ST	Dummy variable where yes = 0 and no = 1	3.47	3.79	0.02	0.02*
SP	Dummy variable where yes = 0 and no = 1	4.24	3.34	1.61	0.20^{ns}
IT	Dummy variable where yes = 0 and no = 1	5.60	3.81	2.16	0.04*
AES	Dummy variable where yes = 0 and no = 1	3.41	2.10	0.04	0.01*
ASN	Dummy variable where yes = 0 and no = 1	0.28	0.15	3.61	0.06^{ns}
Knowledge					
ALMED	Dummy variable where yes = 0 and no = 1	2.45	2.42	0.36	0.04*
PSA	Dummy variable where less than 10 yes = 0 and more than 10 years = 1	3.01	3.28	0.85	0.02*
DHL	Dummy variable where less than 5km = 0 and more than 10km = 1	2.30	4.67	0.24	0.02*
HALED	Dummy variable where yes = 0 and no = 1	4.70	1.90	6.13	0.01*
Attitude					
HRLHES	Dummy variable where yes = 0 and no = 1	3.03	1.72	5.11	0.02*
PHLEP	Dummy variable where yes = 0 and no = 1	3.89	2.12	8.32	0.01**
PLRP	Dummy variable where yes = 0 and no = 1	6.10	21031.48	0.00	0.02*
Benefits					
AFL	Dummy variable where yes = 0 and no = 1	0.92	1.57	2.97	0.04*
IF	Dummy variable where yes = 0 and no = 1	2.71	1.58	2.75	0.01**
LMLS	Dummy variable where yes = 0 and no = 1	2.62	21031.48	0.00	0.02*

Hosmer and Lemeshow test, Chi-square = 8.22 (df = 8), P = 0.69 -2 log likelihood = 66.8%, Note: Nagelkerke R Square = 0.84, Cox & Snell R Square = 0.39. ns indicates not significant while ** and * indicate significance at 0.01 and 0.05 probability level of Confidence. Note: AGH means age of the household, GH means gender of the household, HS means household size, LL means literacy level, LI means level of income, MS means marital status, IIF means involved in fishing, LO means land ownership, ST means social trust, SP means social position, IT means institutional trust, AES means access to extension services, ASN means access to social network, aware of Lake Malombe ecosystem degradation (ALMED), period stay in this area (PSA), a distance of the household from the lake (DHL), household affected by the lake ecological dynamics (HALED), having the hope of reviving the lake health ecological status (HRLHES), perception of having lake ecological restoration program, (PHLEP), participation in lake restoration program (PLRP), access to food from the lake (AFL), involved in fishing (IF) and Lake Malombe main livelihood sources (LMLS).

amounts. About 56% of the sampled households were willing to pay a mean lump sum of US$28.42/household/year-a scenario also depicted in other freshwater ecosystems across the globe (Table 5). The binary logistic regression results showed that socio-economic factors such as AGH, GH, LL, and LI were significant at p = 0.05 and positive. Age displayed a positive regression coefficient and was significant, suggesting that respondents aged 20–45 were more willing to pay than 46 and above. The study showed that the younger the household head, the more willing to pay for the lake ecosystem restoration. Aladi and Olujobi (2014) and Bani and Damnyag (2017) also showed that the age of the household influences the decision to participate in restoration programs positively. The findings agree with Harun et al. (2015) in the study conducted in Kurdistan Regional Government, Iraq, and Kim et al. (2017) in Korea and contradict with, Lamsal et al. (2015), who argued that older people are more willing to pay than the younger ones, due to their experience of deriving ESs from the lake.

Gender had a positive regression coefficient because males made up a significant proportion of respondents than females and represented significant beneficiaries of the lake ecosystem compared to women. The 2020 Annual Fisheries Frame survey report showed that 100% of the gear owners and fish crew members in Lake Malombe are males (Department of Fisheries 2020). Individual awareness of the impact of lake ecosystem changes is linked to education. The study found that households with a high education level were conscious of the degraded lake ecosystem and its impact on the local population. These individuals were more willing to pay than their counterparts. A similar observation was made by Makwinja et al. (2019) in Malawi, Lamsal et al. (2015) in Nepal, Tziakis et al. (2009) in Northwest Crete, and Kanyoka et al. (2008) in South Africa. The respondents with a higher level of income and more benefits from the lake ecosystem were more willing to pay than their counterparts. Similar observation was made by von Stackelberg and Hammitt (2009), Tziakis et al. (2009), and Breffle et al. (2015).

Stern and Baird (2015) suggested that the resilience of management institutions depends on the capacities and organizations within those institutions to adapt both individually and collectively to the ecosystem dynamics. Trust in this context is a vital component of the institutional relationships that support adaptive governance and a collaborative decision-making system (Harris and Lyon 2013; Stern and Baird 2015). It influences the resilience of the governance structures and the local population to respond to the ecological dynamics effectively (Stern et al., 2013). On the other hand, distrust between the local population and diverse stakeholders leads to standoffs that hold up management action, non-compliance with regulations, loss of public interest, public protests, and conflict-hence undermining the potential implementation of the lake ecosystem restoration program (Stern 2008; Lachapelle and McCool 2012). In this study, ST and IT were considered essential tools to organize local communities and diverse stakeholders to effectively deal with lake ecological problems and dilemmas (Olsson et al., 2008; Njaya et al., 2011). An exponential body of literature has demonstrated that these factors bring diverse norms and promote reciprocity in coping with

Table 5. The WTP values for freshwater ecosystems across the global.

Freshwater ecosystems	Country	WTP (US/ household/yr	Reference
Lake Malombe	Malawi	28.42	-
Heine River basin	China	19.96	Khan et al. (2019)
Lake Chiuta	Malawi	10.92	Zuze (2013)
Naivasha watershed	Kenya	88.35–218.48	Nyongesa et al. (2016)
Ghodaghodi Lake	Nepal	5.4	Lamsal et al. (2015)
Guadiana estuary	Portugal and France	55.6	Guimarães et al. (2011)
Bhod wetland	India	5.43	Verma and Negandhi (2011)
Shadegon wetland	Iran	1.74	Kaffashi et al. (2011)
Central Rift Valley wetlands	Ethiopia	7.5	Dechasa et al. (2021)
Linthipe River	Malawi	3.51	Chigamba et al. (2021)
McKenzie River	USA	7.5	Nielsen-Pincus et al. (2017)
Chia lagoon	Malawi	128.78	Makwinja et al. (2019)
Natural urban lake	Philippines	4.17	Bueno et al. (2016)
Platte River	USA	252	Loomis et al. (2000)
Yaqui River delta	Mexico	61.2	Ojeda et al. (2008)
Wei River	China	17.96	Khan et al. (2020)

ecological problems (Hara 2006; Hahn et al., 2006; Stern and Baird 2015; Hara and Njaya 2016; Nagoli and Chiwona-Karltun 2017; Makwinja et al., 2019). The logistic regression model showed that ST and IT influenced WTP amount positively-suggesting that a high degree of ST and IT within the local population governance structures and diverse stakeholders allow all the parties to share the responsibilities and work together to achieve the common objective. Access to extension services plays a vital role in promoting institutional and social trust (Wheeler et al., 2017). It facilitates the linkage between the local population and diverse stakeholders such as private sectors, government institutions, non-governmental organizations, Research Institutes, and education centers (Makwinja et al., 2019; Maulu et al., 2021). The relationship between WTP amount and AES was positive, suggesting that failure and success of the proposed Lake Malombe ecosystem restoration program depend on this factor, though other factors such as ALMED, PSA, HALED, HRLHES, IF, LMLS were also equally important. This study demonstrates that monetary value in freshwater ecosystem restoration assists in analyzing the trade-offs between conservation and exploitation and guides the management efforts and public investments to protect and enhance the benefits from the lake (Makwinja et al., 2021e).

Table 6 shows that 56% of the respondents were willing to pay because they believed the proposed program would improve the ESs and benefit future generations. Their response resulted from the influence of the past awareness campaign focusing on natural resources conservation conducted in the catchment. However, those who perceive the proposed program as an investment suggested that successful implementation of the program will improve their income as the fish biodiversity in the lake increases. On the other hand, 44% of respondents who said “No” had a household income of less than US$1/day. Makwinja et al. (2021b) suggested that low-income households are linked to over-dependency on ESs, government, and Non-governmental Organizations' food aid -a perfect example of socio-economic traps in which households cannot find enough resources to overcome the shock and consequently fail to participate in restoration programs. Creating temporary jobs that focus on restoring the lake's ecological status could create incentives for this group of people and stimulate them to participate in the ecosystem restoration program. About 45% of the respondents suggested they could not pay because they had no trust in the local government and the governance structures assigned to handle the collected funds due to high corruption - a typical reflection of some African countries. The common corrupt practices mentioned during the FGD include illegal fishing, charcoal production, abuse of funds by the authorities, and rental-seeking behavior locally known as *ya Nchere* (buy salt). A high rate of corruption perception decreases public trust and impedes ecosystem restoration efforts (Zulu 2008). About 15% of the respondents pushed the responsibility to the government, while 8% suggested that they pay through tax. The ecosystem management approach follows top-down in Malawi, where the government creates rules and imposes them on the local population (Lewins et al., 2013). However, this approach has faced strong resistance in its implementation (Wilson et al., 2010), as reflected in the negative WTP responses. Some respondents expressed that they were not interested in the proposed program, which could be attributed to political reasons (Makwinja et al., 2019).

Table 6. The percentage of positive and negative WTP responses and the reasons.

Factors	Categories	Freq	percent
WTP	yes	235	56
	No	185	44
Reasons for WTP	Improve ESs	17	4
	improved income	118	28
	Mitigate climate change impact	25	6
	Improved fish biodiversity	168	40
	Improve water quality	8	2
Reasons for not WTP	Cannot afford	42	10
	Has no trust	189	45
	It is a government responsibility	63	15
	Does not get affected by ESs change	8	2
	We pay through tax	34	8
	Not interested	84	20

5. Conclusion and recommendation

This study offered theoretical and practical perspectives on how different individuals perceive the degraded lake ESs and respond to the restoration effort. It demonstrates how science and policy can be integrated to achieve a sustainable flow of ESs. Although the study reflected varying perceptions regarding the lake ESs, there is evidence that the current status of the lake will affect the achievement of SDGs and Aichi Biodiversity Targets. The study demonstrates that conflicting ideas are expected in a complex long-term restoration effort, even with the significant participation of various stakeholders. The study suggested a need to hold a practical debate to reach a consensus regarding the lake ecosystem restoration since the proposed program attracted mixed views among the various stakeholders, with one group (56%) supporting the WTP concept while the other (44%) against it. Despite broad participation, the study proved that failure to set a practical debate, the restoration effort will be perceived as a command control tool and will eventually face strong resistance from the local communities. The study further suggested the need to comprehensively accommodate the broader interests and concerns of the local population into the policy formulation as this influences their perceptions, how they embrace the governance system, and their support towards the WTP concept for the proposed ecosystem restoration program. The current findings are a reference point for fragile global inland freshwater shallow lakes' ecosystem restoration effort and feed into the national, regional, and global policy frameworks.

Declarations

Author contribution statement

Rodgers Makwinja: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Seyoum Mengistou, Emmanuel Kaunda & Tena Alamirew: Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data availability statement

Data will be made available on request.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

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