Received: 26 February 2018 | Accepted: 8 June 2018
DOI: 10.1111/lre.12225

ORIGINAL ARTICLE

WILEY Lakes & Reservoirs

Fishing community preferences and willingness to pay for alternative developments of ecosystem-based fisheries management (EBFM) for Lake Naivasha, Kenya

Dawit W. Mulatu[1] | Pieter R. van Oel[2] | Vincent Odongo[3] | Anne van der Veen[4]

[1]Environment and Climate Research Centre (ECRC), Environment for Development (EfD), Ethiopian Development Research Institute (EDRI), Addis Ababa, Ethiopia

[2]Water Resources Management Group, Wageningen University, Wageningen, The Netherlands

[3]Department of Agricultural Engineering, Faculty of Engineering and Technology, Egerton University, Njoro, Kenya

[4]Faculty of Geo-Information Science and Earth Observation (ITC), Department of Urban and Regional Planning and Geo-Information Management, University of Twente, Enschede, The Netherlands

Correspondence
Dawit W. Mulatu, Environment and Climate Research Centre (ECRC), Ethiopian Development Research Institute (EDRI), Environment for Development (EfD), P.O. Box: 2479, Addis Ababa, Ethiopia.
Email: dawitwmulatu@gmail.com

Funding information
Netherlands Organization for Scientific Research, WOTRO Science for Global Development (NWO/WOTRO)

Abstract

Ecosystem-based fisheries management (EBFM) is an important complement to existing fisheries management approaches to maintain ecosystem health and function; to translate goals and aspirations for sustainability into operational objectives, the preferences of the fishing communities should be considered for successful implementation of EBFM. This study analysed the preferences of the fishing community for alternative EBFM developments for Lake Naivasha, Kenya, and estimated the willingness to pay, using a choice experiment approach. Protection of fish breeding grounds, improving tilapia fish abundance and accessibility of fishing zones were identified as relevant EBFM attributes for the choice experiment. A monetary attribute (payment for fishing permit) was also included. In addition to a conditional logit model, mixed logit models are estimated to account for heterogeneity in preferences. This study results indicated fishing communities are most concerned about tilapia fish abundance and protection of fish breeding grounds. The welfare measures reveal that members of the Lake Naivasha fishing community are willing to pay a considerable sum of money for ecosystem services improvement, relative to their low income derived from fishing. These study findings highlighted that evaluating the preferences of the fishing community and valuing the fishery at an ecosystem level are vital to prioritize and choose between alternative interventions for sound implementation of EBFM.

KEYWORDS
choice experiment, ecosystem-based fisheries management (EBFM), fishing community, Welfare and Lake Naivasha, willingness to pay

1 | INTRODUCTION

Fisheries are a major provisioning ecosystem service, being a key component of both diet and income for many communities. Most rivers and lakes in the world support inland fisheries (Wang, Xu, Yu, & Lei, 2014), providing one-third of global small-scale fish catches. Moreover, inland fisheries provide employment for more than 60 million people, of which more than 50% are women (UNEP, 2010). A continued supply of benefits from fisheries, however, depends on the health of these ecosystems. It is widely believed the collapse of inland and marine fisheries are attributable primarily to mismanagement of the fisheries (Costello, Gaines, & Lynham, 2008). Fisheries in developing countries particularly suffer from overfishing and *inter-alia* poor enforcement of existing fishery-related laws (Blaber, 2009; Wang et al., 2014). Mismanagement of inland fisheries is not only due to lack of law enforcement, but also to the fact that traditional fisheries management often ignores habitat, predators and the prey of the target species and other physical components of ecosystems (Nguyen, 2012; Pikitch et al., 2004). To overcome these fisheries mismanagement concerns, therefore, ecosystem-based fisheries management (EBFM) provides a new approach. EBFM essentially reverses management priorities to ensure ecosystem quality, rather than targeting specific species. It is a holistic approach to maintaining ecosystem quality and sustaining associated benefits (Garcia & Cochrane, 2005; Hiddink et al., 2008; Pikitch et al., 2004; Pomeroy, Garces, Pido, & Silvestre, 2010). As such, EBFM is an important complement to existing fisheries management approaches in maintaining ecosystem health and functioning (Essington & Punt, 2011). In the context of Africa, however, EBFM faces a number of constraints, including limited data and limited scientific efforts (Musinguzi, Natugonza, & Ogutu-Ohwayo, 2017).

The concept of EBFM is evolving, with no universal definition or consistent application (Brodziak & Link, 2002). Moreover, effective EBFM requires identification of goals and conservation targets reflecting the interconnected nature of ecosystems and their multiple natural, social, cultural and economic values (Clarke & Jupiter, 2010; Mathew, 2003, 2011). A management approach focusing on valuing fishery at ecosystem level is needed to examine conservation strategies. In 2011, the Kenya government launched the "Imarisha Naivasha" (or the "Empower Naivasha" programme), a public–private partnership initiative to coordinate local industries and communities with government agencies and Non-Government Organizations (NGOs) in an effort to ensure environmental sustainability and development within the Lake Naivasha basin (Gherardi et al., 2011). The "Imarisha Naivasha" programme recognized the need to encompass fishing communities through the EBFM approach to improve lake ecosystem services (Imarisha Naivasha Trust, 2012).

The Lake Naivasha ecosystem is very fragile, with the fishery almost collapsing completely in 2001, partly attributable to mismanagement and lack of conservation measures (Kundu, Aura, Muchiri, Njiru, & Ojuok, 2010). More recently in 2010, a sudden fish-kill was attributed to water-quality deterioration in the lake (WWF, 2011). Loss and degradation of habitat and overfishing are seen as the most important factors causing a declining fish stocks (Kundu et al., 2010). Over-abstraction of lake water also has reduced the lake surface area and increased the proportion of the shallow littoral zone to open water (Harper, Morrison, Macharia, Mavuti, & Upton, 2011). Other related threats include unpredictable lake-level fluctuations (Van Oel et al., 2013), illegal fishing by unlicensed fishermen who ignore regulations (Hickley et al., 2002), degradation of riparian vegetation and unprotected critical fish habitats (i.e., breeding and nursery grounds) (Yongo et al., 2013). Water hyacinth has been reported in Lake Naivasha since 1988 (Njuguna, 1991), spreading throughout the littoral zones of lake within three years after being first recorded (Aloo, 1996). The excessive invasion of water hyacinth has affected access to fishing zones and disrupted fishing activities (e.g., fishermen trapped for long hours and losing their fishing nets). This invasion also infested the lake ecosystem, suppressed and occupied ecological niches, thereby disrupting plant–animal–physical environment interactions and balances (Mironga, Mathooko, & Onywere, 2012). Further, the fish breeding grounds have been exposed to illegal fishing practices, and the fish stock (e.g., *Aplocheilichthys antinori* (Vinciguerra)) is also endangered and now believed to be extinct (Yongo et al., 2013). A declining fish population could affect the diversity of piscivorous bird communities around the lake that depend on fish for food (Becht, Odada, & Higgins, 2005; Oyugi, Harper, Ntiba, Kisia, & Britton, 2011).

Considerable research has been conducted on Lake Naivasha ecosystem services management, habitat degradation, invasion of species, fisheries resources and eco-hydrological regime. Restoration, protection and recovery of the lake's natural fringe zone of *Cyperus papyrus* could help reduce eutrophication. Relevant activities include facilitating a transition to a clear water state and promote macrophyte growth (Harper & Mavuti, 2004; Hickley et al., 2004), applying improved water management schemes with the aim of maintaining water availability and quality (Becht & Harper, 2002; Oyugi et al., 2011; Van Oel et al., 2014), implementing conservation management frameworks and collaborative management (co-management) to improve the lake ecosystem services and fishery resources (Gherardi et al., 2011; Hickley et al., 2002; Kuhn, Britz, Willy, & Van Oel, 2016; Kundu et al., 2010; Mulatu, Van Oel, & Van der Veen, 2015; Ogada, Krhoda, Van der Veen, Marani, & Van Oel, 2017; Waithaka, Mugo, Obegi, & Last, 2015) and linking socioeconomic factors to eco-hydrological processes that can greatly improve understanding of the lake's eco-hydrological system (Harper et al., 2011; Odongo et al., 2014).

The EBFM approach seeks to play a fundamental role in maintaining the Lake Naivasha ecosystem health and functions, in contrast to approaches addressing only parts of the ecosystem or individual species. The preferences of the fishing community around Lake Naivasha should be taken into account to set goals and conservation strategies for an effective EBFM. To the knowledge of the authors of this study, no research into ecosystem-based fisheries management of Lake Naivasha has yet been conducted. More generally, only limited research has been carried out in developing countries on the economic valuation of fisheries and EBFM (Agimass & Mekonnen, 2011; Barnes-Mauthe, Oleson, & Zafindrasilivonona, 2013; Beard Jr. et al., 2011; Evans, Cherrett, & Pemsl, 2011; McClanahan, 2010; Wells, Makoloweka, & Samoilys, 2007). Thus, this study analyses fishing community preferences and estimates their willingness to pay for implementation of alternative developments for EBFM, using a choice experiment approach for Lake Naivasha, Kenya.

2 | LAKE NAIVASHA AND FISHERY

Lake Naivasha lies ~1,890 m above mean sea level, with a strongly varying volume (Van Oel et al., 2013). Its surface area varies between 100 and 160 km^2 (Oyugi et al., 2011). Although Lake Naivasha is a wetland of international importance for socioeconomic and ecological functions (Ramsar, 2014), there are extensive human pressures exerted on its ecosystem, including habitat degradation and wide fluctuations in water levels due to climatic variability, as well as anthropogenic activities and the adverse impacts attributable to the introduction of alien species (Britton et al., 2007). The lake is affected by turbidity (Britton & Harper, 2006; Harper et al., 2011), driven by the introduction of alien species and physicochemical degradation (Gherardi et al., 2011). The physicochemical degradation of the lake is affected by the inflow of run-off, nutrients and sediments (Kitaka, Harper, & Mavuti, 2002). Apart from the invaluable freshwater resource, the lake supports a range of important economic activities, including large-scale agricultural farms, geothermal power generation and small-scale fishing practices (Becht & Harper, 2002; Mulatu, Van der Veen, Becht, Van Oel, & Bekalo, 2013). The lake also supports livestock farming and a growing tourism sector (Becht et al., 2005; Mulatu, Van der Veen, & Van Oel, 2014).

Lake Naivasha maintains a high ecological interest and biodiversity value despite its food web being controlled at three trophic levels by alien species over the past 40 years (Harper et al., 2011). The fish community in Lake Naivasha is almost entirely exotic, noting the introduction of various fish species into the lake since 1925. Although some species' introduction has been successful, others have failed (Hickley et al., 2004). One successful species introduction was the red-bellied tilapia *Tilapia zillii* (Gervais) (note the genus name for this fish species has changed to *Coptodon zillii*) and blue-spotted tilapia *Oreochromis leucostictus* (Trewavas), which were introduced in 1956 (Hickley, Muchiri, Britton, & Boar, 2008; Oyugi et al., 2011). Hickley et al. (2008) provide a summary of changes to the fish community, history, and subsequent introductions to Lake Naivasha. Lake Naivasha's socio-ecological system and ecological history are more generally described by Harper et al. (2011).

Cyprinus carpio, commonly known as common carp, was reported in 2001 and is believed to have been accidentally introduced through inflowing rivers from fish farms in the catchment after the heavy *El Niño* rains of 1997/98 (Yongo et al., 2013). Common carp contributes to increasing turbidity, being the dominant fish in the lake system (Hickley, Britton, Macharia, Muchiri, & Boar, 2015). It provides a viable and profitable species for exploitation during periods when fish catch returns of the other target species have declined substantially. Nevertheless, the price of *C. zillii* is relatively high because it is more in demand than common carp as a table fish. This is because it is a known species consistent with traditional cooking methods and has a flavour preferred by local consumers.

Although the Lake Naivasha fishery comprises an important source of income and animal protein for the human population around the lake and nearby towns, several factors threaten this

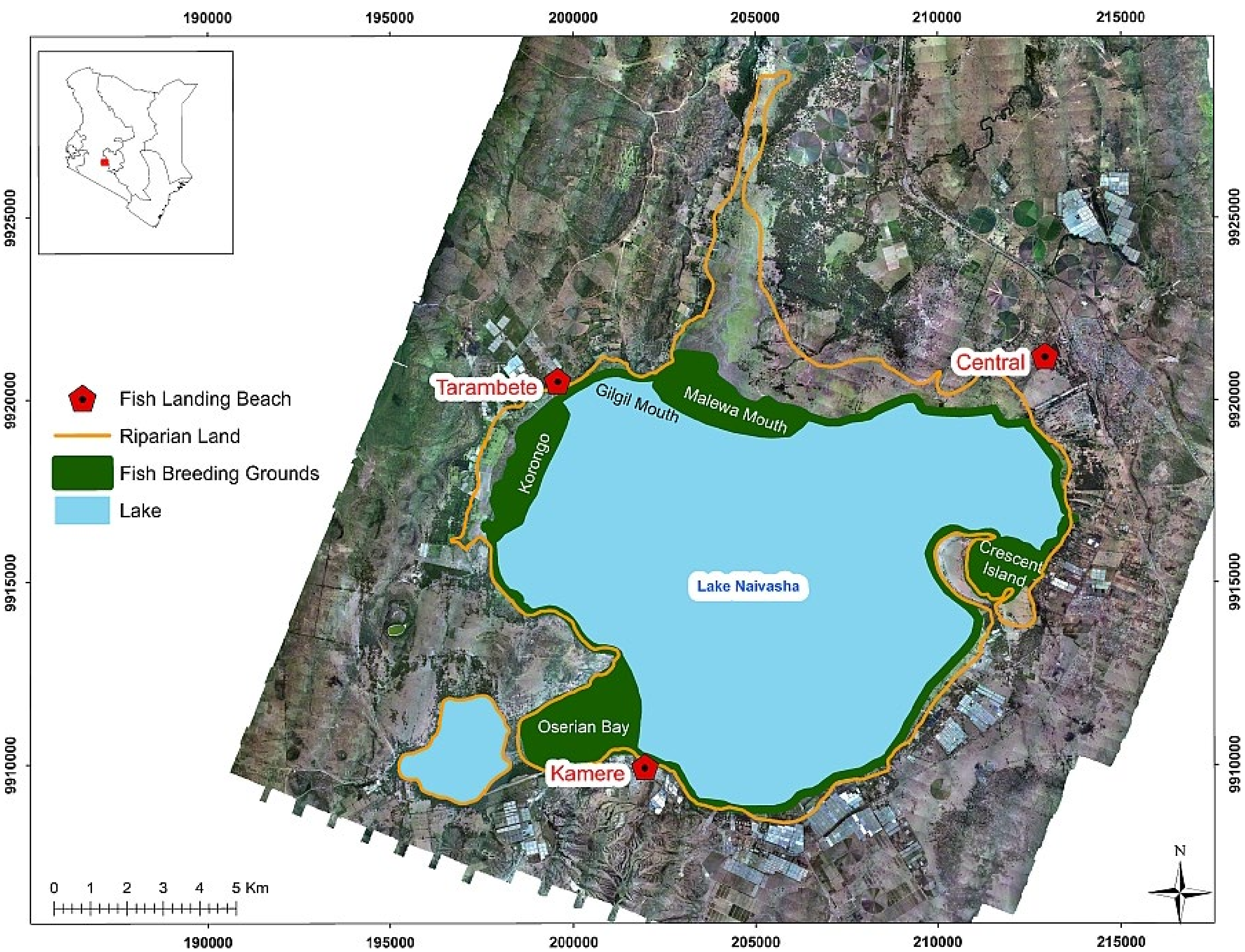

FIGURE 1 Lake Naivasha and surroundings, fish landing beaches, fish breeding grounds (areas) and lake riparian zone boundary

activity, including uncontrolled and excessive fishing, rampant use of prohibited fishing gears, disturbance of critical fish habitats in the shallow lakeshore areas and weak enforcement of fisheries regulations (Kundu et al., 2010). The critical fish habitats (breeding and nursery grounds) require protection to assist recovery of the Lake Naivasha fish stocks (Figure 1). These areas have been identified, mapped and delineated for protection and revival of the fishery stock (Yongo et al., 2013). There are considerable temporal fluctuations in fish catches and, despite the regulations and periods of closure, there has been a general decline in the total catch of all species since the mid-1980s. Annual fish catches from Lake Naivasha for the period 1963 to 2013 are presented in Figure 2, which makes the Lake Naivasha fishery small scale (Harper et al., 2011).

Fishing communities in Lake Naivasha are organized in Beach Management Units (BMUs). A BMU is a fisheries management concept that identifies and defines the lake ecosystem and the fishing communities, offering a viable option to attain sustainable fishery resource utilization. BMUs and other welfare groups have been formed in the Lake Naivasha area and have been supportive in solving beach-related conflicts, especially at the fisher-to-fisher level (Kundu et al., 2010). There are three BMU sites used for fish landing and trading activities around Lake Naivasha, including Kamere beach (South lake), Tarambete beach (North Lake) and Central beach (near Naivasha town; Figure 1). Based on 2012 records, there were 453 registered fishing community members, comprising 168 licensed fishermen (i.e., 50 canoes with three crewmembers on average) and 285 licensed fish traders and transporters that carry fish from the main fish landing sites to fish markets.

3 | DATA AND CHOICE EXPERIMENT DESIGN

3.1 | Data

The data for this study were collected from BMU members, using a questionnaire conducted through face-to-face interview from July

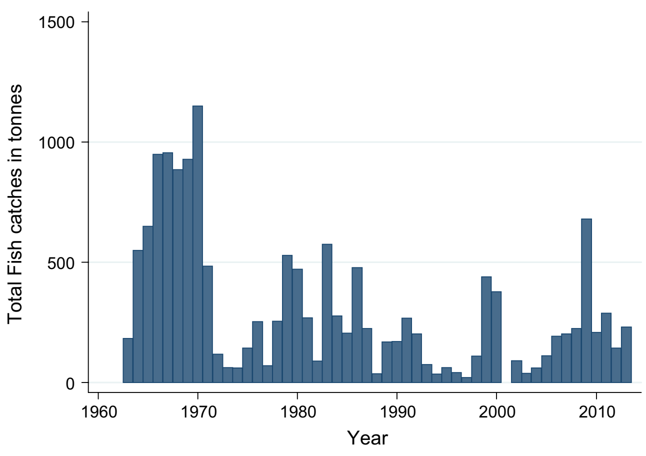

FIGURE 2 Lake Naivasha fish catches (tonnes) from 1963 to 2013 (MoFD 2013)

to August 2012. A total of 91 respondents were selected at random from 453 registered members of the BMUs and interviewed. The first part of the questionnaire focused on choice experiment exercises for the implementation of alternative EBFM developments. This study uses the term "attribute" to characterize EBFM developments. As with other valuation studies, the valuation scenario description was presented to respondents prior to the choice experiment exercises. Information on the socioeconomic characteristics of the respondents was collected to complement the experimental data, in addition to information on awareness and observations about the Lake Naivasha ecosystem and its surroundings. The questionnaire was tested by conducting a pilot survey to check the relevance of the choice experiment questions. The pilot survey results suggested pictures in choice cards are important to more easily understand the choice experiment exercises. Thus, the choice experiments were supported by choice cards and pictures to explain the EBFM attributes. The questionnaires were administered by trained enumerators, with interviews conducted in the local language.

3.2 | Choice experiment design

The first step in a choice experiment design is to identify EBFM choice attributes and define their levels. The attributes should be consistent with the proposed interventions and expected outcomes, thereby being relevant to the policy-making process. Supply- and demand-driven approaches were applied to develop and determine the EBFM choice attributes and levels (Sangkapitux et al., 2009). For the supply-driven approach, research into Lake Naivasha ecosystem services management, habitat degradation, species invasion, fisheries resources and eco-hydrological regime was explored (Harper & Mavuti, 2004; Harper et al., 2011; Hickley et al., 2004, 2008; Kundu et al., 2010; Odongo et al., 2014; Oyugi et al., 2011). Focus group discussions (FGD) were organized to support the design of the choice experiments regarding the demand-driven approach. The main FGD objective was to understand the fishing community perspective towards EBFM.

Four fishermen and three fish traders participated from each BMU. Local knowledge was a key asset in the decision-making process as it inspires a sense of stewardship in the lake and its resources (Kundu et al., 2010). Therefore, the knowledge and experience of the local fishing community and expert knowledge from Lake Naivasha Fisheries Department were incorporated to develop the EBFM alternatives. At last, three EBFM attributes and their levels were identified and used in the choice experiment. A monetary attribute payment for fishing permits was included in the choice experiment. The three EBFM attributes and the monetary attribute are summarized in Table 1. Four main areas were identified by local fishermen as critical fish habitats (Figure 1), including Oserian bay in the southwest, Korongo in the northwest, and Malewa and Gilgil river mouths in the north and east of Crescent Island (Yongo et al., 2013). The choice experiments valuation scenario and attributes were presented briefly to the respondents before engaging in the detailed exercise of valuation explaining the proposed alternative EBFM

TABLE 1 Lake Naivasha EBFM attributes and their levels used in choice experiment

Attributes	Description for EBFM attributes to improve lake ecosystem	Status quo	Management levels
Protection of fish breeding grounds/areas	Protection of critical fish habitats (breeding and nursery grounds/areas) through implementing collaborative management (co-management) tools to take measures on illegal fishermen (fish poachers) and restoration of vegetation covers of Lake riparian zones	<15% of Lake Naivasha fish breeding grounds are protected	The protected fish breeding grounds/areas will be: Moderate level: 25% High level: 50%
Tilapia fish abundance	Tilapia fish stock enhancement through restocking and reducing discharges to the lake would contribute to improving tilapia fish abundance. Interventions to improve lake water quality include controlling lake water pollution by installing appropriate water treatment plants and cyperus papyrus restoration along lake fringe zones	<2% of total fish landings	The proportion of tilapia in total fish landing will be: Moderate level 15% High level 35%
Accessibility of fishing zones	Measures to improve accessibility fishing zones through implementing programmes to use water hyacinth for other economically productive and alternative uses	<50% of fishing zone is easily accessible	The fishing zones that will be easily accessible Moderate level 65% High level 80%
Fishing permit or Willingness to Pay (WTP) in Kenyan Shillings (KES) per year	Payment for fishing permit or the willingness to pay (WTP) for Lake Naivasha ecosystem improvement	300 KES per year	Proposed fishing permit fees: 500, 650, 750 and 1,000 KES per year

Note. The tilapia fish abundance attribute in this case is to indicate restocking of *C. zillii* (Gervais), *Oreochromis niloticus* (Nile tilapia) and *Oreochromis leucostictus* (Trewavas) species.

attributes. During the focus group discussions and while conducting the survey, it was clearly mentioned to respondents that funding the programme would require an increase in the current fees. They were currently paying 300 Kenyan shillings (KES) per year as a fishing permit fee, which is used mostly to implement different interventions for restoring the lake ecosystem. It was clarified that to estimate the willingness to pay for each choice attribute, a monetary attribute as a fishing permit fee in Kenyan shillings per year was included as one attribute in the choice sets).

The combination of all attributes and levels resulted in a full factorial design with 32 different EBFM alternatives (i.e., 4×2^3). The number of combinations of attributes from the full factorial design, however, can be very large, and it is impractical to administer such a large number of choice sets for meaningful research in most cases (Hanley, Mourato, & Wright, 2001; Lusk & Norwood, 2005). Thus, a cyclical and fractional factorial main effect design principle using an orthogonal approach was applied to reduce and select the choice sets. Additional alternative attributes were constructed by cyclically adding alternatives into the choice set, based on the attribute levels (Asrat, Yesuf, Carlsson, & Wale, 2010; Carlsson, Frykblom, & Lagerkvist, 2007). Eight choice sets were generated, consisting of only the main effects and being independent of two-factor interactions. These eight choice sets were assigned randomly to two blocks, with each respondent asked to make four choices having three alternatives in each choice set. An example of a choice set in the experiment is presented in Figure 3.

The current status (status quo option) was included in all the choice sets, thereby allowing the respondents not to select the two provided alternatives in order to give an idea about the potential to improve the lake ecosystem. The inclusion of the status quo option in the choice sets was also instrumental for achieving welfare measures consistent with demand theory (Bateman et al., 2002). The choice experiments are analysed using 1,092 observations elicited from the 91 respondents. The conditional logit model and mixed logit models were estimated using the statistical package of Stata version 12.0. The three EBFM attributes were entered in label format and coded as zero, one and two for the status quo, moderate and high-level EBFM alternatives, respectively. The fishing permit attribute was entered in cardinal-linear form. To be consistent with the expected policy instruments as outcomes from the provided alternatives, and following the numerous practices to identify cost attribute in fisheries valuation research (Agimass & Mekonnen, 2011), fishing permit payment was considered as a cost attribute by taking the current annual fishing permit payment as status quo level.

4 | ECONOMETRIC APPROACH

The term choice modelling encompasses a range of stated preference methods, which take a similar approach in environmental nonmarket valuations (Bateman et al., 2002). One choice modelling method is choice experiment. The choice experiment method has

Ecosystem Attributes	Pictures[a] to explain the attributes	Choice 1	Choice 2	Status quo
Protection of fish breeding grounds/area		50% of Lake Naivasha fish breeding grounds will be protected	25% of Lake Naivasha fish breeding grounds will be protected	Less than 15% of Lake Naivasha fish breeding grounds is protected
Tilapia fish abundance/ stock		15% of total fish landings will be from Tilapia	35% of total fish landings will be from Tilapia	Less than 2% of total fish landings is from Tilapia
Improvement on Fishingzones accessibility		65% of fishing zone will be easily accessible	80% of fishing zone will be easily accessible	Less than 50% of fishing zone is easily accessible
Fishing permit or Willingness to Pay WTP) in Kenyan Shillings (KES)/yr^{-1}		650	750	300

Would you please select and tick your preference from the above choices?
Choice 1 ☐ ☐ Choice 2 ☐ Current status/Status quo

FIGURE 3 Sample choice set. [a]Pictures taken during field-work to collect survey data

its theoretical grounding in Lancaster's model of consumer choice (Lancaster, 1966), and its econometric basis is a random utility model (RUM). Lancaster proposed that consumers derive satisfaction not only from the goods and services themselves, but also the attributes they provide (Birol, Karousakis, & Koundouri, 2006). The random utility approach describes the utility of a choice as being comprised of a systematic (explainable) component and an error (unexplained) component (Rolfe, Bennett, & Louviere, 2000), and assumes the utility function (U_i) consists of two parts, as follows:

$$U_i = V_i + \varepsilon_i \tag{1}$$

where V_i = observable component of the utility; and ε_i = random or "unexplained" component. As a result to the random component, one can never expect to predict choices perfectly. As fishing community's preferences are observed in terms of their choices, a random utility framework was employed to analyse the responses for different choice sets. A respondent's choice was considered for alternative ecosystem-based fisheries management (EBFM) scenario, assuming utility depends on choices made from a choice set C, which includes all the possible EBFM scenario alternatives. The respondent is assumed to have a utility function of the form:

$$U_{ij} = V(E_j, S_i) + \varepsilon_{ij} \tag{2}$$

where U_{ij} = utility from a given option j of individual I; E_j = vector of EBFM attributes for option j; and S_i = vector of socioeconomic characteristics of individual i. Following Lancaster's model of consumer's choice, the respondent utility function U_{ij} can be expanded to the following form:

$$U_{ij} = V(E_j, S_i) + \varepsilon(E_j, S_i) \tag{3}$$

where $V(\cdot)$ = observable component; and $\varepsilon(\cdot)$ = random component of the utility associated with any option j for individual i. Choices made between alternatives are a function of the probability that the utility associated with a particular option (j) is higher than for other alternative (Rolfe et al., 2000). Thus, the probability (P_{ij}) that an individual i prefers option j over some other option q can be represented as the probability that the utility associated with option j exceeds that associated with option q in a given choice set C (i.e., $U_{ij} > U_{iq}$ for all $q \neq j$), presented by Hanley et al. (2001), as follows:

$$P_{ij} = P(V_{ij} + \varepsilon_{ij} > V_{iq} + \varepsilon_{iq}); \quad \forall q \in C \tag{4}$$

The model in Equation (3) can be estimated using a conditional logit (CL) model. The conditional logit model assumes the random components are distributed independently and identically (IID) with a Weibull distribution, and choices are consistent with the independence of irrelevant alternatives (IIA) property (Train, 2003; Greene, 2003). The IIA property states the relative probabilities of two options being chosen are unaffected by the introduction or removal of other alternatives (Greene, 2003; Train, 2003). Thus, the conditional logit model to be estimated for the probability of choosing a particular option j is given as follows:

$$P_{ij} = \frac{\exp\left(V(E_{ij}, S_i)\right)}{\sum_{q \in C} \exp\left(V(E_{iq}, S_i)\right)} \tag{5}$$

The conditional indirect utility function can be estimated as follows:

$$V_{ij} = \beta + \beta_1 E_1 + \beta_2 E_2 + \cdots + \beta_n E_n + \delta_1 S_1 + \delta_2 S_2 + \cdots + \delta_m S_m \quad (6)$$

The constant term β can be portioned to alternative specific constants (ASCs) unique to each alternative considered in the choice sets (Rolfe et al., 2000) and captures the effects of any attribute (i.e., not included in choice specific attributes) on utility (Hanley, Wright, & Adamowicz, 1998). The vector of coefficients β_1 to β_n and δ_1 to δ_m is attached to the vector of EBFM scenario attributes (E), and the vector of socioeconomic characteristics (S) that influence utility, respectively. The socioeconomic characteristics are introduced as interaction terms with either the attributes or the alternative specific constants, as these characteristics do not vary across the alternatives (Hanley, Wright, & Alvarez-Farizo, 2006). If the IIA property is violated, the CL model result will be biased. In that case, a discrete choice model that does not require the IIA property should be applied (e.g., the heteroscedastic extreme value (HEV) model) and the random parameter logit (RPL) or mixed logit (MXL) model can be applied (Hensher & Greene, 2003). These models are able to overcome the IIA limitations by explicitly accounting for correlations in unobserved utility over repeated choices by each respondent and improving the model fit (Hensher & Greene, 2003; Hoyos, 2010). Willingness to pay (WTP) was then derived using estimates of coefficients from the indirect utility model for each attribute in the choice experiment that validate the demand theory, using the following formula (Hanemann, 1984):

$$\text{WTP} = \beta_C^{-1} \ln \left(\frac{\sum_{j \in C} \exp V_j^1}{\sum_{j \in C} \exp V_j^0} \right) \quad (7)$$

where WTP = welfare measure V_j^0 = utility of initial state; and V_j^1 = utility of an alternative state. The coefficient β_C is equal to the marginal utility of income, being the coefficient of the price or monetary attribute in the choice experiment. It is then straightforward to show that, from the linear utility index of Equation (2) (Hanley et al., 2001), the marginal value of a single EBFM attribute can be represented as a ratio of coefficients, and Equation (7) can be simplified as:

$$\text{WTP} = -1 \left(\frac{\beta_E}{\beta_C} \right) \quad (8)$$

where β_E = coefficient of any EBFM attribute in the choice experiment. These ratios are often known as implicit prices, indicating the WTP for a change in any attribute. The implicit prices are useful to demonstrate trade-offs between individual attributes. A comparison of the implicit prices of attributes affords some understanding of the relative importance the respondents give them. On the basis of such comparisons, policymakers are better placed to design resource use alternatives to favour those attributes with higher (relative) implicit prices. The welfare measure from a quality or a quantity change of an environmental good and service is given by the measure of compensating surplus. Compensating surplus welfare measures can be obtained for different EBFM scenarios associated with multiple changes in attributes. Thus, Equation (7) also simplifies to:

$$\text{CS} = \frac{-(V_j^0 - V_j^1)}{\beta_C} \quad (9)$$

The randomly distributed parameters were assumed constant across the choice situations for each individual. Moreover, the assumption of a fixed monetary coefficient (i.e., fish permits) was made because keeping at least one parameter fixed facilitates the willingness to pay estimation, with the distribution of the willingness to pay simply becoming the distribution of the random parameter (Asrat et al., 2010). In addition to the conditional logit model, mixed logit models were estimated with and without interactions terms to account for preference heterogeneity and to explain its source.

5 | RESULTS

5.1 | Descriptive statistics

The descriptive statistics for selected socioeconomic variables of the sample respondents are presented in Table 2. The average monthly income of the respondent was about 19,500 Kenyan shillings (~227 USD). About 28% of the respondents were above primary-level education. The average respondents' age was 37 years, with 79% of them being married with a family size of 4.5 members. It is an interesting fact that about 47% of the respondents agreed on the current 3-month lake closure period per year to enhance the fish population and to improve the lake ecosystem. Of the 53% of the respondents who did not agree to the current closure period, 12% proposed that the lake should not be closed at all, although 8% and 33% proposed a 1- or 2-month lake closure period, respectively. The fishing experience for respondents averaged 8 years, and a catch of 80 kg of fish per day. Respondents have a wide range of fishing experiences from 1 to 30 years. About 36% of the respondents believed their living condition was better off compared to 5 years ago, although about 12% and 52% believed their living conditions were similar, or they were less well off, compared to 5 years ago, respectively. About 51% of the respondents believed the current situation of the lake ecosystem was not good. It is an interesting fact that nearly 72% of the respondents claimed farmers around the lake (i.e., not belonging to the fishery community) were responsible for the lakeside degradation.

Debriefing questions were used to investigate whether or not attributes had been ignored by respondents, and to identify the choice attributes they focused on in the choice experiments. Although all respondents noticed an EBFM attribute while choosing alternatives in the choice sets (Table 3), they indicated their concern from the choice attributes when making a choice. About 24% of the respondents considered fishing permit attributes in selecting their choices. Table 3 indicates the attribute least considered in the choice experiment was the accessibility of fishing zones, followed by protection of fish breeding grounds (about 60% and 52% of the respondents, respectively). Nearly 69% of the respondents believed the tilapia fish stock enhancement attribute required attention.

5.2 | Econometric model estimation

Except for the payment attribute, all the parameters were specified to be normally distributed (Carlsson, Frykblom, & Liljenstolpe, 2003).

TABLE 2 Descriptive statistics for selected socioeconomic variables of sample respondents

Variables	Description	Mean	*SD*
Age	Age of respondent	36	10
Income	Respondent monthly income in Kenyan shillings	19,490	9,408
Family size	The number of family members	4.58	2.33
Family head	=1 if family head is male, and zero otherwise.	0.81	0.39
Marital status	=1 if respondents are married, and zero otherwise	0.79	0.40
Education	=1 if respondent education level is above primary, and zero otherwise	0.28	0.45
Environmental, natural resource and fisheries management advice	=1 if respondent has been advised on environmental, natural resources and fisheries management in last 12 months, and zero otherwise	0.42	0.49
Fish catches/trading	Respondent's average fish catch/trading per day/kg	78.57	78.95
Fishing or fish trading experience	Number of years respondent is in fishing or fish trading	8.26	6.13
Lake fishing beaches closure	=1 if respondent agrees with current lake fishing beach closure practice in Lake Naivasha to sustain fish population, and zero otherwise	0.47	0.50

TABLE 3 Concerns of respondents while choosing alternatives in the choice set

	Choice attribute				
Group	Protection of fish breeding grounds/areas (1)	Tilapia fish abundance/ stock (2)	Improving Fishing zones accessibility (3)	Fishing permit (4)	~Percentage
1	✓	✓	✓	✓	6
2	✓	✓	✓		7
3		✓	✓	✓	6
4	✓	✓			34
5		✓	✓		14
6	✓		✓		11
7			✓	✓	4
8				✓	8
9			✓		4
10		✓			2
11	✓				3
Total	~61%	~69%	~52%	~24%	~100

Note. ✓ indicates respondents were focused on the attributes when choosing alternatives.

The likelihood ratio test was conducted to investigate whether or not preferences differed between fishermen and fish traders. The Likelihood ration test was 4.24 (p = 0.375) indicating a statistically insignificant difference between the two groups. Thus, the estimates were only for the complete sample set. The results of the IIA property test for the conditional logit model using Hausman and McFadden (1984) are presented in Table 4. In all three cases, the IIA assumption could not be rejected (Hensher, Rose, & Greene, 2005), meaning the conditional logit model was the appropriate model for estimation of the choice experiments data. The result for the conditional logit model estimates for all EBFM attributes is significant and has positive signs, implying the probability of choosing an alternative option with changes in attribute improvement will increase as the levels of the attributes increase. The negative sign of the

TABLE 4 Hausman test for IIA assumption

Alternative dropped	Chi.sqr (4) (χ^2)	*p*-value
Choice 1	2.56	0.633
Choice 2	5.62	0.229
Status quo	2.52	0.642

fishing permit attribute indicated the choice option with "cheaper" alternatives was preferred above "expensive" alternatives, meaning the effect on the utility by choosing a choice with higher payment is negative.

The choice experiments data were estimated using mixed logit models to account for respondents' preference heterogeneity and unbiased estimates in individual preferences (Birol et al., 2006). Two mixed logit models are estimated with simulated maximum likelihood using Halton draws with 500 replications (Hensher & Greene, 2003; Train, 2003). The alternative specific constants (ASCs) are dummy variables coded as one when the alternative in the choice set was selected, and zero otherwise. Two ASCs (Choice1_ASC and Choice2_ASC) were included in the regression analysis for alternatives because the choice attributes were entered in label format, and the ASC dropped for the status quo to avoid multicollinearity. Including the ASCs is important to determine whether any factors other than the attributes affected the respondents' choices, and to interpret the preferences of the individuals (Train, 2003). The alternative specific constants in the mixed logit models are significant, indicating factors other than EBFM attributes affected individual choice behaviour. Except for tilapia fish stock attributes in the extended mixed logit model, the results revealed significant standard deviations for the EBFM attributes, and unobserved heterogeneity with mixed logit specification was captured (Table 5). The relative magnitude of the standard deviations also implied a probability respondent that might have the reverse preference for a particular attribute (Carlsson et al., 2003). This result was supported by the mean coefficient estimates of the extended mixed logit model because the accessibility of fishing zones attribute has a negative sign, meaning respondents were not willing to pay for this attribute.

The basic mixed logit model estimates revealed improved tilapia fish abundance and protection of fish breeding ground attributes are significant, having positive signs. In the extended mixed logit model, improved tilapia fish abundance and accessibility of fishing zones attributes are also significant, although the latter attribute has a negative sign. The negative sign for accessibility of fishing zones attribute indicates fishing communities are deterred to pay for this attribute, which might be due to the fishermen's current involvement in using water hyacinth as alternative energy sources to reduce the impact of the infestation on the lake ecosystem. Fishermen carry the weed from the lake when returning from fishing activities to feed the 16 m^3 biogas plant at the Central landing beach, which was installed with support of the "Imarisha Naivasha" programme. Moreover, the result suggests fishing communities might be willing to participate in a compensation scheme to improve this EBFM attribute. The results of all models revealed that fishing communities had a higher preference for tilapia fish abundance attribute than the other two EBFM attributes.

To account the sources of preference heterogeneity, inclusions of respondents' specific characteristics with choice attributes are important, enabling the RPL model to pick preference variation of both unconditional taste heterogeneity and individual characteristics, thereby improving model fit (Birol et al., 2006; Rolfe et al., 2000). As a result to potential multicollinearity problems, however, it was not possible to include all interactions between the explanatory variables and the EBFM attributes. After extensive testing of various interaction terms with EBFM attributes, the mixed logit model (which includes family head, marital status and number of years (experience) in fishing and/or fish trading) was found to fit the data the best. The log-likelihood ratio test (i.e., calculated statistic for log-likelihood ratio test is 19.94 (i.e., 2 (307.31–297.34) =19.94), which compares with a chi-square statistic of 16.92 at nine degrees of freedom) rejects the null hypothesis that the regression parameters for the mixed logit model with only EBFM attributes (the basic model) and the mixed logit model that includes the interaction terms (the extended model) are equal at the 0.5% significance level. The test result indicates that improvement in the model fit can be achieved, and the inclusion of the socioeconomic variables enables one to pick up preference variation (Birol et al., 2006). Among the interaction terms, the interaction between the head of the family and accessibility of fishing zones is significant and positive, indicating male-headed households are likely to be more inclined towards EBFM scenarios providing higher levels of this attribute than female-headed households. The negative and significant interaction between marital status and tilapia fish abundance indicates unmarried respondents are likely to prefer higher levels of tilapia fish attributes in EBFM scenarios than are married respondents. This might be attributable to young generations having a higher expectation to capitalize on benefits, as well as being close to fish market information. This study indicates there is considerable preference heterogeneity within the fishing community that should be considered in implementing alternative EBFM attributes to manage the Lake Naivasha fishery.

5.3 | Estimation of marginal willingness to pay and welfare measures

The marginal willingness to pay (MWTP) indicates how much money respondents are willing to pay to improve the EBFM attributes (calculated with Equation (8); Table 6). The MWTP for all three EBFM attributes is significant from the conditional logit model estimates. The MWTP value is significantly higher for improving the tilapia fish abundance attribute with the extended mixed logit model. A lower and insignificant MWTP is revealed for accessibility of fishing zones in the basic mixed logit model estimates. The exchange rate for one US dollar was 85.9 Kenyan Shillings (1USD~ 85.9 KES) during the course of this study. Respondents are willing to pay 153 (1.78 USD) and 115 KES (1.34 USD) per year for improved tilapia fish abundance and for fish

TABLE 5 Results of conditional logit and mixed logit models

Variables	Conditional Logit (S.er., *p*-value)	Mixed logit (basic) (S.er., *p*-value)	Mixed logit (extended) (S.er., *p*-value)
	Mean parameters		
Choice1_ASC	0.528 (0.404, 0.191)	2.094*** (0.553, 0.000)	2.23*** (0.569, 0.000)
Choice2_ASC	0.173 (0.415, 0.676)	1.624*** (0.560, 0.007)	1.754*** (0.580, 0.003)
Fishing permit	−0.0017*** (0.0005,0.000)	−0.0026*** (0.0005,0.000)	−0.0032*** (0.0006, 0.000)
Fish breeding grounds	0.277** (0.122, 0.024)	0.308* (0.163, 0.059)	0.614 (0.470, 0.191)
Tilapia fish abundance	0.356*** (0.122, 0.004)	0.411** (0.161, 0.011)	1.264** (0.467, 0.007)
Accessibility of fishing zones	0.247** (0.123, 0.046)	0.135 (0.217, 0.532)	−2.008*** (0.671, 0.003)
Fish breeding grounds × Experience	–	–	−0.018 (0.015, 0.239)
Fish breeding grounds × Head	–	–	−0.158 (0.402, 0.693)
Fish breeding grounds × Marital	–	–	0.054 (0.373, 0.884)
Tilapia fish stock × Experience	–	–	−0.001 (0.014, 0.929)
Tilapia fish stock × Head	–	–	−0.071 (0.406, 0.865)
Tilapia fish stock × Marital	–	–	−0.982*** (0.374, 0.009)
Fishing zones × Experience	–	–	−0.032 (0.021, 0.105)
Fishing zones × Head	–	–	1.413** (0.576, 0.014)
Fishing zones × Marital	–	–	0.762 (0.510, 0.136)
Standard deviation parameter			
Fish breeding sites	–	0.608** (0.262, 0.021)	0.650** (0.262, 0.013)
Tilapia fish stock	–	0.542* (0.284, 0.056)	0.475 (0.308, 0.137)
Fishing zones	–	1.411*** (0.252, 0.000)	1.282*** (0.246, 0.000)
Number of respondents	91	91	91
Number of Obs.	1,092	1,092	1,092
Log likelihood	−346.26	−307.31	−297.34

Note. Significant at *10%; **5% and ***1%.

breeding ground protection, respectively. Fishing communities place a higher value on tilapia fish abundance attributes, expecting improved tilapia fish abundance will enhance their livelihoods. It might also be the government-concerted efforts to re-stock tilapia in order to improve its dominance. Protection of fish breeding grounds had a significant willingness to pay value, implying they might expect measures to control fish poachers and illegal fishing practices on fish breeding grounds, which would have a positive impact on fisheries management and stock.

Eight EBFM scenarios were proposed to estimate the respondents' compensating surplus for improving the EBFM over the status quo (i.e., current situation), with the results presented in Table 7. The

TABLE 6 Marginal willingness to pay for EBFM attributes per KES per year

	Conditional logit model		Mixed logit model			
			Basic model		Extended model	
EBFM attributes	KES per year	Equivalent $ value	KES per year	Equivalent $ value	KES per year	Equivalent $ value
Tilapia fish abundance	202.86** (87.86, 0.021)	2.36	153.10* (66.16, 0.083)	1.78	392.39*** (146.09, 0.007)	4.56
Fish breeding grounds/area	157.74** (79.91, 0.048)	1.84	114.82** (70.28, 0.031)	1.33	190.66 (146.92, 0.194)	2.21
Accessibility of fishing zones	140.67* (73.99, 0.057)	1.63	50.61 (80.48, 0.529)	0.58	−623.21*** (211.07, 0.003)	−7.25

Note. Significant at *10%; **5% and ***1%, standard errors and *p*-value in parenthesis.

TABLE 7 Estimates of compensating surplus (CS)

	EBFM attributes			Compensating surplus	
EBFM scenario	Protection of fish breeding grounds/area	Tilapia fish abundance	Accessibility of fishing zones	KES per year	Equivalent $ value
1	Moderate level	Moderate level	Moderate level	328.46	3.82
2	Moderate level	Moderate level	High level	376.92	4.38
3	Moderate level	High level	Moderate level	486.53	5.66
4	Moderate level	High level	High level	538.40	6.26
5	High level	High level	High level	653.84	7.61
6	High level	Moderate level	High level	498.84	5.80
7	High level	High level	Moderate level	603.80	7.02
8	High level	Moderate level	Moderate level	446.15	5.19

compensating surplus measures the change in income that would make an individual indifferent in regard to the status quo (i.e., initial EBFM level) and the subsequent situations (i.e., improvement scenario in EBFM), assuming the individual has the right to be on the initial utility level (Bateman et al., 2002). To find the compensating surplus associated with each proposed EBFM scenario, the difference between the welfare measures under the status quo and the eight EBFM scenarios is calculated using Equation (9) for the basic mixed logit model. To estimate overall willingness to pay for EBFM scenarios, it is important to include the alternative specific constants in the model, which capture the systematic, but unobserved, information about respondents' choices.

It is evident from the above compensating surplus estimates that the change from the status quo to the scenarios considered increases as one moves towards an improved lake ecosystem. The average willingness to pay for the moderate-level EBFM scenario (i.e., improvement scenario 1) is 328 KES/year (3.81 USD per year). The average willingness to pay is 653 KES per year (7.60 USD per year) for a higher-level EBFM scenario (i.e., improvement scenario 5). The welfare measures results reveal that low-income fishing communities are willing to pay a considerable quantity of money relative to their low income from fishing to improve Naivasha ecosystem services. Moreover, the willingness to pay results has interesting implications regarding fishing permit fees, noting fishing communities are willing to pay more than the prevailing fishing permit fees, indicating fishing permit fees can be an alternative source of funding for restoration of the lake ecosystem, and might encourage community involvement in co-management of fisheries resources.

6 | DISCUSSION

The results of the present study appear consistent with other research evidence focusing on how to support restoration of a lake ecosystem, how to manage fishery resources, and how to better understand the hydrological and ecological functioning of Lake Naivasha (i.e., an eco-hydrological approach and restoration of the lake's natural fringe of papyrus suggested by Hickley et al. (2004) and Harper and Mavuti (2004)). Oyugi et al. (2011) indicated improved water management schemes would contribute to the maintenance of the lake level and provide considerable ecological benefits. A spatial integrated assessment (IA) approach has been proposed to support the implementation of integrated water resources management (IWRM) and to understand the mismatch between required knowledge and efforts by scientists and stakeholders in the Lake Naivasha basin (Van Oel et al., 2014).

A co-management approach was suggested as an opportunity for increased participation and empowerment of the fishing communities (Kundu et al., 2010). Morrison and Harper (2009) stressed the restoration of *Cyperus papyrus* in Lake Naivasha and the importance of wetland system for water quality. Improving land use management in the basin and along the lake's riparian zone was recommended to reduce silt and nutrient loads as a means of controlling the proliferation of water hyacinth (Mironga et al., 2012). Odongo et al. (2014) recommended coupling socioeconomic factors to eco-hydrological processes as a means to improve the understanding of hydrological and ecological functioning of the Lake Naivasha basin. Harper et al. (2011) examined the recent and ongoing governance initiatives in linked socio-ecological systems in the Lake Naivasha basin, suggesting new governance initiatives with a wider network with external interventions initiated in 2011 may aid restoration of the ecosystem health. Hickley et al. (2002) suggested any fish introduction should be part of an overall management package that should also include conservation measures based on sound ecology, appropriate legislation and enforcement, and addressing associated social issues, such as redeployment of poachers. Yongo et al. (2013) also recommended that "critical fish habitats" (breeding and nursery areas) in Lake Naivasha should be protected to assist in the recovery of its fish stocks. The need for a clear restocking programme and alternative livelihood programmes was also recommended to ensure sustainable stocks and to reduce fishing pressure in the lake, respectively (Waithaka et al., 2015). Therefore, the present study indicates that valuing the fishery at the ecosystem level, and considering fishing community preferences, are vital to prioritize and choose between alternative interventions for implementation of EBFM.

The results of the present study suggest that understanding the preferences of the fishing community for alternative EBFM interventions can contribute to improving Lake Naivasha ecosystem services. They also indicate that applying a choice experiment model can significantly improve understanding of EBFM valuation studies. Although the methodology and the model results appear very appealing, applying these methods requires including other EBFM attributes in future studies. Choosing between species as the lake is dominated by alien species, and choosing different annual closure periods as a fisheries management approach, as examples, can be included in further research as an attribute in choice experiments to support implementation of the EBFM approach in Lake Naivasha.

7 | CONCLUSION

EBFM can be an important complement to existing fisheries management approaches to maintain ecosystem health and functioning. The preferences of the fishing communities should be considered for successful EBFM implementation. This study analysed the preferences of the fishing communities and estimated their willingness to pay for alternative EBFM attributes of Lake Naivasha, using a choice experiment approach. This study contributes to the limited literature on economic valuation of fishery at the ecosystem level using a choice experiment approach. In addition to the monetary attribute regarding fishing permits, three attributes are identified as relevant EBFM attributes for the choice experiment exercises, including protection of fish breeding grounds, improving tilapia fish abundance and increasing accessibility of fishing zones. In addition to a conditional logit model, mixed logit models are estimated to account for preference heterogeneity.

This study results also suggest fishing communities are most concerned about the protection of fish breeding grounds and tilapia fish abundance, as they indicated a higher willingness to pay for these two EBFM attributes. The results also indicated fishing communities are willing to pay a considerable sum of money to improve Lake Naivasha ecosystem services, relative to their low income from fishing. Moreover, the results of the marginal willingness to pay highlighted some remarkable implications on fishing permit fees as an alternative source of funding to restore the lake ecosystem and encourage involvement of the fishing community in co-management of fisheries resources. Overall, the findings indicated that valuing the fishery at an ecosystem level is vital in informing and guiding prioritization and providing choices between alternate interventions for implementing EBFM. Further study of these aspects therefore may contribute to implementation of sound ecosystem-based fisheries management to improve the Lake Naivasha ecosystem.

ACKNOWLEDGEMENTS

This research is financed by the Netherlands Organization for Scientific Research, WOTRO Science for Global Development (NWO/WOTRO). We are very grateful to the Chairmen of the Lake Naivasha Beach Management Units (BMUs) for his assistance in mobilizing the fishermen and fish traders for focus group discussions (FGD), as well as all respondents who participated in the FGD and survey. We also would like to thank Phil Hickley for his support and providing us with available data on fish catches from 1963 to 2013.

ORCID

Dawit W. Mulatu http://orcid.org/0000-0003-4758-1220

REFERENCES

Agimass, F., & Mekonnen, A. (2011). Low-income fishermen's willingness-to-pay for fisheries and watershed management: An application of choice experiment to Lake Tana, Ethiopia. *Ecological Economics*, *71*, 162–170. https://doi.org/10.1016/j.ecolecon.2011.08.025

Aloo, P. A. (1996). Anthropogenic impact on Fisheries Resources of Lake Naivasha. In T. C. Johnson, & E. O. Odada (Eds.), *Limnology, climatology and paleoclimatology of the East African lakes*. Amsterdam, The Netherlands: Gordon and Breach.

Asrat, S., Yesuf, M., Carlsson, F., & Wale, E. (2010). Farmers' preferences for crop variety traits: Lessons for on-farm conservation and technology adoption. *Ecological Economics*, *69*, 2394–2401. https://doi.org/10.1016/j.ecolecon.2010.07.006

Barnes-Mauthe, M., Oleson, K. L. L., & Zafindrasilivonona, B. (2013). The total economic value of small-scale fisheries with a characterization of post-landing trends: An application in Madagascar with global relevance. *Fisheries Research*, *147*, 175–185. https://doi.org/10.1016/j.fishres.2013.05.011

Bateman, I. J., Carson, R. T., Day, B., Hanemann, M., Hanleys, N., Hett, T., … Swanson, J. (2002). *Economic valuation with stated preference techniques: a manual*. Cheltenham, UK: Edward Elgar. https://doi.org/10.4337/9781781009727

Beard Jr., T. D. , Arlinghaus, R., Cooke, S. J., McIntyre, P. B., De Silva, S., Bartley, D., & Cowx, I. G. (2011). Ecosystem approach to inland fisheries: Research needs and implementation strategies. *Biology Letters*, *7*, 481–483. https://doi.org/10.1098/rsbl.2011.0046

Becht, R., & Harper, D. M. (2002). Towards an understanding of human impact upon the hydrology of Lake Naivasha, Kenya. *Hydrobiologia*, *488*, 1–11. https://doi.org/10.1023/A:1023318007715

Becht, R., Odada, E. O., & Higgins, S. (2005). Lake Naivasha: Experience and lessons learned brief. In ILEC (Ed.), *Lake Basin management initiative: Experience and lessons learned briefs. Including the final report: Managing lakes and basins for sustainable use, a report for Lake Basin managers and stakeholders* (pp. 277–298). Kusatsu, Japan: International Lake Environment Committee Foundation (ILEC).

Birol, E., Karousakis, K., & Koundouri, P. (2006). Using a choice experiment to account for preference heterogeneity in wetland attributes: The case of Cheimaditida wetland in Greece. *Ecological Economics*, *60*, 145–156. https://doi.org/10.1016/j.ecolecon.2006.06.002

Blaber, S. J. M. (2009). Can the ecosystem approach improve management of tropical estuarine fisheries for diadromous species? In A. Haro, K. L. Smith, R. A. Rulifson, et al. (Eds.), *Challenges for diadromous fishes in a dynamic global environment*Vol 69 (pp. 649–661). Bethesda, MD: American Fisheries Society Symposium.

Britton, J. R., Boar, R. R., Grey, J., Foster, J., Lugonzo, J., & Harper, D. M. (2007). From introduction to fishery dominance: The initial impacts of the invasive carp Cyptinus carpio in Lake Naivasha, Kenya, 1999 to 2006. *Journal of Fish Biology*, *71*, 239–257. https://doi.org/10.1111/j.1095-8649.2007.01669.x

Britton, J. R., & Harper, D. M. (2006). Length-weight relationships of fish species in the freshwater rift valley lakes of Kenya. *Journal of Applied Ichthyology*, *22*, 334–336. https://doi.org/10.1111/j.1439-0426.2006.00769.x

Brodziak, J., & Link, J. (2002). Ecosystem-based fishery management: What is it and how can we do it? *Bulletin of Marine Science*, *70*, 589–611.

Carlsson, F., Frykblom, P., & Lagerkvist, C. J. (2007). Consumer benefits of labels and bans on GM foods - Choice experiments with Swedish consumers. *American Journal of Agricultural Economics*, *89*, 152–161. https://doi.org/10.1111/j.1467-8276.2007.00969.x

Carlsson, F., Frykblom, P., & Liljenstolpe, C. (2003). Valuing wetland attributes: An application of choice experiments. *Ecological Economics*, *47*, 95–103. https://doi.org/10.1016/j.ecolecon.2002.09.003

Clarke, P., & Jupiter, S. (2010). *Principles and practice of ecosystem-based management: A guide for conservation practitioners in the tropical Western Pacific*. Suva, Fiji: Wildlife Conservation Society.

Costello, C., Gaines, S. D., & Lynham, J. (2008). Can catch shares prevent fisheries collapse? *Science*, *321*, 1678–1681. https://doi.org/10.1126/science.1159478

Essington, T. E., & Punt, A. E. (2011). Implementing ecosystem-based fisheries management: Advances, challenges and emerging tools. *Fish and Fisheries*, *12*, 123–124. https://doi.org/10.1111/j.1467-2979.2011.00407.x

Evans, L., Cherrett, N., & Pemsl, D. (2011). Assessing the impact of fisheries co-management interventions in developing countries: A meta-analysis. *Journal of Environmental Management*, *92*, 1938–1949. https://doi.org/10.1016/j.jenvman.2011.03.010

Garcia, S. M., & Cochrane, K. L. (2005). Ecosystem approach to fisheries: A review of implementation guidelines. *ICES Journal of Marine Science*, *62*, 311–318. https://doi.org/10.1016/j.icesjms.2004.12.003

Gherardi, F., Robert Britton, J., Mavuti, K. M., Pacini, N., Grey, J., Tricarico, E., & Harper, D. M. (2011). A review of allodiversity in Lake Naivasha, Kenya: Developing conservation actions to protect East African lakes from the negative impacts of alien species. *Biological Conservation*, *144*, 2585–2596. https://doi.org/10.1016/j.biocon.2011.07.020

Greene, W. H. (2003). *Econometric Analysis (5th Ed.), Prentice Hall, Upper Saddle River, New Jersey, New York University*.

Hanemann, W. M. (1984). Discrete/continuous models of consumer demand. *Econometrica*, *52*, 541–561. https://doi.org/10.2307/1913464

Hanley, N., Mourato, S., & Wright, R. E. (2001). Choice modelling approaches: A superior alternative for environmental valuation? *Journal of Economic Surveys*, *15*, 435–462.

Hanley, N., Wright, R. E., & Adamowicz, V. (1998). Using choice experiments to value the environment: Design issues, current experience and future prospects. *Environmental & Resource Economics*, *11*, 413–428. https://doi.org/10.1023/A:1008287310583

Hanley, N. D., Wright, R. E., & Alvarez-Farizo, B. (2006). Estimating the economic value of improvements in river ecology using choice experiments: An application to the water framework directive. *Journal of Environmental Management*, *78*, 183–193. https://doi.org/10.1016/j.jenvman.2005.05.001

Harper, D. M., & Mavuti, K. M. (2004). Lake Naivasha, Kenya: Ecohydrology to guide the management of a tropical protected area. *Ecohydrology and Hydrobiology*, *4*, 287–305.

Harper, D. M., Morrison, E. H. J., Macharia, M. M., Mavuti, K. M., & Upton, C. (2011). Lake Naivasha, Kenya: Ecology, society and future. *Freshwater Reviews*, *4*, 89–114. https://doi.org/10.1608/FRJ-4.2.149

Hausman, J., & McFadden, D. (1984). Specification tests for the multinomial logit model. *Econometrica*, *52*, 1219–1240. https://doi.org/10.2307/1910997

Hensher, D. A., & Greene, W. H. (2003). The mixed logit model: The state of practice. *Transportation*, *30*, 133–176. https://doi.org/10.1023/A:1022558715350

Hensher, D. A., Rose, J. M., & Greene, W. H. (2005). *Applied choice analysis: A primer*. Cambridge, UK: Cambridge University Press. https://doi.org/10.1017/CBO9780511610356

Hickley, P., Bailey, R., Harper, D. M., Kundu, R., Muchiri, M., North, R., & Taylor, A. (2002). The status and future of the Lake Naivasha fishery, Kenya. *Hydrobiologia*, *488*, 181–190. https://doi.org/10.1023/A:1023334715893

Hickley, P., Britton, J. R., Macharia, S., Muchiri, S. M., & Boar, R. R. (2015). The introduced species fishery of Lake Naivasha, Kenya: Ecological impact vs socio-economic benefits. *Fisheries Management and Ecology*, *22*, 326–336. https://doi.org/10.1111/fme.12130

Hickley, P., Muchiri, M., Boar, R., Britton, R., Adams, C., Gichuru, N., & Harper, D. M. (2004). Habitat degradation and subsequent fishery collapse in Lakes Naivasha and Baringo, Kenya. *Ecohydrology & Hydrobiology*, *4*, 503–517.

Hickley, P., Muchiri, M., Britton, R., & Boar, R. (2008). Economic gain versus ecological damage from the introduction of non-native freshwater fish: Case studies from Kenya. *Open Fish Science Journal*, *1*, 36–46. https://doi.org/10.2174/1874401X00801010036

Hiddink, J. G., MacKenzie, B. R., Rijnsdorp, A., Dulvy, N. K., Nielsen, E. E., Bekkevold, D., … Ojaveer, H. (2008). Importance of fish biodiversity for the management of fisheries and ecosystems. *Fisheries Research*, *90*, 6–8. https://doi.org/10.1016/j.fishres.2007.11.025

Hoyos, D. (2010). The state of the art of environmental valuation with discrete choice experiments. *Ecological Economics*, *69*, 1595–1603. https://doi.org/10.1016/j.ecolecon.2010.04.011

Imarisha Naivasha Trust (2012). *Lake Naivasha sustainable development action plan 2012–2017*. Naivasha, Kenya: Imarisha Naivasha Trust.

Kitaka, N., Harper, D. M., & Mavuti, K. M. (2002). Phosphorus inputs to Lake Naivasha, Kenya, from its catchment and the trophic state of the lake. *Hydrobiologia*, *488*, 73–80. https://doi.org/10.1023/A:1023362027279

Kuhn, A., Britz, W., Willy, D. K., & Van Oel, P. (2016). Simulating the viability of water institutions under volatile rainfall conditions—The case of the Lake Naivasha Basin. *Environmental Modelling and Software*, *75*, 373–387. https://doi.org/10.1016/j.envsoft.2014.08.021

Kundu, R., Aura, C. M., Muchiri, M., Njiru, J. M., & Ojuok, J. E. (2010). Difficulties of fishing at lake Naivasha, Kenya: Is community participation in management the solution? *Lake and Reservoir Management*, *15*, 15–23. https://doi.org/10.1111/j.1440-1770.2010.00419.x

Lancaster, K. J. (1966). A new approach to consumer theory. *Journal of Political Economy*, *74*, 132–157. https://doi.org/10.1086/259131

Lusk, J. L., & Norwood, F. B. (2005). Effect of experimental design on choice-based conjoint valuation estimates. *American Journal of Agricultural Economics*, *87*, 771–785. https://doi.org/10.1111/j.1467-8276.2005.00761.x

Mathew, S. (2003). Small-scale fisheries perspectives on an ecosystem-based approach to fisheries management. In M. Sinclair, & G. Valdimarsson (Eds.), *Responsible fisheries in the marine ecosystem* (pp. 47–63). Rome, Italy and Wallingford, UK: FAO and CAB International. https://doi.org/10.1079/9780851996332.0001

Mathew, S. (2011). Fishery-dependent information and the ecosystem approach: What role can fishers and their knowledge play in developing countries?. *ICES Journal of Marine Science*, *68*, 1805–1808. https://doi.org/10.1093/icesjms/fsr113

McClanahan, T. R. (2010). Effects of fisheries closures and gear restrictions on fishing income in a Kenyan Coral Reef. *Conservation Biology*, *24*, 1519–1528. https://doi.org/10.1111/j.1523-1739.2010.01530.x

Mironga, J. M., Mathooko, J. M., & Onywere, S. M. (2012). Effect of water hyacinth infestation on the physicochemical characteristics of Lake Naivasha. *International Journal of Humanities and Social Sciences*, *2*, 103–113.

MoFD. (2013). *Republic of Kenya Ministry of Fisheries Development (MoFD): Naivasha Fisheries Station Annual Report*, *Ministry of Fisheries Development*, *Naivasha*, *Kenya*.

Morrison, E., & Harper, D. M. (2009). Ecohydrological principles to underpin the restoration of *Cyperus papyrus* at Lake Naivasha, Kenya. *Ecohydrology & Hydrobiology*, *9*, 83–97. https://doi.org/10.2478/v10104-009-0036-6

Mulatu, D. W., Van der Veen, A., Becht, R., Van Oel, P. R., & Bekalo, D. J. (2013). Accounting for spatial non-stationarity to estimate population distribution using land use/cover. Case Study: the Lake Naivasha Basin, Kenya. *Journal of Settlements and Spatial Planning*, *4*, 33–44.

Mulatu, D. W., Van der Veen, A., & Van Oel, P. R. (2014). Farm households' preferences for collective and individual actions to improve water-related ecosystem services: The Lake Naivasha basin, Kenya. *Ecosystem Services*, *7*, 22–33. https://doi.org/10.1016/j.ecoser.2013.12.001

Mulatu, D. W., Van Oel, P. R., & Van der Veen, A. (2015). Firms' willingness to invest in a water fund to improve water-related ecosystem services in the Lake Naivasha basin, Kenya. *Water International*, *40*, 463–482. https://doi.org/10.1080/02508060.2015.1050580

Musinguzi, L., Natugonza, V., & Ogutu-Ohwayo, R. (2017). Paradigm shifts required to promote ecosystem modeling for ecosystem-based fishery management for African inland lakes. *Journal of Great Lakes Research*, *43*, 1–8. https://doi.org/10.1016/j.jglr.2016.11.007

Nguyen, T. V. (2012). Ecosystem-based fishery management: A review of concepts and ecological economic models. *Journal of Ecosystem Management*, *13*, 1–14.

Njuguna, S. (1991). *Studies on phytoplankton and nutrients in lakes of the Naivasha basin*. Nairobi, Kenya: University of Nairobi.

Odongo, V. O., Mulatu, D. W., Muthoni, F. K., van Oel, P. R., Meins, F. M., van der Tol, C., … van der Veen, A. (2014). Coupling socio-economic factors and eco-hydrological processes using a cascade-modeling approach. *Journal of Hydrology*, *518*(Part A), 49–59. https://doi.org/10.1016/j.jhydrol.2014.01.012

Ogada, J. O., Krhoda, G. O., Van der Veen, A., Marani, M., & Van Oel, P. R. (2017). Managing resources through stakeholder networks: Collaborative water governance for Lake Naivasha basin, Kenya. *Water International*, *42*, 271–290. https://doi.org/10.1080/02508060.2017.1292076

Oyugi, D. O., Harper, D. M., Ntiba, J. M., Kisia, S. M., & Britton, J. R. (2011). Management implications of the response of two tilapiine cichlids to long-term changes in lake level, allodiversity and exploitation in an equatorial lake. *Ambio*, *40*, 469–478. https://doi.org/10.1007/s13280-011-0139-3

Pikitch, E. K., Santora, C., Babcock, E. A., Bakun, A., Bonfil, R., Conover, D. O., … Sainsbury, K. J. (2004). Ecosystem-based fishery management. *Science*, *305*, 346–347. https://doi.org/10.1126/science.1098222

Pomeroy, R., Garces, L., Pido, M., & Silvestre, G. (2010). Ecosystem-based fisheries management in small-scale tropical marine fisheries: Emerging models of governance arrangements in the Philippines. *Marine Policy*, *34*, 298–308. https://doi.org/10.1016/j.marpol.2009.07.008

Ramsar, S. (2014). Ramsar Sites Database: Ramsar report for Lake Naivasha, Site No. 724, Wetlands International Site Reference No. 1KE002, Designation Date: 10-04-1995.

Rolfe, J., Bennett, J., & Louviere, J. (2000). Choice modelling and its potential application to tropical rainforest preservation. *Ecological Economics*, *35*, 289–302. https://doi.org/10.1016/S0921-8009(00)00201-9

Sangkapitux, C., Neef, A., Polkongkaew, W., Pramoon, N., Nonkiti, S., & Nanthasen, K. (2009). Willingness of upstream and downstream resource managers to engage in compensation schemes for environmental services. *International Journal of the Commons*, *3*, 41–63. https://doi.org/10.18352/ijc.123

Train, K. (2003). *Discrete choice methods with simulation*. Cambridge, UK: Cambridge University Press. https://doi.org/10.1017/CBO9780511753930

UNEP (2010). *Blue harvest: Inland fisheries as an ecosystem service*. Penang, Malaysia: World Fish Center.

Van Oel, P. R., Mulatu, D. W., Odongo, V. O., Meins, F. M., Hogeboom, H. J., Becht, R., … Van der Veen, A. (2013). The effects of groundwater and surface water use on total water availability and implications for water management: The case of Lake Naivasha, Kenya. *Water Resources Management*, *27*, 3477–3492.

Van Oel, P. R., Odongo, V. O., Mulatu, D. W., Muthoni, F. K., Ndungu, J. N., Ogada, J. O., & Van der Veen, A. (2014). Supporting IWRM through spatial integrated assessment for the Lake Naivasha basin, Kenya. *International Journal of Water Resources Development*, *30*, 605–618.

Waithaka, E., Mugo, J., Obegi, B., & Last, J. (2015). Socio-economics of the re-introduced *Oreochromis niloticusin* Lake Naivasha (Kenya) . *International Journal of Fisheries and Aquatic Studies*, *2*, 142–146.

Wang, Y., Xu, J., Yu, X., & Lei, G. (2014). Fishing down or fishing up in Chinese Freshwater Lakes. *Fisheries Management and Ecology*, *21*, 374–382. https://doi.org/10.1111/fme.12088

Wells, S., Makoloweka, S., & Samoilys, M. (2007). *Putting adaptive management into practice: Collaborative Coastal Management in Tanga, Northern Tanzania*. Nairobi, Kenya: IUCN and Irish Aid.

WWF (2011). *Shared risk and opportunity in water resources: Seeking a sustainable future for Lake Naivasha*. Naivasha, Kenya: World Wide Fund for nature (WWF).

Yongo, E. O., Morara, G., Ojouk, J., Nyamweya, C., Ojwang, W. O., Masai, M., & Wasike, C. (2013). Socio-economic aspects of fisheries management in Lake Naivasha. *African Journal of Tropical Hydrobiology and Fisheries*, *13*, 27–32.

How to cite this article: Mulatu DW, van Oel PR, Odongo V, van der Veen A. Fishing community preferences and willingness to pay for alternative developments of ecosystem-based fisheries management (EBFM) for Lake Naivasha, Kenya. *Lakes & Reserv*. 2018;23:190–203. https://doi.org/10.1111/lre.12225