AN ENDLINE SURVEY REPORT OF SELECTED SMALL WATER BODIES (SWBS) STOCKED WITH NILE TILAPIA (*Oreochromis niloticus*) FINGERLINGS

Aquaculture Business Development Programme (ABDP)

May 2022

DECLARATION

Participants herein include the Kenya Marine and Fisheries Research Institute (KMFRI), the Aquaculture Business Development Programme (ABDP), the Kenya Fisheries Service (KeFS), and the State Department of Fisheries, Aquaculture, and Blue Economy (SDFA & BE). To the best of our knowledge, all the information included in this report accurately and accurately reflects the survey and findings as they pertain to the report.

ACKNOWLEDGEMENT

We wish to thank the International Fund for Agricultural Development (IFAD) and The Government of Kenya (GoK) through the Aquaculture Business Development Programme (ABDP) for funding the expedition. We also wish to thank all the KMFRI-Kisumu, Kenya Fisheries Service (KeFS), and the County Government Fisheries staff for their valuable contribution.

CITATION

KMFRI-KeFS-SDFA & BE-ABDP-, 2022. An Endline Survey Report of Selected Small Water Bodies (SWBs) Stocked with Nile Tilapia (*Oreochromis niloticus*) Fingerlings. Kenya Marine and Fisheries Research Institute (KMFRI), Aquaculture Business Development Programme (ABDP), Kenya Fisheries Service (KeFS), and the State Department of Fisheries, Aquaculture, and Blue Economy (SDFA & BE) for small water bodies technical report funded by the International Fund for Agricultural Development (IFAD) and The Government of Kenya (GoK) through the Aquaculture Business Development Programme (ABDP). Technical report submitted to The Programme Coordinator (PC), Aquaculture Business Development Programme (ABDP), IFAD Building, Kamakwa Road (Opp. Nyeri Club), P.O Box 904-10100, Nyeri. 126pp.

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SUBMISSION LETTER

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RE: SUBMISSION OF FINALIZED TECHNICAL REPORTS AND FACTSHEETS ON CAGE CULTURE, AQUAPARK AND RESTOCKED SMALL WATER BODIES

The Government of Kenya (GoK) in partnership with the International Fund for Agricultural Development (IFAD) is implementing the Aquaculture Business Development Programme (ABDP) whose aim is to increase the incomes, food security and nutritional status of the wider communities of poor rural households involved in aquaculture in the fifteen targeted Counties in Kenya. As part of ABDP implementation activities, the programme is expected to undertake relevant studies that will form a basis of advising the relevant county governments and the State Department of Fisheries, Aquaculture & Blue Economy (SDFA & BE) on environmental and socio-economical sustainability aquaculture production in the country.

In-line with the aforementioned, Kenya Marine and Fisheries Research Institute (KMFRI) led participants from ABDP, Kenya Fisheries Service (KeFS), SDFA & BE in the development of following technical reports and their related briefs:

i) Sustainable Community-based cage aquaculture in Lake Victoria; and
ii) An end-line survey report of selected small water bodies (SWBs) stocked with Nile tilapia fingerlings.

The purpose of this letter is therefore to submit the aforementioned reports and briefs to your office for further actions.

Thank you.

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Kenya Marine and Fisheries Research Institute ISO 9001:2015 CERTIFIED

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EXECUTIVE SUMMARY

Small Water Bodies (SWBs) offer a wide range of livelihood opportunities across the world, contributing significantly to economic growth, food security, and national development. Stocking fish in SWBs is one of the oldest management techniques, and when done properly and at the correct spot, it may play an important part in fisheries management. Following the stocking of some of the dams, an endline survey was done to assess stock performance and the initiative's socioeconomic effect. This research was carried out in 15 counties in the Western and Central regions where the Aquaculture Business Development Programme (ABDP) is implemented. The SWBs considered for this survey included mainly those that had been restocked with tilapia fingerlings. The study employed both primary and secondary data from socioeconomics, environmental characteristics and fisheries and aquaculture aspects. There was no restocked dam with a low (<1.66) socioeconomic impact, indicating the potential of restocking SWBs. The majority (n = 27; 79%) of the restocked SWBs had a moderate (1.66 – 2.33) effect, owing to the inherent constraints of such an initial activity in natural contexts. Twenty one percent (n = 7; 21%) of the SWBs had a high (2.34-3.00) socioeconomic impact and also had better environmental conditions. Some of the reasons for the moderate performance of the restocked SWBs included environmental challenges, lack of fishing abilities and gear. The average relative condition factor (Kn) of tilapia in restocked SWBs was 1.24±0.53 SD, suggesting that the fish were in excellent growth condition. Additionally, water conditions also revealed that the studied SWBs had good primary and secondary production. From these findings it is clear that restocking the SWBs could benefit riparian fishing communities by improving their livelihoods and providing food and nutrition security. Given the limited exploitation of fish in some SWBs, additional community awareness and capacity building interventions are needed to realize the enormous potential identified during the baseline study and in this survey.

1.0 INTRODUCTION

Small Water Bodies (SWBs), including dams, were erected in ancient times for the sole purpose of water supply or irrigation. Water supply, irrigation, flood control, navigation, energy, and fishery development all became more important as civilizations advanced. SWBs are so critical to the development and management of water resources, and thus to the overall development of a country (Kenya National Assembly, 2019). SWBs are the most abundant freshwater ecosystems on the planet, are crucial for freshwater biodiversity, and are increasingly recognized for their role in ecosystem service delivery (KMFRI-ABDP-SWBs, 2020; Aura et al., 2022a). SWBs also help to ensure an adequate supply of water by storing it in times of surplus and releasing it in times of scarcity, preventing or mitigating floods and contributing significantly to the efficient management of finite water resources that are unevenly distributed and subject to large seasonal fluctuations (Kenya National Assembly, 2019).

SWBs provide a variety of livelihood options in Kenya, contributing considerably to economic growth, food security, and national development. They also assist societies in dealing with climate change by storing water, safeguarding people and properties from flooding, and producing cleaner electricity (Aura et al., 2022b). As a result, they are essential components of the Big 4 Agenda and the fulfilment of Kenya's Vision 2030 Economic Blueprint (GoK, 2007). Despite their economic importance and ability to contribute to food and nutritional security, SWBs are not adequately recognized at the national level, and hence not appropriately reflected in national economic data. For example, even though the country has at least a thousand (1000) SWBs, many of which are stocked with fish, national statistics only capture three major dams: Jipe, Tana, and Turkwel (KMFRI-ABDP-SWBs, 2020).

Fish stocking in lakes and SWBs is one of the oldest management strategies, but it has sparked controversy because it has disrupted native fish ecosystems, contributed to the loss of wild strains, and reduced genetic diversity in many cases (Schramm and Piper, 1995). Nonetheless, when done correctly and at the proper area, stocking can play an important part in SWB's supplementing capture fisheries management. If the lack or poor quality of spawning habitat limits reproductive success, stocking juveniles can augment those produced naturally, improving fish numbers and fisheries yields. Since reproduction is impossible in the water, certain fish populations in SWBs rely completely on stocking.

In many cases, stocking to restore threatened and endangered species has been successful. The size of the fish stocked is frequently a significant concern, with fish survival increasing directly with size, but acceptable success can occasionally be accomplished by mass stocking of undersized fish (Welcomme and Bartley, 1998). The size and number of fish stocked are frequently determined by economic factors. Many SWBs allow for the diversification of fish stocks available to fisheries. Several non-native prey and predator species have been introduced into SWBs with varying degrees of success (Balayut, 1983; Schramm and Piper, 1995; Cowx, 1997; Quiros, 1998; Petr and Mitrofanov, 1998). Where fisheries are primarily managed for food production, as in most poor nations, fast-growing, self-propagating herbivores with short food chains are desired (Sugunan, 1995).

Tilapia introductions have been among the most successful in SWBs around the world in terms of fishery development. Several tilapia species have been successfully introduced into reservoirs in Africa, Asia, and South America (Oglesby, 1985; Moreau and De Silva, 1991; Paiva et al., 1994; Sugunan, 1995). Their adoption typically results in massive increases in fishery productivity in SWBs that retain lacustrine conditions with long water retention durations. Stocking is done in nursery zones in various African dams and SWBs (Kapetsky, 1986). Since predators are eliminated and fishing is prohibited, nursery areas allow the development of tilapia populations in a virtually predator-free environment. Nonetheless, tilapia invasions have apparently harmed native ichthyofauna from India to Africa and North America (Sugunan 1995; Moyle, 1976). Riverine limnological conditions tend to hinder the establishment of tilapia fisheries in reservoirs and SWBs with high turnover rates.

However, introductions have caused more harm than help in some cases (Li and Moyle, 1993); hence, numerous preventative measures have been advocated (Bartley and Minchin, 1996). Several concerns should be carefully evaluated before beginning stocking or introduction programs (Cowx, 1998). Other management strategies could achieve fishery objectives at a lesser cost, with longer-term benefits, or with fewer changes to the current biological community. The size and number of fish that must be stocked have an impact on whether the endeavour is cost-effective and sustainable. The duration of the benefits is a key factor; if stocking must be continued indefinitely, other enhancing strategies may be more cost effective in the long run (Abobi et al. 2019). The possibility for negative effects on the environment and biota should be adequately considered, and attempts should be abandoned if negative repercussions are predicted. This requires considerable understanding of the biology and ecology of the species candidate for introduction, as well as careful consideration of previous histories of introduction of the species or related species. In general, the introduction of migratory and predatory animals should be avoided (Furey et al. 2018; FAO, 2001).

Many developing countries manage SWBs and reservoirs using models developed in North America or Europe. Foreign specialists frequently impose or copy strategies that do not consider climatic, faunal, socio-economic, or political factors. Despite apparent similarities in environmental challenges, management policy must be country-specific and take into consideration local realities (Sugunan, 1997); blind adoption of imported principles leads to policy failures. The inability of fishery administrators to defend the interests of their sector, whether recreational or commercial, is a significant barrier to the growth and management of fisheries in SWBs. Decisions impacting fisheries and aquatic habitats are frequently made with little or no regard for the communities living near the SWBs. Most SWB fisheries in a number of developing nations suffer from a lack of defined rights and institutional backing, making it difficult to acquire political and financial support for monitoring and managing the fisheries. Therefore, because of this lack of political power, the interests and requirements of fishers in SWBs are frequently not adequately represented within current political frameworks and are thus disregarded or ignored (FAO, 2001)

This activity was carried out by KMFRI in collaboration with the ABDP, KeFS, SDFA & BE and the fifteen (15) county governments that are implementing ABDP. The same institutions carried out a baseline survey in selected SWBs in Kenya earlier in 2021 with the goal of determining their biological, ecological, and socioeconomic status, as well as carrying capabilities for species introductions. The ABDP is a joint project of the Kenyan

Government (GoK) and the International Fund for Agricultural Development (IFAD), and it is being executed by the Ministry of Agriculture, Livestock, and Fisheries (MoALF), which is part of the State Department for Fisheries, Aquaculture, and the Blue Economy (SDFA & BE). Following the survey and the study's recommendations, ABDP stocked selected SWBs with tilapia (Appendix 1). Based on this concept, an endline study was undertaken 6 months after the SWBs were stocked with tilapia. The endline survey results were compared to comparable data from the baseline survey to assess the impact of the stocked fish on the water body and riparian populations.

The utilization of these SWBs will go a long way toward achieving the United Nations' Sustainable Development Goals (SDGs) SDG 1: no poverty, SDG 2: no hunger, SDG 3: good health and wellbeing, SDG 14: life below water, and SDG 17: partnership for the goals; Kenya's Vision 2030 Economic Blue Print in empowering local communities in income generation and improved livelihoods, as well as the Big 4 Agenda on food security and nutrition by providing high quality omega-3 fatty acids and protein sources.

2.0 METHODOLOGY

2.1 Study area

The study was undertaken in the counties where the program is being implemented in Western and Central regions, i.e., Homa Bay, Migori, Kakamega, Kisii, Kisumu, Siaya, Busia, Kirinyaga, Nyeri, Meru, Tharaka Nithi, Embu, Kiambu, Machakos and Kajiado (Figure 1). Geographical Positioning System (GPS) locations of the small water body sites were obtained per site and mapping done using ArcGIS 10.0 (The Environmental System Research Institute, USA). The SWBs which were considered for this survey included the restocked ones (ABDP and KeFS) that had initially been assessed in the study on Carrying Capacity Assessment of SWBs for Aquaculture Production as well as others that had also been identified and restocked albeit without the initial baseline assessment. A summary of details of the SWBs sampled are in Appendix 1. Under this restocking programme, forty-seven (47) SWBs were each stocked with fingerlings (in respect to their carrying capacities) in 2021 as seen in the table. Baseline information was collected from 22 SWBs while 25 were not initially surveyed. The number of SWBs sampled was reached by considering the constrained period allocated and the vastness of the sites. This was arrived at by first considering 2 SWBs per county which had baseline information. In case of absence of baseline information, a dam per sub county and eventually, per ward was prioritised to still end up with 2 or 3 SWBs per county. This was aimed at ensuring full representation of the ABDP Counties. The SWBs sampled have high concentrations of aquaculture activity, high production, have existing sectoral infrastructure (processing, marketing and research), adequate water resources and marketing potential.

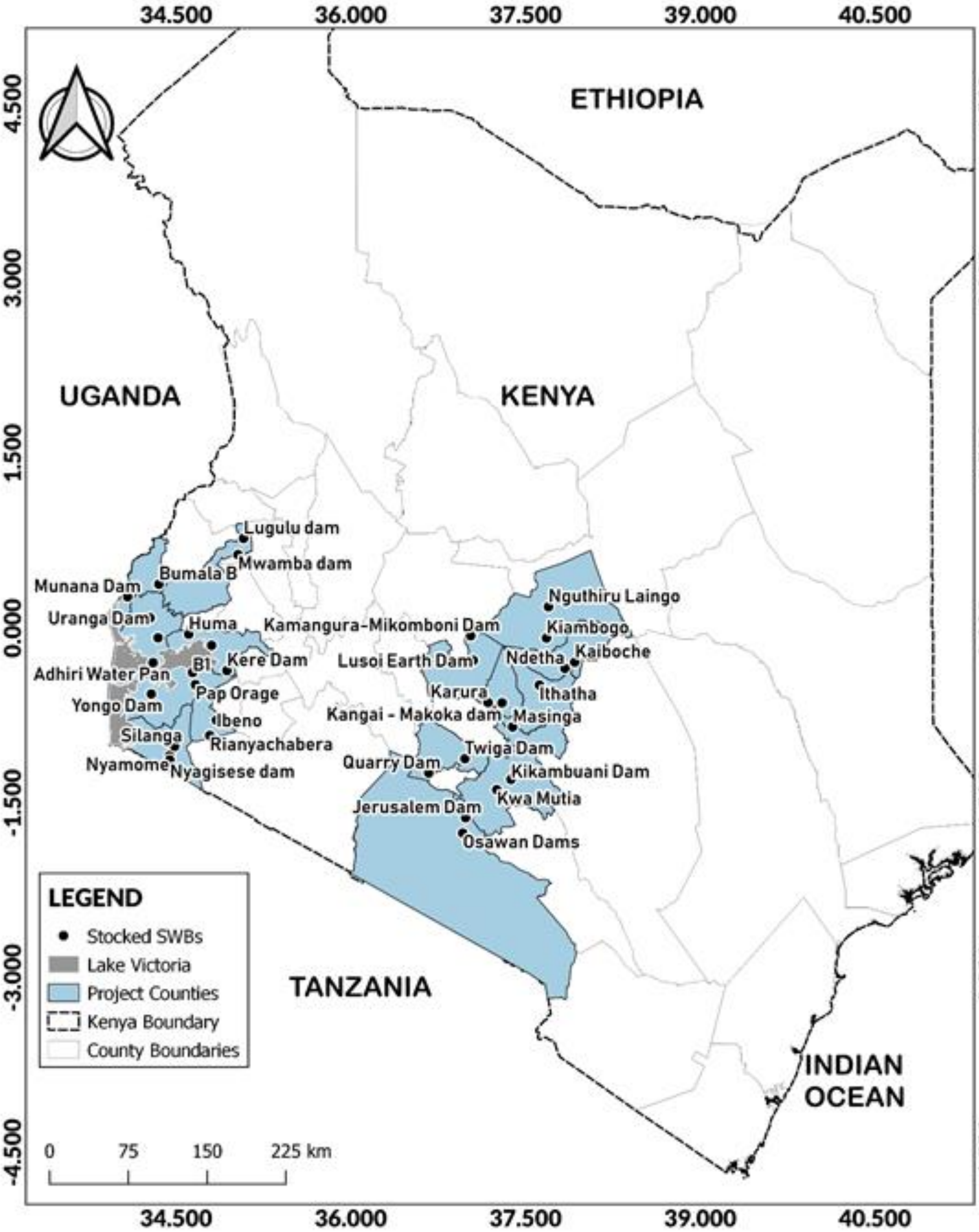

Figure 1: Map of Kenya showing the location of the stocked SWBs for the endline survey activity in both Central and Western regions.

2.2 Data collection and analysis

The study had 3 main components; socioeconomics, water quality and environmental integrity, and fish biology.

2.2.1 Socio-economic assessment of restocked SWBs

Observations on the general environmental conditions of the basin/or the catchment including land use patterns, substrate types, basin vegetation cover, and the climatic elements, were recorded immediately on arrival at the site to capture any changes that had occurred in the previously studied SWBs and to capture data of the new ones.

A socio-economics status index (SES) was calculated as a measure of impact of the intervention. This score was derived from weighted averages of the specific ordinal scores subject to the Likert scale ratings (3 = High; 2=Moderate; 1= Low). This index incorporated ten socio-economic dimensions related to fish restocking, including food security, access to good nutrition, adoption of aquaculture, improved market linkages, improved collaboration and partnership, household status in relation to nutrition, disposable income generation and its utilization such as payment of school fee, initiation of other projects/diversification, family stability and improved social status. The choice of the variables for the index construction was based on empirical studies on aquaculture (Obiero et al., 2019). The overall socio-metric scale was segmented as follows: $\leq$2.34 High <3.00; $\leq$1.67 Moderate <2.33; $\leq$1.00 Low <1.66.

2.2.2 Environmental integrity

Water quality assessment

Assessment of water characteristics followed published standard methods for aquatic environmental studies (APHA, 2012). Physicochemical electronic sensor-based probes were used to take measurements at every sampling site. Data was immediately captured on field data sheets as well as the online Kobo Collect system for onward transmission and archiving. The main physical and chemical parameters measured were; water column depth (m), temperature (^oC), dissolved oxygen (mgL^{-1}), conductivity ($\mu S\ cm^{-1}$), pH, salinity (ppt), oxidation-reduction potential (ORP) and total dissolved solids (TDS) (mgL^{-1}). Water transparency was measured using a standard Secchi disk (20 cm Ø). .

Water sampling for laboratory analysis was conducted at three pre-selected sites and sampled; two at the littoral areas and one at the center. The samples were then composited to make one sample. The water samples for soluble nutrient fractions were filtered and stored in polyethylene bottles under refrigeration at about 4°C for further laboratory analyses. Samples for TN and TP were refrigerated without filtration. Samples for chlorophyll-*a* were filtered using GF/C filters, securely wrapped in aluminium foil before refrigeration at about 4˚C and then later transported to the laboratory for further analysis (APHA, 2012).

Levels of nitrogen (ammonium-NH_4^+-N; nitrite-NO_2^--N; nitrate-NO_3^-- N; total nitrogen-TN), phosphorus (soluble reactive phosphorus-SRP; total phosphorus-TP), silicate species, chlorophyll-*a*, and total suspended solids (TSS) concentrations were analysed for all the study sites.

Microbiology

Samples for microbial assessment were collected directly into 500 ml labelled aseptic plastic bottles and corked. Total and fecal coliforms were analysed using Lauryl Sulphate broth at 37°C and 44°C, respectively. 1.0 ml of the sample water was mixed with 9.0 ml saline solution from which 0.1 ml of the inoculum was used for incubation. Measurements, sample collection and analyses were done according to standard methods for the examination of water and wastewater (APHA, 2012). The data were analyzed using R-software v4.1.2 (R Core Team, 2020). Descriptive statistics was used to determine the mean and range for the various parameters. Pearson correlation test was used to determine the correlations between the concentration of total and fecal coliforms. The results were compared with the optimal ranges/values as per Water Resources Authority (WARA) standards.

Phytoplankton

Samples were taken using a horizontal 2.2 litre Van Dorn sampler from sub-surface to a depth of about 0.5 m. A portion of the sample (25 ml) was preserved in acidic Lugol's solution. Utermöhl sedimentation chamber was used to process the samples ahead of microscopy analysis. Phytoplankton cells were identified to species level, as much as possible, and counted using a Zeiss Axiovert 35 inverted microscope. The taxa were identified using the methods of Huber–Pestalozzi (1942) and from publications on Komarek and Anagnostidis (2014).

Plate 1: Plankton sampling at SWBs in Western and Central Kenya regions

Zooplankton

Zooplankton samples were collected using a Nansen type plankton net of 60 μm mesh size and 30 cm aperture diameter. The net was lowered as close to the bottom as possible without disturbance and a vertical haul taken. Where this was not possible, a known volume of dam water was filtered. Samples were preserved in 5% formaldehyde solution. In the laboratory, samples were made to a known volume and sub samples of known volume taken and placed in a counting chamber. Copepods were grouped into nauplii, Cyclopoida and Calanoida. Cladocerans were identified to species level using identification keys by Smirnov (1996) and Korovchinsky (1996). Estimates of abundance of zooplankton were made from counts of sub samples under a Leica dissecting microscope (x25) considering the sample, sub-sample and water volume filtered.

Macroinvertebrates

At each sampling station, triplicate samples were taken from the shoreline and the bottom, washed with a sieve having a mesh of 500 µm, sorted live in a white tray then preserved in (70%) ethanol.

Plate 3: Deployment of the Ekman grab for sampling of macroinvertebrates at the bottom sediments in the Central Kenya region.

The samples were then transported to the laboratory, separated objectively, observed and counted under light microscope and identified to genus level with the aid of different keys (Merritt and Cummins, 2006; Gerber and Gabriel, (2002; Samways, (2008); and (http://extension.usu.edu/water quality). The organisms were further examined for stomach contents to assign feeding habits, and where this was not possible, the feeding guild was assigned according to Gerber and Gabriel (2002) and Chesire et al. (2005). Macroinvertebrate community structure and functional composition were described in terms of number of genera per station, relative abundance, numerical abundance, evenness, dominance, diversity, species richness, and functional feeding guilds (FFGs) of all taxa. The ratios of the various FFGs were calculated based on numerical abundance.

2.2.3 Fisheries and Aquaculture

Fish Samples Collection

Fish samples were collected using a beach seine net 50 m long with a depth of 3 m and a stretched mesh size of 1 inch provided with a towing manila rope of 100 m reduced to 50 m due to the size of the SWBs. The net was mounted on a portable inflatable rubber dinghy. The ropes were operated by at least 8 member teams boosted by the hired local community members. Catches were weighed to a range of 0.01 Kg to 0.1 Kg depending on the size. All the fish samples collected were sorted out according to families and identified to species level as described by Witte & Van Densen (1995), although the target species was *O. niloticus* stocked earlier in the SWBs. The total length (TL mm), the standard length (SL mm), the total weight (g) using a digital weighing scale, the sex, and where possible, the maturity status was determined as described by Bagenal, (1978).

Plate 4: Setting of nets for on-site fishing at the SWBs in Central region.

Plate 5: Retrieval of nets from the SWBs during sampling for fish

The fisheries data collected was supplemented with commercial catches from fishermen where possible. The fish were then gutted to reveal their sex and maturity stage, and the guts carefully removed and preserved for stomach content analysis in the laboratory. Additionally, the health status of fish was assessed by using the standard fish health diagnostic protocol.

Plate 6: Research scientists taking on site biological data on fish catches at the SWBs in Western and Central regions

Fish biomass estimation was computed by fishing within a specific known volume. Growth performance was estimated by determining the length-weight relationship. It is described by the equation $W=aL^b$, where W is total body weight (g) and L is the total length (cm). Whereas a and b are the coefficients of the functional regression between W and L (Gupta et al., 2012). Moreover, condition factor (K) was determined to understand the health condition of fish by using the formula; $K=100W/L^3$, where K= condition factor, W=weight (g) and L=Length (cm) (Bannister, 1976). Environmental integrity and fish biology data was entered in Excel spreadsheet and eventually analyzed using R statistical software version 3.6.0 (R Development Core Team, 2020).

3.0 RESULTS AND DISCUSSION

Results for the socioecological variables and observations measured at every dam during the endline surveys have been summarised in tables, for each individual dam. The information on the tables compares the means and ranges and indices between the endline survey and the baseline.

3.1 Western Kenya

3.1.1 Kisii County

1. Ibeno Dam

Plate 5. Google Earth Image of Ibeno Dam, Kisii county

Located around GPS point, -0.78913139, 34.84856306, the dam lies within a forested landscape with exotic trees (mainly Eucalyptus) dominating the tall shady groves.
Almost derelict surrounding land highly impacted by excavations for brick making. Muddy substrate

Table 1. Means and ranges of Socio-economics impact index, water quality physical and chemical variables and nutrient species measured at Ibeno dam, Kisii county.
(EL = Endline, BL = Baseline, mgL^{-1} = Milligram per litre, μScm^{-1} – Micro-Siemens per cm, μgL^{-1} = Microgram per litre, ppm = Parts per million, cfu = Colony forming unit).

Parameter	Mean		Range	Discussion	
	BL	EL	EL	Reference value	Interpretation
Socio-economics impact index	0.47	2.12	1-3	≤1.67 Moderate <2.33	Restocking had moderate impact on the community
Temp (ºC)	28	25.6	25.6-25.6	20-31 for fish adapted to higher temperatures,	Values recorded for these parameters fall within tolerable

				<20 for fish adapted to low temperatures (Mires, 1995)	ranges for fish growth, except for Secchi *depth* which indicate high turbidity (Mineral turbidity) which may not favour primary productivity
DO (mgL^{-1})	5.8	7.46	7.46-7.46	5mgL^{-1} and above (Ross, 2000)	
Cond(µS/cm-1)		36.4	36.4-36.4	200-1000µScm^{-1} (Horne and Goldman,1994)	
TDS (mgL^{-1})		23.4	23.4-23.4		
Sal (ppm)		0.02	0.02-0.02		
pH	7.67	6.09	6.09-6.09	6-9 (Ross, 2000)	
ORP (mV)		156	156-156	300-500 mV (Horne and Goldman,1994)	
Secchi(m)		0.1		0.35- 0.5 (Berveredge, 2004, Aura et al., 2021)	
Nitrites (µgL-1)		1.73		0.75-5mgL^{-1}	
Nitrates (µgL-1)		2.94		0 – 40 mgL^{-1}	
Ammonium (µgL^{-1})	16.56	18.44		60µgL^{-1} at pH 9 and temperature of 25^{0}C (El -Shafey,1998) (El -Shafey,1998)	Elevated ammonium due to increased metabolism of higher fish biomass
TN (µgL-1)		51.79			
TN:TP	3.7	2.37		<15	Values are within the optimal ranges. Suitable for aquaculture practices
SRP (µgL^{-1})		10.33		10-50 µgL^{-1}	
TP (µgL^{-1})		21.86		0.3-0.5mgL^{-1}	
Silicate(mgL-^{1})		1.49		4–20 mgL^{-1}	Low silicate level, a disadvantage to the growth of essential phytoplankton like diatoms. This in turn staggers fish growth.
Alk (mgL-^{1})		20			The values recorded has no effect on fish
Hard(mgL-^{1})		34		>150mgL^{-1} (Hall 1991)	
Chlorophyll a (µgL^{-1})		31.58		>7.5 and <40 for Lake Victoria (Aura et al., 2021, Kashindye et al., 2015, Aura et al., 2016)	High primary productivity. Favourable for aquaculture
Fish condition (Relative condition factor of stocked *O. niloticus)* (Relative condition factor of stocked *O. niloticus*)	1.08	1.10	0.92-1.32	1.01±0.17 to 1.05±0.5 (Daliri et al., (2012), Lloret et al., (2014)	Species performance was good
Total coliforms		26 x10^{3}		<1000 cfu/100ml	Low counts of fecal coliforms. Contamination sources need monitoring to
E. coli	0	1 x10^{3}		<10 cfu/100ml	

					improve water quality.
Phytoplankton Shannon Index	1.699	1.497		H’ ≥ 2.5 (Aura et al., 2021)	Enough natural food was recorded hence the dam supports aquaculture.
Phytoplankton Abundance (IndL^{-1})	415.9	4808		300	
Zooplankton Shannon Index	1.49	0.8729			Potentially supports aquaculture practices because chlorophytes were abundant and acts as food for zooplankton
Zooplankton Abundance (IndL^{-1})	29.2	180.2			

Conclusion and recommendations

Irrigation is one of the dam's primary functions. The restocking of fingerlings has drawn attention to fish farming in the dam. However, due to insufficiency in aquaculture management and fish harvesting abilities, as well as dam inaccessibility, the community has only seen a moderate impact from restocking. The dam's artisanal brick-making operations have a significant direct influence on the dam's dykes and water. The presence of extensive eucalyptus woods surrounding the dam may result in evapotranspiration.

As a result, the following management steps are proposed for the dam's long-term community use.

- Dam fencing to prevent animal defecation and brick-makers from interfering.
- Human water abstraction under control.
- Dam landscape reengineering to regulate runoff and thereby limit direct intake from polluted zones.
- Monitoring of pollution sources, both point and non-point, on a regular basis to enhance water quality.
- Reforestation using water-drainage-friendly plant types and fruit trees

2. Rianyanchabera

Plate 6. Google Earth Image of Rianyanchabera dam

Rianyanchabera dam is an earthen reservoir having a southern inflow and a northwest exit. The eastern dyke is vegetated, whereas the others are barren. It is located in Kenyenya subcounty, Kisii, in Rianya village, at an elevation of 1781 m above sea level. The dam is located at -0.9204 and 34.79006147 degrees south of the equator. The dam is flanked by big corn fields and eucalyptus tree plantations. The only settlement in the region is a massive school. The dam color reflectance is black, and the soil type is clay. Water covered the whole nearby terrain at the time of sampling.

Table 2. Means and ranges of Socio-economics impact index, water quality physical and chemical variables and nutrient species measured at Rianyanchabera dam in Kisii county. (EL = Endline, BL = Baseline, mgL^{-1} = Milligram per litre, µScm-1 – Micro-Siemens per cm, µgL-1 = Microgram per litre, ppm = Parts per million, cfu = Colony forming unit).

Parameter	Mean		Range	Discussion	
	BL	EL	EL	Reference value	Interpretation
Socio-economics impact index		2.20	1-3	≤1.67 Moderate <2.33	Restocking had moderate impact on the community
Temp (ºC)		23.8	23.8-23.8	20-31 for fish adapted to higher temperatures, <20 for fish adapted to low temperatures Mires (1995)	Temperatures recorded fall within suitable ranges for fish growth

DO (mg L^{-1})		6.2	6.2-6.2	5 mgL^{-1} and above. Ross (2000)	DO well above the critical DO for fish survival
Cond (μScm^{-1})		69.4	69.4-69.4		Values recorded for these parameters fall within tolerable ranges for fish growth
TDS (mgL^{-1})		46.15	46.15-46.15		
Sal (ppm)		0.03	0.03-0.03	0.02-0.2 for freshwater	Values recorded are within the optimal ranges for fish growth
pH		6.99	6.99-6.99	6-9 Ross (2000)	Values recorded for these parameters fall within tolerable ranges for fish growth
ORP (mV)		102.9	102.9-102.9	300-400 Horne and (Golman 1994)	
Secchi (m)		0.1		0.35- 0.5 (Beveridge, 2004, Aura et al., 2021)	Low Secchi disc readings observed due to high mineral turbidity
Nitrites (µgL-1)		2.03		0.75-5mgL^{-1}	Values recorded for water chemical parameters/ nutrients within limits of optimum concentrations for fish survival and growth
Nitrates (µgL-1)		5.36		0 – 40 mgL^{-1}	
Ammonium (μgL^{-1})		23.44		0.06 ppm at pH 9 and temperature of 25 degrees to 160 ppm at pH 6 and temperature of 5^{o}C. L-Shafey (1998)	
TN (µgL-1)		51.79			
SRP (μgL^{-1})		3.67		<15	
TP (μgL^{-1})		76.14		10-50 μgL^{-1}	
TN:TP		0.68		0.3-0.5 μgL^{-1}	
Silicate(mgL-^{1})		2.89		4–20 μgL^{-1}	
Alk (mgL-^{1})		32.00			
Hard(mgL-^{1})		32.00		>150mgL^{-1} (Hall 1991)	
Chlorophyll a (μgL^{-1})		34.57		>7.5 and <40 for Lake Victoria (Aura et al., 2021, Kashindye et al., 2015, Aura et al., 2016)	Sufficient level of primary productivity. Favourable for aquaculture
Fish condition (Relative condition factor of stocked *O. niloticus)* (Relative condition factor of stocked *O. niloticus*)		1.09	0.22-3.45	1.01±0.17 to 1.05±0.5 (Daliri et al., (2012), Lloret et al., (2014))	Species performance was good.
Total coliforms		98 x10^{3}		<1000 cfu/100ml	Water quality unsuitable for aquaculture in the current form.
E. coli		22 x10^{3}		<10 cfu/100ml	

Phytoplankton Shannon Index		1.83		H’ ≥ 2.5 (Aura et al., 2021)	Plankton diversity and abundance reflect Good ecological health and production which supports fish farming
Phytoplankton Abundance (IndL^{-1})		403		300	
Zooplankton Shannon Index		0.9754			
Zooplankton Abundance (IndL^{-1})		151.1			

Conclusion and recommendations

The social-performance indicator was moderate, suggesting that the activity had a poor start. Crop farming was dominant, but various problems were mentioned as contributing causes to low adoption: floods, drowning incidents, the presence of many reptiles/fish predators, an unfenced dam, and insecurity. These problems, along with a lack of experience in fishing and post-harvest management, have resulted in inefficient dam exploitation.

Organic waste from farm animals and agricultural hinterland runoff have resulted in fast phytoplankton growth as a direct consequence of fertilizer availability from agricultural fields around the dam. The dam can sustain a fishery because certain phytoplankton species, particularly diatoms, are excellent food for tilapia. The choice of *Oreochromis niloticus* for dam stocking was excellent since it has a greater economic value than the endemic *Enterimious neumayeri*. The presence of fecal coliforms indicates that water has been contaminated by animal/human organic waste.

Management suggestions are provided below.

- Frequent water quality monitoring to detect and manage point and non-point pollution sources in order to enhance water quality.
- Dam fencing to restrict direct feces by domestic animals
- Controlled water abstraction by the designation of a water collecting site

3.1.2 Migori County

1. Silanga Dam

Plate 7. Aerial View of Silanga Dam, Source: Google Earth®

The reservoir is located around GPS coordinates -1.01361658, 34.48967412 in a basin with a variety of cultivated crops (mainly sugarcane, plantains, and planted trees, predominantly eucalyptus). The majority of the water originates from groundwater or natural spring seepage. The whole beach is mostly covered with hippo grass. The reservoir is located in a deep basin and seems to be silted due to thick coastal substrate and steep gullies along feeder roads. The reservoir is supplied by runoff and empties into the Kajami River. On-site water for washing clothes and bathing. Hippo grass is the major macrophyte. Submerged Egeria densa and free-floating water lillies are the others.

Table 3. Means and ranges of Socio-economics impact index, water quality physical and chemical variables and nutrient species measured at Silanga dam, Migori county (EL = Endline, BL = Baseline, mgL^{-1} = Milligram per litre, µS/cm – Micro- Siemens per cm, μgL^{-1} = Microgram per litre, ppm = Parts per million, cfu = Colony forming unit).

Parameter	**Mean**		**Range**	**Discussion**	
	BL	**EL**	**EL**	**Reference value**	**Interpretation**
Socio-economics impact index		2.08	1-3	≤1.67 Moderate change <2.33	Restocking had moderate impact on the community
Temp(ºC)		26.4	26.4-26.4	20-31 for fish adapted to higher temperatures, <20 for fish	Values recorded for these parameters fall within tolerable ranges for fish growth

				adapted to low temperatures Mires (1995)	
DO (mgL^{-1})		6.24	6.24-6.24	5mgL^{-1} and above	
Cond(µS/cm)		25.1	25.1-25.1		
TDS ($mg\ L^{-1}$)		61.75	61.75-61.75		Values recorded for these parameters fall within tolerable ranges for fish growth
Sal(ppm)		0.04	0.04-0.04		
pH		6.79	6.79-6.79	6-9	
ORP (mV)		242.7	242.7-242.7		
Secchi(m)				0.35- 0.5 (Berveredge, 2004, Aura et al., 2021)	
Nitrites(μgL^{-1})		1.73		0.75-5m L^{-1} g	
Nitrates(μgL^{-1})		4.15		0 – 40 mg L^{-1}	
Ammonium(μgL^{-1})		54.06		0.06 ppm at pH 9 and temperature of 25 degrees to 160 ppm at pH 6 and temperature of 5 oC	Elevated ammonium due to increased metabolism of higher fish biomass
TN(μgL^{-1})		114.95			
SRP(μgL^{-1})		87.00		10-50 μgL^{-1}	Values are within the optimal ranges. Suitable for aquaculture practices
TP (μgL^{-1})		103.29		0.3-0.5mgL^{-1}	
TN:TP		0.1			
Silicate (mgL^{-1})		7.13		4–20 mgL^{-1}	Tolerable silicate level, an advantage to the growth of essential phytoplankton like diatoms. This in turn promotes fish growth.
Alk (mgL^{-1})		42.00			The values are within the recommended ranges for fish growth
Hard (mgL^{-1})		46.00		>150mgL^{-1} (Hall 1991)	
Chlorophyll a (μgL^{-1})		18.878		>7.5 and <40 for Lake Victoria (Aura et al., 2021, Kashindye et al., 2015, Aura et al., 2016)	High primary productivity. Favourable for aquaculture
Fish condition (Relative condition factor of stocked *O. niloticus)*		3.10	0.11-38.51	1.01±0.17 to 1.05±0.5 (Daliri et al., (2012), Lloret et al., (2014))	Species performance was good
Total coliforms		24 x10^3		<1000 cfu/100ml	Low counts of fecal coliforms. Mitigate contamination from point and nonpoint sources to improve water quality.
E.coli	2300 x10^3	8 x10^3		<10 cfu/100ml	

Phytoplankton Shannon Index	0.7054	3.988			Supports aquaculture practices in that diatom species like *Surillella* spp were abundant and diverse
Phytoplankton Abundance ($IndL^{-1}$)		234		300	
Zooplankton Shannon Index		1.212			
Zooplankton Abundance ($IndL^{-1}$)		35.4			

Conclusion and recommendations

The dam had a moderate socioeconomic impact after restocking probably attributed to crop farming and business/trade as the area's primary economic activity. The dam's water quality is good for aquaculture in line with good management practices. Nutrient enrichment is represented by the expansion of algae blooms and aquatic macrophytes, while natural food supplies are adequate to sustain fish farming.

We recommend the following:

- Community awareness on optimal practices in integrated fish farming and aquaculture.
- Dam fencing to prevent encroachment.
- To enhance water quality, frequent monitoring of point and non-point pollution sources is required.
- With further future restocking there should be intermittent harvesting

2. Nyamome Dam

Plate 8. Aerial View of Nyamome Dam, Source: Google Earth®

The reasonably big reservoir, lying around GPS position -1.09556386, 34.4453455 at a height of 1356 m.a.sl., drains mostly from groundwater sources but is also the confluence point of the surface runoff ridges in the region. The surrounding vegetation is mostly made up of bushes. Human habitation may be seen everywhere around the dam. Papyrus fringe, home water collecting There are many open beaches around the lake mass. Sandy foundation.

Table 4. Means and ranges of Socio-economics impact index, water quality physical and chemical variables and nutrient species measured at Nyamome dam, Migori county (EL = Endline, BL = Baseline, mgL^{-1} = Milligram per litre, μScm^{-1} = Micro-Siemens per cm, μgL^{-1} = Microgram per litre, ppm = Parts per million, cfu = Colony forming unit).

Parameter	**Mean**		**Range**	**Discussion**	
	BL	**EL**	**EL**	**Reference value**	**Interpretation**
Socio-economics impact index		2.33	1-3	≤1.67 Moderate <2.33	Restocking had moderate impact on the community
Temp(°C)		26	26-26	20-31 for fish adapted to higher temperatures, <20 for fish adapted to low temperatures	Values recorded for these parameters fall within tolerable ranges for fish growth

DO (mgL^{-1})		7.28	7.28-7.28	5mgL^{-1} and above	
Cond(µS/cm)		196.2	196.2-196.2		
TDS (mgL^{-1})		125.45	125.45-125.45		
Sal(ppm)		0.09	0.09-0.09		
pH		6.92	6.92-6.92	6-9	
ORP (mV)		252.5	252.5-252.5		
Secchi(m)		0.1		0.35- 0.5 (Berveredge, 2004, Aura et al., 2021)	
Nitrites(µgL^{-1})		1.42		0.75-5mgL^{-1}	
Nitrates(µgL^{-1})		4.15		0 – 40 mgL^{-1}	
Ammonium(µgL^{-1})		31.56		0.06 ppm at pH 9 and temperature of 25^{0}C	Elevated ammonium due to increased metabolism of higher fish biomass
TN(µgL^{-1})		51.79			
SRP(µgL^{-1})		53.67		10-50 µgL^{-1}	
TP(µgL^{-1})		156.14		0.3-0.5mgL^{-1}	Values are within the optimal ranges. Suitable for aquaculture practices
TN:TP		0.1		<15	
Silicate(mgL^{-1})		11.99		4–20 mgL^{-1}	
Alk(mgL^{-1})		66.00			
Hard(mgL^{-1})		58.00			
Chlorophyll a (µgL^{-1})				>7.5 and <40 for Lake Victoria (Aura et al., 2021, Kashindye et al., 2015, Aura et al., 2016)	Low primary productivity. Favourable for aquaculture with supplemental feeding
Fish condition (Relative condition factor of stocked *O. niloticus)*		1.07	0.26-2.87	1.01±0.17 to 1.05±0.5 (Daliri et al., (2012), Lloret et al., (2014))	Species performinance was good
Total coliforms		80 x10^{3}		<1000 cfu/100ml	Low counts of fecal coliforms. Mitigate contamination from point and nonpoint sources to improve water quality.
E. coli		36 x10^{3}		<10 cfu/100ml	
Phytoplankton Shannon Index	1.687	0.876		H’ ≥ 2.5 (Aura et al., 2021)	Supports aquaculture practices
Phytoplankton Abundance (IndL^{-1})	770	355		300	
Zooplankton Shannon Index		0.7794			
Zooplankton Abundance (IndL^{-1})		342.2			

Conclusion and recommendations

With no harvesting since restocking, the dam's social-performance rating was moderate. Limited capacity/skills and a shortage of harvesting equipment hampered dam utilization. The water quality is acceptable for fish farming, with a noticeable rise in ammonium levels due to increasing biological activity in the dam. There is an abundance of natural food supply to sustain fish aquaculture. The condition of *Oreochromis niloticus* documented inside this dam was excellent, suggesting that the dam has the capacity to sustain aquaculture. However, pollution sources from nearby enterprises such as industries must be monitored.

The following steps are proposed to maximize the dam's aquaculture potential.

- Community aquaculture best practices training and awareness, as well as aquaculture business development
- Fencing the dam to prevent animal excrement and monitoring water entry points to decrease polluted discharge
- Human water abstraction under control.

3. Nyegesese Dam

Plate 9. Aerial View of Nyagesese Dam, Source: Google Earth®

Located around GPS point, -1.12982, 34.44548, at an altitude of 1402 m in Migori county Kuria west subcounty, the dams had few macrophytes (papyrus) the dam is located around a densely populated area. The dam lacks inlet rivers or brooklets, it is fed with through underground aquifers.

Table 5. Means and ranges of Socio-economics impact index, water quality physical and chemical variables and nutrient species measured at Nyegesese dam in Migori County (EL = Endline, BL = Baseline, mgL^{-1} = Milligram per litre, µS/cm = Micro-Siemens per cm, μgL^{-1} = Microgram per litre, ppm = Parts per million, cfu = Colony forming unit)

Parameter	**Mean**		**Range**	**Discussion**	
	BL	**EL**	**EL**	**Reference value**	**Interpretation**
Socio-economics impact index		1.86	1-3	≤1.67 Moderate <2.33	Restocking had moderate impact on the community
Temp(ºC)		27	27-27	20-31 for fish adapted to higher temperatures, <20 for fish adapted to low temperatures	Values recorded for these parameters fall within tolerable ranges for fish growth
DO ($mg\ L^{-1}$)		6.04	6.04-6.04	5mg L^{-1} and above	
Cond(µS/cm)		90.9	90.9-90.9		
TDS ($mg\ L^{-1}$)		66.54	66.54-66.54		

Sal(ppm)		0.04	0.04-0.04		
pH		6.92	6.92-6.92	6-9	
ORP (mV)		254.2	254.2-254.2		
Secchi(m)				0.35- 0.5 (Berveredge, 2004, Aura et al., 2021)	
Nitrites(μgL^{-1})		0.52	0.75-5mg L-1	0.75-5mgL^{-1}	
Nitrates(μgL^{-1})		2.03	0 – 40 mg L-1	0 – 40 mgL^{-1}	
Ammonium(μgL^{-1})		30.94		0.06 ppm at pH 9 and temperature of 25 degrees to 160 ppm at pH 6 and temperature of 5 oC	Elevated ammonium due to increased metabolism of higher fish biomass
TN(μgL^{-1})		42.32			
SRP(μgL^{-1})		63.67		10-50 μgL^{-1}	
TP(μgL^{-1})		87.57		0.3-0.5mgL^{-1}	Values are within the optimal ranges. Suitable for aquaculture practices
TN:TP		0.1		<15	
Silicate(mgL^{-1})		11.52		4–20 mgL^{-1}	Tolerable silicate level, an advantage to the growth of essential phytoplankton like diatoms. This in turn promotes fish growth.
Alk(mgL^{-1})		28.00			
Hard(mgL^{-1})		24.00			
Chlorophyll a (μgL^{-1})		78.674		>7.5 and <40 for Lake Victoria (Aura et al., 2021, Kashindye et al., 2015, Aura et al., 2016)	High primary productivity. Favourable for aquaculture
Fish condition (Relative condition factor of stocked *O. niloticus)*		1.02	0.55-1.20	1.01±0.17 to 1.05±0.5 (Daliri et al., (2012), Lloret et al., (2014))	Species performance was good
Total coliforms		84 $x10^3$		<1000 cfu/100ml	High counts of fecal coliforms. Mitigate contamination from point and nonpoint sources to improve water quality.
E. coli		45 $x10^3$		<10 cfu/100ml	
Phytoplankton Shannon Index		2.758			Supports aquaculture related practices
Phytoplankton Abundance (IndL^{-1})		429		300	
Zooplankton Shannon Index		1.61			
Zooplankton Abundance (IndL^{-1})		427.5			

Conclusion and recommendations

The water quality in the dam is favorable for fisheries and aquaculture production, with values reported within the ideal limits for fish development. It is distinguished by high primary production and an abundance of zooplankton and phytoplankton, which serve as natural food sources for fish and may not need extra feeds. Due to a shortage of fishing equipment, less fishing has happened, resulting in a moderate socio-performance score.

The following are recommended:

- Support for aquaculture inputs, such as the purchase of fishing equipment.
- Fence the dam and allow for an integrated resource management strategy
- Monitoring water input points to decrease runoff from polluted areas
- Building aquaculture commercialization capacity for community empowerment

3.1.3 Homa Bay County

1. Pap Orage Dam

Plate 10. Aerial View of Pap Orage Dam, Source: Google Earth®

The dam is located in the Rachuonyo South subcounty at GPS coordinates -0.48347, 34.66687, at an elevation of 1260 m a.s.l. Around the dam, there is a lot of bare land and grass cover, with some sedges on the western margins. Northern coasts have rocky outcrops with planted eucalyptus farther out. Grazing is permitted on the land outside the dam. Substrate that is muddy.

Table 6. Means and ranges of Socio-economics impact index, water quality physical and chemical variables and nutrient species measured at Pap Orage dam in Homa Bay county. (EL = Endline, BL = Baseline, mgL^{-1} = Milligram per litre, μScm^{-1} – Micro-Siemens per cm, μgL^{-1} = Microgram per litre, ppm = Parts per million, cfu = Colony forming unit)

Parameter	Mean		Range	Discussion	
	BL	EL	EL	Reference value	Interpretation
Socio-economics impact index	0.54	2.28	1-3	≤2.34 High <3.00; ≤1.67 Moderate <2.33; ≤1.00 Low <1.66	Restocking had moderate impact on the community
Temp (ºC)	22.4	26.2	26.2-26.2	20-31 for fish adapted to higher temperatures, <20 for fish adapted to low temperatures	The ranges of physico-chemical parameters recorded in dam supports fish farming. ORP which was below the recommended range There was also improvement of D.O as
DO (mgL^{-1})	2.2	5.94	5.94-5.94	5 mgL^{-1} and above	
Cond(μScm^{-1})		144.7	144.7 -144.7		

TDS (mg L^{-1})		92.34	92.34-92.34		measured in the endline survey.
Sal (ppm)		0.07	0.07-0.07		
pH	7.46	6.42	6.42-6.42	6-9 (Rosse, 2000)	
ORP (mV)		162.2	162.2 -162.2	300-500mv (Horen and Goldman,1994)	
Secchi(m)		0.1		0.35- 0.5 (Berveredge, 2004, Aura et al., 2021)	The was turbidity associated with plankton popullation
Nitrites (µgL-1)		14.76		0.75-5mgL^{-1}	The dam had enough nutrients to support primary productivity hence suitable for aquaculture. SRP was observed to be high in the dam.
Nitrates (µgL-1)		26.27		0 – 40 mgL^{-1}	
Ammonium (µgL^{-1})	95.94	149.06		0.06 ppm at pH 9 and temperature of 25 degrees to 160 ppm at pH 6 and temperature of 5oC	
TN (µgL-1)		378.11			
TN:TP	17.5	5.60		<15	
SRP (µgL^{-1})		85.33		10-50 µgL^{-1}	
TP (µgL^{-1})		67.57		0.3-0.5mgL^{-1}	
Silicate(mgL-¹)		21.06		4–20 mgL^{-1}	
Alk (mgL-¹)		36.00			
Hard(mgL-¹)		44.00			
Chlorophyll a (µgL^{-1})		105.93		>7.5 and <40 for Lake Victoria (Aura et al., 2021, Kashindye et al., 2015, Aura et al., 2016)	There was high primary productivity in the dam as indicated by the high concentration of chlorophyl-a above the recommended values
Fish condition (Relative condition factor of stocked *O. niloticus)*	2.36	1.07	-0.37-1.76	1.01±0.17 to 1.05±0.5 (Daliri et al., (2012), Lloret et al., (2014))	The species performance was good
Total coliforms		54 x10^3		<1000 cfu/100ml	Faecal pollution was observed in the dam.
E. coli	700 x10^3	21 x10^3		<10 cfu/100ml	
Phytoplankton Shannon Index	1.326	1.619		H' ≥ 2.5 (Aura et al., 2021)	The dam has reliable primary producers hence favourable for aquaculture. There was improved plankton abundance and diversity during the end line survey
Phytoplankton Abundance (IndL^{-1})	178.59	208		300	
Zooplankton Shannon Index	0.9074	1.397			
Zooplankton Abundance (IndL^{-1})	284.3	426			

Conclusion and recommendations

Due to constraints such as management's restriction on accessing the dam, the community has not taken fish from the dam since restocking. Because of the community's focus on agricultural production, aquaculture received little attention. High turbidity was also observed in the dam, however this was mostly due to high primary production, as shown by plentiful plankton, optimal nutrient concentrations, and high chlorophyl-a concentrations. High concentration of soluble reactive phosphorus detected favored primary production. The possible source of phosphorous might be the activities like laundry done in the dam area by the community using detergents.

The following are the proposed recommendations to enhance fish farming in the dam:

- Dam fencing to restrict unauthorised access by animals and people
- Laundry at the damside may be encouraged but limited to safe practices
- Frequent monitoring of point and non-point sources of pollution should be explored to improve water quality;

2. Yongo Dam

Plate 11: Aerial View of Yongo Dam, Source: Google Earth®

The reservoir is situated in the Suba South subcounty at GPS -0.5642, 34.2882 at an elevation of 1159 meters above sea level. Shrubs, acacia trees, euphoria, and leafy macrophytes cover the surrounding ground. Muddy black cotton-derived substrate

Table 7. Means and ranges of Socio-economics impact index, water quality physical and chemical variables and nutrient species measured at Yongo dam, Homabay county (EL = Endline, BL = Baseline, mgL^{-1} = Milligram per litre, µScm^{-1} – Micro-Siemens per cm, µgL^{-1} = Microgram per litre, ppm = Parts per million, cfu = Colony forming unit).

Parameter	Mean		Range	Discussion	
	BL	EL	EL	Reference value	Interpretation
Socio-economics impact index	0.50	2.17	1-3	≤1.67 Moderate <2.33	Restocking had moderate impact on the community
Temp(°C)	25.5	25.2	25.2-25.2	20-31 for fish adapted to higher temperatures, <20 for fish adapted to low temperatures Morgan (1972) and Mires (1995)	Values recorded for these parameters fall within tolerable ranges for fish growth
DO (mg L^{-1})	2.66	6.78	6.78-6.78	5mg L-1 and above (Ross, 2000)	
Cond(µS/cm)		438.7	438.7-438.7		
TDS (mg L^{-1})		282.1	282.1-282.1		
Sal (ppm)		0.21	0.02-0.2 for fresh water		
pH	7.19	6.02	6.02-6.02	6-9 (Ross, 2000)	

ORP (mV)		187.9	187.9-187.9	300-500 mV (Horne and Goldman, 1994)	
Secchi(m)	0.2	0.1		0.35- 0.5 (Berveredge, 2004, Aura et al., 2021)	
Nitrites(µgL¯¹)		0.52		0.75-5mgL¯¹	
Nitrates(µgL¯¹)		1.42		0 – 40 mgL¯¹	
Ammonium(µgL¯¹)	175.31	36.56		0.06 ppm at pH 9 and temperature of 25 degrees to 160 ppm at pH 6 and temperature of 5 ºC (El-Shafey, 1998)	Elevated ammonium due to increased metabolism of higher fish biomass
TN(µgL¯¹)		45.47			
TN:TP	92.0				Values are within the optimal ranges. Suitable for aquaculture practices
SRP(µgL¯¹)		22.00		10-50 µg L¯¹	
TP(µgL¯¹)		71.86		0.3-0.5mg L¯¹	
Silicate(mgL¯¹)		13.30		4–20 mg L¯¹	Tolerable silicate level, an advantage to the growth of essential phytoplankton like diatoms. This in turn promotes fish growth.
Alk (mgL¯¹)		168.00			
Hard (mgL¯¹)		134.00			
Chlorophyll a (µgL¯¹)		0.1			Moderate primary productivity. favourable for aquaculture
Fish condition (Relative condition factor of stocked *O. niloticus)*		*1.66O. niloticus*	0.28-80.50	1.01±0.17 to 1.05±0.5 (Daliri et al., (2012), Lloret et al., (2014))	Species performance was good
Total coliforms		75 x10^3		<1000 cfu/100ml	Low counts of fecal coliforms. Mitigate contamination from point and nonpoint sources to improve water quality.
E.coli	0	20 x10^3		<10 cfu/100ml	
Phytoplankton Shannon Index	0.851	1.469			Enough natural food was recorded hence the dam supports aquaculture. Potentially supports aquaculture practices because chlorophytes were abundant and acts as food for zooplankton

Conclusion and recommendations

The dominance of crop production by the SWB community constrains aquaculture's growth. Due to a lack of fisheries/aquaculture skills, no fish have been collected from the SWB. The nitrogen deficiency as observed, may consequently stimulate the development of undesirable algae like chlorophytes, cyanophytes, and centric diatoms that can cling to debris. Phytoplankton productivity was adequate and is beneficial to fish growth.

The following guidelines are intended to promote the positive effects of stocked fish on the community.

- Continued raising of the community’s awareness of the relevance and best practices in aquaculture;
- To minimize retardation of progress brought about by group dynamics, there is a need for increased awareness of the necessity of cohesiveness.
- Dam fencing to prevent unauthorised access with the attendant contaminant transfer, and controlled human water abstraction; and
- Frequent monitoring of point and non-point pollution sources is required to enhance water quality.

3. B1 Dam

Plate 12. Aerial View of B1 Dam, Source: Google Earth®

B1 Dam is located in Homa Bay's Rachuonyo North sub-county, near the villages of Opuk and Nyandhiwa in Kendu Bay town ward. It is located south of the equator at latitude 0.38065 and longitude 34.642267 and has an elevation of 1120 meters above sea level. The dam's dykes are made of concrete on all four sides and serve as a reservoir for irrigating the Oluch Kimira rice plantations. Crop production is underway on the western side, while fields to the east remain barren, most likely in preparation for cropping. The land around the dam has very little habitation and no forest cover. The water was light brown at the time of sampling.

Table 8. Means and ranges of Socio-economics impact index, water quality physical and chemical variables and nutrient species measured at B1 dam, Homabay county (EL = Endline, BL = Baseline, mgL^{-1} = Milligram per litre, μScm^{-1} – Micro-Siemens per cm, μgL^{-1} = Microgram per litre, ppm = Parts per million, cfu = Colony forming unit)

Parameter	**Mean**		**Range**	**Discussion**	
	BL	**EL**	**EL**	**Reference value**	**Interpretation**
Socio-economics impact index		2.24	1-3	≤1.67 moderate <2.33	Restocking had moderate impact on the community
Temp(°C)		29.2	29.2-29.2	20-31 for fish adapted to higher temperatures, <20 for fish adapted to low temperatures Mires (1995)	Values recorded for these parameters fall within tolerable ranges for fish growth
DO (mgL^{-1})		4.45	4.45-4.45	5mgL^{-1} and above	Reduced DO values due to the possibility of organic matter decomposition
Cond(µS/cm)		144.1	144.1-144.1		Values recorded for these parameters fall within tolerable ranges for fish growth
TDS (mgL^{-1})		86.45	86.45-86.45		Values recorded for these parameters fall within tolerable ranges for fish growth
Sal(ppm)		0.06	0.06-0.06		
pH		5.71	5.71-5.71	6-9	
ORP (mV)		198.3	198.3-198.3		
Secchi(m)		0.1			
Nitrites(μgL^{-1})		0.82		0.75-5mg L^{-1}	
Nitrates(μgL^{-1})		5.97		0 – 40 mg L^{-1}	
Ammonium(μgL^{-1})		21.56		0.06 ppm at pH 9 and temperature of 25 degrees to 160 ppm at pH 6 and temperature of 5 °C (El-Shafey, 1998)	Elevated ammonium due to increased metabolism of higher fish biomass
TN(μgL^{-1})		66.00			Values recorded for nutrient species and physico-chemical attributes within tolerable ranges for fish
SRP(μgL^{-1})		13.67		10-50 μgL^{-1}	
TP(μgL^{-1})		139.00		0.3-0.5mgL^{-1}	
TN:TP				<15	
Silicate(mgL^{-1})		9.55		4–20 mgL^{-1}	
Alk (mgL^{-1})		50.00			
Hard (mgL^{-1})		54.00			
Chlorophyll a (μgL^{-1})					
Fish condition (Relative condition factor of stocked *O. niloticus)*	-			1.01±0.17 to 1.05±0.5 (Daliri et al.,	-

				(2012), Lloret et al., (2014))	
Total coliforms		28 $x10^3$		<1000 cfu/100ml	Mitigate contamination from point and nonpoint sources to improve water quality.
E. coli	400 $x10^3$	16 $x10^3$		<10 cfu/100ml	
Phytoplankton Shannon Index		0.876			Supports fish farming and has abundant food for fish
Phytoplankton Abundance ($IndL^{-1}$)		355			
Zooplankton Shannon Index		1.297			
Zooplankton Abundance ($IndL^{-1}$)		122.4		300	

Conclusion and recommendations

The dam's moderate impact on the community may be attributed to variables such as the community's preference for agricultural production over other economic activities, given that this aquaculture venture is at its debut stages. Little harvesting has occurred since restocking. Notwithstanding, the assessment also revealed an abundance of natural food (phytoplankton primary producers), suitable for fish production.

We recommend the following procedures to maximize the advantages of stocked fish in the affluent neighbourhood:

- Sensitization of the community to the value of aquaculture;
- Dam fencing to contain animal excrement.
- Controlled human water abstraction; and
- Monitoring water input points to prevent runoff from polluted zones.

3.1.4 Kisumu County

1. Buoye Dam

Plate 13. Aerial View of Bouye Dam, Source: Google Earth®

This dam is located in Kisumu East subcounty at an elevation of 1134 m, at the GPS coordinates -0.14802, 34.8072. The dam features clean water and little macrophytes along the beach. Water lilies and Solanum app are examples of floating vegetation. Whistling thorn trees and eucalyptus are abundant along the banks. Substrate that is muddy.

Table 9. Means and ranges of Socio-economics impact index, water quality physical and chemical variables and nutrient species measured at Buoye dam (EL = Endline, BL = Baseline, mgL^{-1} = Milligram per litre, µS/cm – Micro- Siemens per cm, μgL^{-1} = Microgram per litre, ppm = Parts per million, cfu = Colony forming unit).

Parameter	Mean		Range	Discussion	
	BL	EL	EL	Reference value	Interpretation
Socio-economics impact index	0.44	2.12	1-3	≤1.67 Moderate <2.33	Restocking had moderate impact on the community
Temp (°C)	24.7	26	26-26	20-31 for fish adapted to higher temperatures, <20 for fish adapted to low temperatures	Values recorded for these parameters fall within tolerable ranges for fish growth
DO (mgL^{-1})	5.52	6.7	6.7-6.7	5mgL-1 and above	

Cond(µScm^{-1})		195	195^{-1}95		
TDS (mgL-^{1})		126.65	126.65^{-1}26.65		
Sal (ppm)		0.09	0.09-0.09		
pH	7.02	6.56	6.56-6.56	6-9	
ORP (mV)		188	188^{-1}88		
Secchi(m)	0.2			0.35- 0.5 (Berveredge, 2004, Aura et al., 2021)	
Nitrites (µgL-1)		3.85	3.85- 3.85	0.75-5mgL-1	
Nitrates (µgL-1)		4.76	4.76- 4.76	0 – 40 mgL-1	
Ammonium (µgL^{-1})	2.188	25.31	25.31- 25.31	0.06 ppm at pH 9 and temperature of 25 degrees to 160 ppm at pH 6 and temperature of 5oC	Low ammonium due to decreased metabolism of lower fish biomass
TN (µgL-1)		53.37			
SRP (µgL^{-1})		48.67		10-50 µgL^{-1}	
TP (µgL^{-1})		153.29		0.3-0.5mgL^{-1}	
TN:TP	2.4	0.35	0.35	<15	Value is within the tolerable ranges. Suitable for aquaculture practices
Silicate(mgL-^{1})		17.89	17.89- 17.89	4–20 mgL-1	High silicate level, an advantage to the growth for essential phytoplankton like diatoms. This in turn promotes fish growth.
Alk (mgL-^{1})		76.00	76- 76		
Hard(mgL-^{1})		78.00	78- 78		
Chlorophyll a (µgL^{-1})		72.75	72.75- 72.75	>7.5 and <40 for Lake Victoria (Aura et al., 2021, Kashindye et al., 2015, Aura et al., 2016)	Low primary productivity. Unfavourable for aquaculture
Fish condition (Relative condition factor of stocked *O. niloticus)*		*O*1.11	80.88-1.77	1.01±0.17 to 1.05±0.5 (Daliri et al., (2012), Lloret et al., (2014))	Species performance was good
Total coliforms		28 x10^{3}		<1000 cfu/100ml	Low counts of fecal coliforms. Point and non-point sources of contamination need monitoring to improve water quality.
E. coli	400 x10^{3}	16 x10^{3}		<10 cfu/100ml	
Phytoplankton Shannon Index	0.783	0.5602		H' ≥ 2.5 (Aura et al., 2021)	Supports fish farming But needs feed enhancement

Phytoplankton Abundance (IndL^{-1})	197.75	2567		300	
Zooplankton Shannon Index	1.388	1.358			
Zooplankton Abundance (IndL^{-1})	356.0	211.4			

Conclusion and recommendations

The observed moderate impact of restocking to the community is attributable to their prioritization of mixed crop farming over fisheries/aquaculture. This, combined with inexperienced workers (in fishing), has resulted in limited harvesting of fish. Water quality was found to be good and primary productivity assessment revealed an abundance of Chlorophytes and diatoms, supportive of small-scale fish farming of tilapia. Therefore, the existing environmental conditions are expected to support fish farming.

We therefore recommend the following measures to enhance the community's benefit from the fish:

- Fencing of the dam to limit unauthorised access by grazing animals and people.
- Monitoring the water inflow points to reduce runoff from pollution zones.
- Frequent monitoring of point and non-point sources of pollution to improve water quality is essential.

2. Huma Dam

Plate 14. Aerial View of Huma Self Help Group Dam, Source: Google Earth®

Huma self-help group dam is found in Kisumu west subcounty at an altitude of 1407 m around the GPS points, -0.0514, 34.6089. It is a relatively turbid dam with outflow banks.

Table 10. Means and ranges of Socio-economics impact index, water quality physical and chemical variables and nutrient species measured at Huma dam in Kisumu County (EL = Endline, BL = Baseline, mgL^{-1} = Milligram per litre, µS/cm = Micro-Siemens per cm, μgL^{-1} = Microgram per litre, ppm = Parts per million, cfu = Colony forming unit).

Parameter	**Mean**		**Range**	**Discussion**	
	BL	**EL**	**EL**	**Reference value**	**Interpretation**
Socio-economics impact index	0.48	1.88	1-3	≤1.67 Moderate <2.33	Restocking had moderate impact on the community
Temp(ºC)	24.1	22.1	22.1-22.1	20-31 for fish adapted to higher temperatures, <20 for fish adapted to low temperatures	Values recorded for these parameters fall within tolerable ranges for fish growth
DO (mgL^{-1})	7.64	5.83	5.83-5.83	5mg L^{-1} and above	
Cond(µS/cm)		148.6	148.6-148.6		
TDS (mg L^{-1})		102.05	102.05-102.05		
Sal(ppm)		0.07	0.07-0.07		
pH	7.79	5.83	5.83-5.83	6-9	
ORP (mV)		183.2	183.2-183.2		
Secchi(m)				0.35- 0.5 (Berveredge, 2004, Aura et al., 2021)	
Nitrites(μgL^{-1})		6.58		0.75-5mgL^{-1}	
Nitrates(μgL^{-1})		27.18		0 – 40 mgL^{-1}	
Ammonium(μgL^{-1})	9.063	53.44		0.06 ppm at pH 9 and temperature of 25 degrees to 160 ppm at pH 6 and temperature of 5 oC	Elevated ammonium due to increased metabolism of higher fish biomass
TN(μgL^{-1})		437.05			
SRP(μgL^{-1})		18.67		10-50 µg L^{-1}	
TP(μgL^{-1})		286.14		0.3-0.5mg L^{-1}	Values are within the optimal ranges. Suitable for aquaculture practices
TN:TP	2.9	0.1		<15	
Silicate(mgL^{-1})		2.77		4–20 mg L^{-1}	Low silicate level, a disadvantage to the growth of essential

					phytoplankton like diatoms. This in turn staggers fish growth.
Alk(mgL^{-1})		42.00			
Hard(mgL^{-1})		60.00			
Chlorophyll a (μgL^{-1})		0.1		>7.5 and <40 for Lake Victoria (Aura et al., 2021, Kashindye et al., 2015, Aura et al., 2016)	Moderate primary productivity. Favourable for aquaculture with supplemental feeding
Fish condition (Relative condition factor of stocked *O. niloticus)*		0.99	0.21-2.92	1.01±0.17 to 1.05±0.5 (Daliri et al., (2012), Lloret et al., (2014))	Species performance good
Phytoplankton Shannon Index	0.8983	1.632			Can Supports fish farming
Phytoplankton Abundance ($IndL^{-1}$)	217.79	248.7		300	
Zooplankton Shannon Index	1.513	0.7938			
Zooplankton Abundance ($IndL^{-1}$)	386.8	580.5			
Total coliforms		17 x10^3		<1000 cfu/100ml	High counts of fecal coliforms. Point and non-point sources of contamination need monitoring to improve water quality.

Conclusion and recommendations

In this locality, fisheries/aquaculture has not been a priority due to crop farming dominance. This, combined with limited knowledge on aquaculture-based management has resulted in no harvesting. Although the water quality parameters indicated ideal conditions for fish growth, pollution (faecal contamination) sources must be monitored and controlled. There was evidence of high primary productivity, as well as abundance of Chlorophytes and diatoms, which support small-scale fish farming. The current environmental conditions favor fish farming, but subsidized feeding is required.

The following are recommended to enhance the dam productivity and community benefits:

- Community participation at all stages of project implementation
- Dam fencing to minimize unauthorised accdess
- Human water abstraction under control
- Monitoring water inflow points in order to reduce runoff from polluted areas.

3. Kere Women Group

Plate 15. Aerial View of Kere Women Group Dam, Source: Google Earth®

Kere dam is found in Kisumu east sub county at an altitude of 1545 m around the GPS points, -0.3634, 34.9375. It is a reservoir fully enclosed with a cemented inlet channel for runoff of inflow. The dam has high banks.

Table 11. Means and ranges of Socio-economics impact index, water quality physical and chemical variables and nutrient species measured at Kere Women Group dam in Kisumu County (EL = Endline, BL = Baseline, mgL-¹ = Milligram per litre, µS/cm – Micro-Siemens per cm, μgL^{-1} = Microgram per litre, ppm = Parts per million, cfu = Colony forming unit).

Parameter	**Mean**		**Range**	**Discussion**	
	BL	**EL**	**EL**	**Reference value**	**Interpretation**
Socio-economics impact index	0.48	1.88	1-3	≤1.67 Moderate <2.33	Restocking had moderate impact on the community
Temp (ºC)	24.1	22.1	22.1-22.1	20-31 for fish adapted to higher temperatures, <20 for fish adapted to low temperatures	Values recorded for these parameters fall within tolerable ranges for fish growth
DO (mgL^{-1})	7.64	5.83	5.83-5.83	5mg L^{-1} and above	
Cond (µS/cm)		148.6	148.6-148.6		
TDS (mg L^{-1})		102.05	102.05-102.05		
Sal(ppm)		0.07	0.07-0.07		

pH	7.79	5.83	5.83-5.83	6-9	
ORP (mV)		183.2	183.2-183.2		
Secchi(m)				0.35- 0.5 (Berveredge, 2004, Aura et al., 2021)	
Nitrites(µgL^{-1})		6.58		0.75-5mgL^{-1}	
Nitrates(µgL^{-1})		27.18		0 – 40 mgL^{-1}	
Ammonium(µgL^{-1})	9.063	53.44		0.06 ppm at pH 9 and temperature of 25 degrees to 160 ppm at pH 6 and temperature of 5 ºC	Elevated ammonium due to increased metabolism of higher fish biomass
TN(µgL^{-1})		437.05			
SRP(µgL^{-1})		18.67		10-50 µg L^{-1}	
TP(µgL^{-1})		286.14		0.3-0.5mg L^{-1}	Values are within the optimal ranges. Suitable for aquaculture practices
TN:TP	2.9	0.1		<15	
Silicate(mgL^{-1})		2.77		4–20 mg L^{-1}	Low silicate level, a disadvantage to the growth of essential phytoplankton like diatoms. This in turn staggers fish growth.
Alk(mgL^{-1})		42.00			
Hard(mgL^{-1})		60.00			
Chlorophyll a (µgL^{-1})		0.1		>7.5 and <40 for Lake Victoria (Aura et al., 2021, Kashindye et al., 2015, Aura et al., 2016)	Moderate primary productivity. Favourable for aquaculture with supplemental feeding
Fish condtion		1.15	0.66-2.70	1.01±0.17 to 1.05±0.5 (Daliri et al., (2012), Lloret et al., (2014))	Species performance good
Phytoplankton Shannon Index	0.8983	1.632			Can Supports fish farming
Phytoplankton Abundance (IndL^{-1})	217.79	248.7		300	
Zooplankton Shannon Index	1.513	0.7938			
Zooplankton Abundance (IndL^{-1})	386.8	580.5			
Total coliforms		17 x10^3		<1000 cfu/100ml	High counts of fecal coliforms. Point and non-point sources of contamination need monitoring to improve water quality.

Conclusion and recommendations

Crop farming has a stronghold in the community, limiting the time invested by the community on fisheries and aquaculture. Access to the dam and benefit accumulation are hindered until the government settles an existing dispute between the Kere Women Group and the landowners. The dam is nitrogen limited which can promote the growth of undesirable algae. The high turbidity of this dam could be due to siltation from the inflowing water from the surrounding human activities.

To address the existing challenges and promote the positive attributes of the SWB, the following recommendations are made:

- Continued sensitization of the community to the importance of aquaculture
- Fencing of the dam to limit human and animal encroachment
- Planting of trees that can prevent erosion to the dam
- Dam management to work on prevention of pollution (faecal contamination)
- Frequent monitoring of point and non-point sources of pollution to improve water quality.
- Desilting the dam.

3.1.5 Kakamega

1. Lugulu Dam

Plate 16. Aerial View of Lugulu Dam, Source: Google Earth®

Lugulu dam is found in Kakamega county, Likuyani sub county at an altitude of 1776 m around the GPS points (X,Y), 0.7703, 35.0802. The appearance of the dam is milky from clay/ rock sediments. Inflow of clear water from a natural spring, with cement channelized at the inlet. Outflow is through a spill way into the continuing stream.

Table 12. Means and ranges of Socio-economics impact index, water quality physical and chemical variables and nutrient species measured at Lugulu dam in Kakamega County. (EL = Endline, BL = Baseline, mgL^{-1} = Milligram per litre, μScm^{-1} – Micro-Siemens per cm, μgL^{-1} = Microgram per litre, ppm = Parts per million, cfu = Colony forming unit).

Parameter	Mean		Range	Discussion	
	BL	**EL**	**EL**	**Reference value**	**Interpretation**
Socio-economics impact index	0.45	2.33	1-3	≤1.67 Moderate <2.33	Restocking had moderate impact to the community
Temp (ºC)	22.7	23.65	23.6-23.7	20-31 fish adapted to higher temperatures, <20 fish adapted to low temperatures	The recorded physico chemical parameters were within the recommended ranges hence the dam is good for aquaculture
DO (mgL^{-1})	7.26	5.605	5.33-5.88	5 mgL^{-1} and above	
Cond (µScm^{-1})		332.1	163.5 -168.6		
TDS (mgL^{-1})		112.45	111.8-113.1		
Sal (ppm)		0.08	0.08-0.08	0-2 ppm for freshwater	
pH	7.4	8.38	8.08-8.68	6-9	
ORP (mV)		-127.4	-140.8—114		Low value an indication of of dead and decaying material in the water column that cannot be easily decomposed
Secchi(m)	0.2	0.415	0.4-0.43	0.35- 0.5 (Berveredge, 2004, Aura et al., 2021)	Low Secchi an indication of enhanced turbidity due to high siltation
Nitrites (µgL^{-1})		4.15	1.73- 6.58	0.75-5mg L^{-1}	Values recorded fall within tolerable ranges for growth of fish
Nitrates (µgL^{-1})		17.21	3.33- 13.88	0 – 40 mgL^{-1}	
Ammonium (µgL^{-1})	24.6875	26.25	25.31-27.19	0.06 ppm at pH 9 and temperature of 25 degrees to 160 ppm at pH 6 and temperature of 5oC	Elevated ammonium due to increased metabolism of higher fish biomass
TN (µgL-1)		85.74	77.05- 94.42		Range of values recorded for nutrient species favourable for growth of fish
SRP (µgL^{-1})		11.17	7- 15.33	10-50 µgL^{-1}	
TN:TP	12.2	0.59	0.46-0.72	<15	
TP (µgL^{-1})		150.43	131.86- 169	0.3-0.5mgL^{-1}	
Silicate (mgL-^{1})		26.70	26.32- 27.08	4–20 mgL^{-1}	
Alk (mgL-^{1})		74	74- 74		
Hard (mgL-^{1})		54.00	54- 54		
Chlorophyll a (µgL^{-1})		25.26	22.07-28.45		
Fish condition (Relative condition factor of stocked *O. niloticus*)	-	*1.26*	0.00-4.07	1.01±0.17 to 1.05±0.5 (Daliri et al., (2012),	FSpecies performance good

				Lloret et al., (2014))	
Total coliforms		21 x10^3		<1000 cfu/100ml	Mitigate contamination from point and nonpoint sources to improve water quality.
E. coli	300 x10^3	7 x10^3		<10 cfu/100ml	
Phytoplankton Shannon index	1.453	1.937			Improved plankton abundance from BL. Suitable for aquaculture practices.
Phytoplankton Abundance (IndL^{-1})	536	1441		300	
Zooplankton Shannon index	0.8293	0.8616			
Zooplankton abundance (IndL^{-1})	59.5	109.2			

Conclusion and recommendations

It was noted that the fish growth performance was good in this dam. However, since restocking of the dam, the community had not yet harvested any fish, a fact that was attributed to lack of fishing gears and a means to access the deeper portions of the dam, thereby limiting the desired exploitation. Farming practices within the dam's proximity present an environmental challenge from possible runoff leading to input of organic and inorganic compounds into the dam as observed with the negative ORP. This in turn may trigger microbial multiplication and turbidity from these non-decomposing particles suspended in the water colum.

The following actions are recommended to foster the positive impacts of the stocked fish to the communities.

- Intermittent fishing should be encouraged and equitable access of the stocked fish for the community to benefit
- Community sensitization/capacity building on harvesting fish and promoting the purchase of buying fishing gears by the beneficiary of the resource.
- Sensitizing the community and management of the dam to practise cohesion to utilize the stocked fish for the benefit of the society
- Creation of a buffer zone from adjacent agricultural farmlands to minimise pollution from surface runoff and frequent monitoring of point and non-point sources of pollution.

2. Mwamba Dam

Plate 17. Aerial View of Mwamba Dam, Source: Google Earth®

The dam is found in Lugari sub-county, Lumakanda location (Lugari ward), The GPS position of the dam is 0.631246, 35.03224 at an altitude of 1805m. The dam is characterised by muddy waters with heavy sedimentation. It is served by an underground source (limited) with over 60% of its water source from stormwater/runoff thus the high sedimentation. It is surrounded by agricultural farmlands and a major animal watering point for the surrounding community.

Table 13. Means and ranges of Socio-economics impact index, water quality physical and chemical variables and nutrient species measured at Mwamba dam in Kakamega county. (EL =Endline, BL = Baseline, mgL^{-1} = Milligram per litre, μScm^{-1} – Micro-Siemens per cm, μgL^{-1} = Microgram per litre, ppm = Parts per million, cfu = Colony forming unit)

Parameter	**Mean**		**Range**		
	BL	**EL**	**EL**	**Reference value**	**Interpretation**
Socio-economics impact index		2.16	1-3	≤1.67 Moderate <2.33	Restocking had moderate impact on the community
Temp (ºC)		23.15	20.1-26.2	20-31 fish adapted to higher temperatures, <20 fish adapted to low temperatures	Oxgen recorded low value below the recommended range. While other parameters were withing the range.

DO (mgL^{-1})		3.53	3.2-3.86	5 mgL^{-1} and above	This could be due to uptake of oxygen for decomposition
Cond(μScm^{-1})		145	68.1-76.9		
TDS (mgL^{-1})		45.51	42.26-48.76		
Sal (ppm)		0.03	0.03-0.03		
pH		8.175	8.03-8.32	6-9	
ORP (mV)		-142.55	-186.3--98.8		Negative ORP value indicating presence of non-decomposing decomposing particles in the water column
Secchi(m)		0.215		0.35- 0.5 (Berveredge, 2004, Aura et al., 2021)	Low Secchi depth indicating high turbidity
Nitrites (μgL^{-1})		17.64	15.36- 19.91	0.75-5mg L^{-1}	
Nitrates (μgL^{-1})		51.64	23.24- 28.39	0 – 40 mg L^{-1}	
Ammonium (μgL^{-1})		82.50	69.69- 95.31	0.06 ppm at pH 9 and temperature of 25 degrees to 160 ppm at pH 6 and temperature of 5oC	Most of the nutrient species were within the recommended range for aquaculture apart from SRP and TP. This could have been due to decomposition of algal biomass and leaching back of absorbed nutrient into the water Colum
TN (μgL^{-1})		149.68	140.21- 159.16		
SRP (μgL^{-1})		67.00	47- 87	10-50 μgL^{-1}	
TP (μgL^{-1})		728.29	551.86- 904.71	0.3-0.5mgL^{-1}	
TN:TP		0.21	0.18-0.25	<15	
Silicate(mgL^{-1})		12.19	11.73- 12.66	4–20 mgL^{-1}	
Alk (mgL^{-1})		30	30- 30		
Hard (mgL^{-1})		70.00	70- 70		
Chlorophyll a (μgL^{-1})		152.76	143.89^{-1}61.64	>7.5 and <40 for Lake Victoria (Aura et al., 2021, Kashindye et al., 2015, Aura et al., 2016)	Hypertrophic environment due to increased values of nutrients in the water column
Fish condition (Relative condition factor of stocked *O. niloticus*)		1.61	1-2.06	1.01±0.17 to 1.05±0.5 (Daliri et al., (2012), Lloret et al., (2014))	Species performance good
Total coliforms		27 x10^3		<1000 cfu/100ml	Contamination sources to be monitored to improve water quality.
E. coli		1 x10^3		<10 cfu/100ml	

Phytoplankton Shannon Index		2.101		H' ≥ 2.5 (Aura et al., 2021)	High diversity of phytoplankton hence the dam provides wide range of natural food for aquaculture
Phytoplankton Abundance (IndL^{-1})		258		300	
Zooplankton Shannon index		0.8444			
Zooplankton abundance (IndL^{-1})		157.5.			

Conclusion and recommendations

Utilization from the dam had been moderate with little harvesting done since restocking. The dam infrastructure is also poor with broken outlet that led to fish loss during flooding of the basin. There was high level of chlorophyl-a and low levels of dissolved oxygen which indicate utilization of oxygen for decomposition of phytoplankton bloom**.** The dam is dominated by *Oreochrom*is *leucosticus*, a rare indigenous species in Lake Victoria but of poor economic value. The poor condition factor of fish in this dam could be attribute to the low turbidity that hinder proper feeding and low oxygen recorded.

The following management actions are recommended for sustainable utilization of the stocked fish:

- Desilting of the dam should be prioritised, and dykes be built to control the dam outflow.
- Capacity building and sensitization on the nutritional and monetary benefits of fisheries and aquaculture
- Frequent monitoring of point and non-point sources of pollution to improve water quality and reduce excess nutrient load into the dam

3.1.6 Siaya County

1. Uranga Dam

Plate 18. Aerial View of Uranga Dam, Source: Google Earth®

The dam is found in Alego-Usonga sub-county, around GPS point, -0.0888, 34.2768, with a water depth of 3 m and muddy shoreline surrounded with macrophytes. Relatively clear water. Quite expansive, irregularly shaped water mass with multiple sheltered bays and a wide-open main body. Inflow through a permanent stream. Outflow through a controlled channel. Water is mainly used for local irrigation.

Table 14. Means and ranges of Socio-economics impact index, water quality physical and chemical variables and nutrient species measured at Uranga dam in Siaya county. (EL = Endline, BL = Baseline, mgL^{-1} = Milligram per litre, μScm^{-1} – Micro-Siemens per cm, μgL^{-1} = Microgram per litre, ppm = Parts per million, cfu = Colony forming unit).

Parameter	**Mean**		**Range**	**Discussion**	
	BL	**EL**	**EL**	**Reference value**	**Interpretation**
Socio-economics impact index	0.51	1.92	1-3	≤1.67 Moderate <2.33	Restocking had moderate impact on the community
Temp (ºC)	24.5	25.05	24.9-25.2	20-31 for fish adapted to higher temperatures, <20 for fish	All the physico-chemical parameters recorded during EL survey showed that the dam is suitable

				adapted to low temperatures	for aquaculture. D.O improved remarkably during the two periods to favourable concentration for aquaculture
DO (mgL^{-1})	2.59	5.59	5.19-5.99	5mgL^{-1} and above	
Cond(µScm^{-1})		194	192.3 -195.7		
TDS (mgL-^{1})		126.1	125.45-126.75		
Sal (ppm)		0.09	0.09-0.09		
pH	7.62	8.215	8.04-8.39	6-9	
ORP (mV)		$^{-1}$42.1	$^{-1}$67.7-$^{-1}$16.5		
Secchi(m)	0.6	0.45	0.4-0.5	0.35- 0.5 (Berveredge, 2004, Aura et al., 2021)	Clear water fevering primary production and fish farming
Nitrites (µgL^{-1})		2.94	2.03- 3.85	0.75-5mgL^{-1}	
Nitrates (µgL-1)		7.7	7.64- 7.76	0 – 40 mgL^{-1}	
Ammonium (µgL^{-1})	85.31 25	30	27.19- 32.81	0.06 ppm at pH 9 and temperature of 25 degrees to 160 ppm at pH 6 and temperature of 5oC	Reduced ammonium recorded during EL is withing recommended range hence good for aquaculture
TN (µgL-1)		97.58	88.11- 107.05	<15	Most of the nutrient species were within the recommended ranges that favours aquaculture while a few others such as total nitrogen was above the range
SRP (µgL^{-1})		7	3.67- 10.33	10-50 µgL^{-1}	
TP (µgL^{-1})		141.86	133.29- 150.43	0.3-0.5mgL^{-1}	
TN:TP	54.5	0.69	0.59- 0.80	<15	
Silicate(mgL-^{1})		15.97	15.80- 16.15	4–20 mgL^{-1}	
Alk (mgL-^{1})		76	74- 78		
Hard(mgL-^{1})		72	70- 74		
Chlorophyll a (µgL^{-1})		29.04	24.71- 33.38	>7.5 and <40 for Lake Victoria (Aura et al., 2021, Kashindye et al., 2015, Aura et al., 2016)	High primary productivity recorded in the dam hence suitable for aquaculture.
Fish condition (Relative condition factor of stocked *O. niloticus*)	-	1.87	0.8 -16.3	1.01±0.17 to 1.05±0.5 (Daliri et al., (2012), Lloret et al., (2014))	Species in very poor condition
Total coliforms		21 x10^{3}		<1000 cfu/100ml	Mitigate contamination from point and nonpoint sources to improve water quality.
E. coli	200 x10^{3}	3 x10^{3}		<10 cfu/100ml	
Phytoplankton Shannon Index	3.83	1.071		H' ≥ 2.5 (Aura et al., 2021)	Phytoplankton diversity and abundance reflect high suitability for
Phytoplankton Abundance (IndL^{-1})	191	5616		300	

Zooplankton Shannon Index	1.569	0.8882			aquaculture practices
Zooplankton Abundance (IndL^{-1})	56.7	61.7			

Conclusion and recommendations

Resource use conflicts among the community could have led to vandalism of dam infrastructure and unauthorised benefit from the fish by a few community members, hence the socioeconomic assessment registered moderate impact. The trophic state of the dam was eutrophic which was seen to favour the primary productivity. The dam was dominated by *Oreochrom*is *leucosticus* as opposed to the stocked *Oreochrom*is *niloticus.*

The management recommendations listed below aim at promoting the positive benefits from the fish stocks:

- Sensitization of the community on the project's benefits and resource use conflict mitigation is required to enhance cohesion.
- There is need for monitoring and controlling inflow of water from pollution zones to ensure reduced excess nutrient load that will ensure growth of diverse phytoplankton.
- There is need to restock the dam with *Oreochrom*is *niloticus* as it's of a higher economic value.

2. Adhiri Water Pan/Dam

Plate 19. Aerial View of Adhiri Dam, Source: Google Earth®

Adhiri WP is found in Ogango village, West Uyoma ward in Nyabera sub-location, West Uyoma location (Rarieda sub county). Its GPS location is -0.2956, 34.30406 at an altitude of 1182m. The reservoir relies on surface runoff making its water source unreliable with fluctuations observed depending on the season. The adjacent agricultural farmlands are characterised by black cotton soils.

Table 15. Means and ranges of Socio-economics impact index, water quality physical and chemical variables and nutrient species measured at Adhiri dam in Siaya county. (EL = Endline, BL = Baseline, mgL-¹ = Milligram per litre, µScm^{-1} – Micro-Siemens per cm, µgL^{-1} = Microgram per litre, ppm = Parts per million, cfu = Colony forming unit)

Parameter	Mean		Range	Discussion	
	BL	EL	EL	Reference value	Interpretation
Socio-economics impact index		2.58	1-3	≤2.34 High <3.00	Restocking improved the status of the community
Temp (ºC)		24.1	24.1-24.1	20-31 fish adapted to higher temperatures, <20 fish adapted to low temperatures	
DO (mgL^{-1})		3.11	3.11-3.11	5mgL^{-1} and above	
Cond (µScm^{-1})		97.3	97.3-97.3		
TDS (mgL-¹)		63.05	63.05-63.05		
Sal (ppm)		0.04	0.04-0.04		
pH		7.83	7.83-7.83	6-9	
ORP (mV)		-93.2	-93.2--93.2		
Secchi (m)		0.1	0-0.1	0.35- 0.5 (Berveredge, 2004, Aura et al., 2021)	The photic depth is much reduced due to high turbidity in the dam
Nitrites (µgL-1)		10.82	10.82- 10.82	0.75-5mgL^{-1}	All the nutrient species were withing the recommended range hence the dam favours aquaculture production apart from soluble reactive phosphorus which was above the limits. This could have occurred due to remineralization of phosphorus from the sediment since clay soil which characterized the area are good adsorbers of phosphorus
Nitrates (µgL-1)		15.33	15.33- 15.33	0 – 40 mgL^{-1}	
Ammonium (µgL^{-1})		80.31	80.31- 80.31	0.06 ppm at pH 9 and temperature of 25 degrees to 160 ppm at pH 6 and temperature of 5oC	
TN (µgL^{-1})		108.63	108.63-108.63		
SRP (µgL^{-1})		258.67	258.67-258.67	10-50 µgL^{-1}	
TP (µgL^{-1})		356.14	356.14-356.14	0.3-0.5mgL^{-1}	
TN:TP		0.31	0.31- 0.31	<15	
Silicate(mgL-¹)		20.39	20.39- 20.39	4–20 mgL^{-1}	
Alk (mgL-¹)		50.00	50- 50		
Hard (mgL-¹)		70.00	70- 70		
Chlorophyll a (µgL^{-1})		35.75	35.75- 35.75	>7.5 and <40 for Lake Victoria	Primary productivity fevered culture of fish

				(Aura et al., 2021, Kashindye et al., 2015, Aura et al., 2016)	and were within the recommended range
Fish condition (Relative condition factor of stocked *O. niloticus)*	-	1.00	0.01-1.24	1.01±0.17 to 1.05±0.5 (Daliri et al., (2012), Lloret et al., (2014))	Species performance good
Total coliforms		40 x10^3		<1000 cfu/100ml	Contamination sources to be monitored to improve water quality.
E. coli		2 x10^3		<10 cfu/100ml	
Phytoplankton Shannon Index		1.995		H’ ≥ 2.5 (Aura et al., 2021)	Can support fish farming however there was little diversity of primary producers recorded. The abundance of primary producers was also relatively low
Phytoplankton Abundance (IndL^{-1})		255		300	
Zooplankton Shannon Index		1.092			
Zooplankton Abundance (IndL^{-1})		978.7			

Conclusion and recommendations

Fish from the dam were harvested, sold, and the proceeds were utilized to pay labourers, security staff, and reinvest in fishery operations thus benefiting the users. The Fisheries department (specifically training and extension) and KCSAP (solar and two water pumps) respectively have both offered support. The dam also experiences abstraction pressure from the water pan due to dense population living in the area. This might have resulted to stirring of the water sediment leading to observed high turbidity, remineralization of soluble reactive phosphorus into the water colum and limited light penetration in the water colum leading to low diversity of phytoplankton.

Hence, we recommend the following management steps for better utilization of the stocked fish:

- Construction or designation of water abstraction point to avoid direct stirring of water by community and animals watering from the dam.
- Desilting to enhance water clarity hence primary productivity in the future
- Monitoring the water inflow points to reduce runoff from pollution zones

3. Nyandera Dam

Plate 20. Plate 19. Aerial View of Nyandera Dam, Source: Google Earth®

Nyandera dam is found in Bondo Sub County, Barchado sub location (North Sakwa ward) at GPS position -0.08282, 34.34674 at an altitude of 1258m. The dam waters appear greenish (algae) with reduced transparency. It is surrounded by a rocky-vegetated shoreline and forms an important watering point for livestock.

Table 16. Means and ranges o Socio-economics impact index, of water quality physical and chemical variables and nutrient species measured at Nyandera dam in Siaya county. (EL = Endline, BL = Baseline, mgL^{-1} = Milligram per litre, μScm^{-1} – Micro-Siemens per cm, μgL^{-1} = Microgram per litre, ppm = Parts per million, cfu = Colony forming unit)

Parameter	Mean		Range	Discussion	
	BL	EL	EL	Reference value	Interpretation
Socio-economics impact index		2.58	1-3	≤2.34 High <3.00	Restocking improved the status of the community
Temp (ºC)		28.75	27.4-30.1	20-31 fish adapted to higher temperatures , <20 fish adapted to low temperatures	All the physico-chemical parameters favoured aquaculture apart from D.O that recorded low values below the recommended range. This might have happened due to biological oxygen demand during decomposition of the algal bloom noticed in the dam.
DO (mgL^{-1})		3.99	3.91-4.07	$5mgL^{-1}$ and above	
Cond(μScm^{-1})		389.6	184.2-205.4		
TDS (mgL^{-1})		117.6	114.4 -120.8		
Sal (ppm)		0.085	0.08-0.09		
pH		7.5	7.21-7.79	6- 9	

ORP (mV)		-202.25	-205.1-^{1}99.4		
Secchi(m)		0.15	0.15-0.15	0.35- 0.5 (Berveredge, 2004, Aura et al., 2021)	Reduced photic zone due mineral turbidity
Nitrites (µgL-1)		7.79	5.67- 9.91	0.75-5mgL^{-1}	Most of the nutrient species were below the recommended value apart from silicates and SRP This may have occurred due to assimilation of this species into the algal biomass during the bloom of algal cells. Algae absorbs nutrients from the water Colum to aid in growth and multiplication
Nitrates (µgL-1)		11.27	9.91- 12.64	0 – 40 mgL^{-1}	
Ammonium (µgL^{-1})		119.06	102.19- 135.94	0.06 ppm at pH 9 and temperature of 25 degrees to 160 ppm at pH 6 and temperature of 5oC	
TN (µgL-1)		117.32	105.47- 129.16		
SRP (µgL^{-1})		150.33	33.67- 267	10-50 µgL^{-1}	
TP (µgL^{-1})		185.43	64.71- 306.14	0.3-0.5mgL^{-1}	
TN:TP		1.03	0.42 1.63	<15	
Silicate (mgL-^{1})		4.79	4.78- 4.81	4–20 mgL^{-1}	
Alk (mgL-^{1})		58.00	58- 58		
Hard (mgL-^{1})		53.00	52- 54		
Chlorophyll a (µgL^{-1})		84.92	83.45- 86.40	>7.5 and <40 for Lake Victoria (Aura et al., 2021, Kashindye et al., 2015, Aura et al., 2016)	High primary productivity observed hence the dam favours fish culture
Fish condition (Relative condition factor of stocked *O. niloticus)*	-	1.08	0.39-1.52	1.01±0.17 to 1.05±0.5 (Daliri et al., (2012), Lloret et al., (2014))	Species performance good
Total coliforms		32 x10^{3}		<1000 cfu/100ml	Contamination sources to be monitored to improve water quality.
E. coli		1 x10^{3}		<10 cfu/100ml	
Phytoplankton Shannon Index		1.672			High abundance of primary producers hence Suitable for aquaculture
Phytoplankton Abundance (indL^{-1})		1246		300	
Zooplankton Shannon Index		1.181			
Zooplankton Abundance (IndL^{-1})		1060.1			

Conclusion and recommendations

The community benefited from the stocked fish since the fish were harvested and sold for commercial gains of the beneficiaries. The community depended on the dam for multiple uses which include not only aquaculture but also, irrigation, water abstraction and water for domestic animals. A potential for sustainable fisheries in the dam was noted since crop and livestock keeping supplemented fish farming thus reducing the pressure of premature harvesting of the stock. The dam was eutrophic and stimulated proliferation of algal species hence taking up more oxygen during decomposition. Crop fields around the dam may be a direct input source of nutrient in the dam thus leading to excess growth of algae.

The following management actions are therefore recommended for enhanced community benefit from the stocked fish:

- The dam management is advised to fence the dam and designate a watering point for livestock.
- Drainage systems should be put in place to reduce the loading of nutrients from the surrounding agricultural farms into the dam

3.1.7 Busia County

1. Munana Dam

Plate 21. Aerial View of Munana Dam, Source: Google Earth®

Munana dam is found in Samia sub county, Bukhulungu sub-location (Nangina ward) at 0.262322, 34.09285. The dam waters looked clear with floating macrophytes dominated by water lilies.

Table 17. Means and ranges of Socio-economics impact index, water quality physical and chemical variables and nutrient species measured at Munana dam, Busia County (EL = Endline, BL = Baseline, mgL-^{1} = Milligram per litre, µScm^{-1} = Micro-Siemens per cm, µgL^{-1} = Microgram per litre, ppm = Parts per million, cfu = Colony forming unit).

Parameter	Mean	Range	Discussion

	BL	EL	EL	Reference value	Interpretation
Socio economics Status index	0.51	2.12	1-3	≤1.67 Moderate <2.33	Restocking had moderate impact on the community
Temp (ºC)	24.6	26.4	24.9-27.9	20-31 fish adapted to higher temperatures, <20 fish adapted to low temperatures (Mires (1995)	Parameters within ithin tolerable range for aquaculture with improved DO
DO (mgL^{-1})	3.81	6.325	5.87-6.78	5mgL^{-1} and above (Ross 2000)	
Cond(μScm^{-1})		380	376-384		
TDS (mgL^{-1})		240.825	237.25-244.4		
Sal (ppm)		0.175	0.17-0.18		
pH	7.49	8.13	8.09-8.17	6-9 (Ross 2000)	
ORP (mV)		-171	-218.6--123.4	300-400 (Honre & Goldman, 1994)	Low value an indication of lots of dead and decaying material in the water column that cannot be easily decomposed
Secchi(m)	0.8	1	1^{-1}	0.35- 0.5 (Berveredge, 2004, Aura et al., 2021)	Increased photic depth indicating reduced turbidity
Nitrites (µgL-1)		1.12	0.52- 1.73	0.75-5mgL^{-1}	Within tolerable range
Nitrates (µgL-1)		5.36	2.64- 2.73	0 – 40 mgL^{-1}	
Ammonium (μgL^{-1})	68.4375	48.13	36.56- 59.69	0.06 ppm at pH 9 and temperature of 25 degrees to 160 ppm at pH 6 and temperature of 5ºC	Increased ammonia possibly due to more stocked fish
TN (µgL-1)		84.16	78.63- 89.68		
TN:TP	11.0	0.80	0.74-0.87	<15	Nitrogen deficient in the water column while increased phosphorous leading

					eutrophic water column
SRP (µgL^{-1})		7.00	7.33- 8.67	10-50 µgL^{-1}	Within tolerable range for aquaculture
TP (µgL^{-1})		104.71	103.29-106.14	0.3-0.5mgL^{-1}	
Silicate (mgL-¹)		17.56	17.48- 17.63	4–20 mgL^{-1}	Low silicate level, a disadvantage to the growth of essential phytoplankton like diatoms. This in turn staggers fish growth.
Alk (mgL-¹)		124	124- 124		The high value indicates conversion of reduced and oxidized nitrogen species to ammonia which is toxic to fish
Hard (mgL-¹)		152.00	152- 152		
Chlorophyll a (µgL^{-1})		16.69	14.53^{-1}8.85		Values may reflect high primary productivity or an indication of cyanobacterial bloom
Fish condition (Relative condition factor of stocked *O. niloticus)*	-	1.07	0.84-1.22	1.01±0.17 to 1.05±0.5 (Daliri et al., (2012), Lloret et al., (2014))	Species performance good
Total coliforms		22 x10^{3}		<1000 cfu/100ml	Low counts of fecal coliforms. Contamination sources need monitoring to improve water quality.
E. coli	400 x10^{3}	1 x10^{3}		<10 cfu/100ml	
Zooplankton Shannon Index	1.332	0.8308			Poor abundance/low secondary production recorded may not naturally support aquaculture without supplemental feeding
Zooplankton abundance (IndL^{-1})	94.8	44.4			
Phytoplankton Abundance (IndL^{-1})	362.8	487		300	
Phytoplankton Shannon index	0.2231	2.909			

Conclusion and recommendations

The socioeconomic index of the dam was moderate perhaps due to poor perceptions on the dam's utilization and thus no harvesting had been done thus far. Whilst the lack of fishing gears may have contributed to this, there have been reports of drowning, presence of dangerous wildlife and flushing of fish during heavy rains/ dam overflow. The poor fish performance in this dam could be attributed to the ammonia levels possibly from animal waste and influx of nutrients from runoff coupled with the presence of inhibitive phytoplankton species like *Microsytis* spp.

We recommend the following:

- For profitable investment, farmers need to consider supplementary feeding to bridge the nutrition gap
- Repair of broken dam infrastructure to minimise loss of fish
- Fencing of the dam and awareness creation on safe practices on dam use
- Monitoring the water inflow points to reduce runoff from pollution zones.

2. Bumala B Dam

Plate 22. Aerial View of Bumala B Dam, Source: Google Earth®

Bumala B Dam is found in Butula sub-county, (Marachi east ward) at 0.378091, 34.35389 at an altitude of 1195m. The dam is supplied by an underground seepage and surface runoff and with an outlet. It is surrounded by dense vegetation/macrophytes with adjacent farmlands. The dam waters appear clear.

Table 18: Means and ranges of Socio-economics impact index, water quality physical and chemical variables and nutrient species measured at Bumala B Dam, Busia county (BL = Baseline, mgL^{-1} = Milligram per litre, μScm^{-1} = Micro-Siemens per cm, μgL^{-1} = Microgram per litre, ppm = Parts per million, cfu = Colony forming unit).

Parameter	Mean/Index		Range	Discussion	
	BL	EL	EL	Reference value	Interpretation

Socio economics Status index		2.28	1-3	≤1.67 Moderate <2.33	Restocking had moderate impact on the community
Temp (ºC)		26.55	26.5-26.6	20-31 for warm <20 fish adapted to low temperatures (Mires 1995)	Values recorded within tolerable range for optimal growth of fish
DO (mgL^{-1})		5.875	5.86-5.89	5 mgL^{-1} and above (Ross 2000)	
Cond(μScm^{-1})		99.85	96.1^{-1}03.6		
TDS ($mg L^{-1}$)		63.05	60.45-65.65		
pH		8.76	8.71-8.81	6-9 (Ross 2000)	
Secchi(m)		0.36	0.35-0.37	0.35- 0.5 (Berveredge, 2004, Aura et al., 2021)	Recorded Secchi depth will not allow the required light for photosynthesis to take place hence lack food for primary producers
Nitrites (µgL-1)		1.42	1.42- 1.42	0.75-5mgL^{-1}	Safe for fish
Nitrates (µgL-1)		9.52	3.24- 6.27	0 – 40 mgL^{-1}	
Ammonium (μgL^{-1})		52.81	45.31- 60.31	0.06 ppm at pH 9 and temperature of 25 degrees to 160 ppm at pH 6 and temperature of 5ºC	In the event the pH is alkaline ammonium changes to ammonia which is toxic to fish
TN (µgL-1)		107.84	105.47- 110.21	0.62- 0.76 mg^{-1}	
SRP (μgL^{-1})		30.33	20.33- 40.33	10-50 μgL^{-1}	Levels within tolerable limits
TP (μgL^{-1})		127.57	120.43- 134.71	0.3-0.5mgL^{-1}	
TN:TP		0.85	0.78- 0.92	<15	There is nitrogen deficiency in the water column hence autotrophs does not function well in the dam
Hard(mgL^{-1})		42.00	42- 42		
Chlorophyll a (μgL^{-1})		33.22	26.13- 40.31		Values may reflect high primary productivity or an indication of

					cyanobacterial bloom
Fish condition (Relative condition factor of stocked *O. niloticus)*	-	1.15	0.98-1.30	1.01±0.17 to 1.05±0.5 (Daliri et al., (2012), Lloret et al., (2014))	Species performance good
Total coliforms		25 x10^3		<1000 cfu/100ml	Presence of fecal coliforms indicating water contamination. Mitigate contamination from point and nonpoint sources to improve water quality.
E coli		9 x10^3		<10 cfu/100ml	
Phytoplankton Shannon Index		2.154		H’ ≥ 2.5 (Aura et al., 2021)	Poor abundance indicating limited natural food sources. There is also presence of phytoplankton species like Microcystis spp. inhibit growth of juvenile fish
Phytoplankton Abundance (IndL^{-1}) Zooplankton Shannon Index		888 0.916	300		
Zooplankton Abundance (IndL^{-1})		35.0			

Conclusion and recommendations

The community had not harvested fish since the dam's restocking: this could be attributed to a lack of fishing gear as well as the dominance of low-value fish species in the catch thereby limiting the desired exploitation. Other challenges include crop farming being the dominant economic activity, soil erosion from surface run-off resulting in sedimentation, dam land encroachment, and deforestation.

We recommend the following:

- Community sensitization on the aquaculture best practices and aquaculture business development
- Fencing of the dam to prevent encroachment
- Desilting the dam.

3.2 Central Kenya

3.2.1 Nyeri County

1. Kamangura Dam

Plate 23. Aerial View of Kamangura Dam, Source: Google Earth®

The dam is found in Nyeri County, Kieni East Sub-county within (Latitude, Longitude) -0.0646817, 37.03001. The dam is found in a semi-arid area with a highly turbid water mass. The dam was stocked/restocked with *Oreochromis niloticuss* around February 2021 with 33,000 fingerlings.

Table 19. Means and ranges of Socio-economics impact index, water quality physical and chemical variables and nutrient species measured at Kamangura dam in Nyeri County (EL = Endline, BL = Baseline, mgL^{-1} = Milligram per litre, μScm^{-1} = Micro-Siemens per cm, μgL^{-1} = Microgram per litre, ppm = Parts per million, cfu = Colony forming unit).

Parameter	**Mean**		**Range**	**Discussion**	
	BL	**EL**	**EL**	**Reference value**	**Interpretation**
Socio economics Status index		2.18	1-3	≤1.67 Moderate <2.33	Restocking had moderate impact to the community
Temp (ºC)		20	20-20	20-31 fish adapted to higher temperatures <20 fish adapted to low temperatures fish sarig (1969), Morgan (1992), and Mires, (1995)	Parameters recorded were within the range for fish growth

DO (mg L^{-1})				5mgL^{-1} and above (Ross, 2000)	
Cond(µScm^{-1})		291.3	291.3-291.3		
TDS (mg L^{-1})		210.5	210.5-210.5		
Sal (ppm)		0.16	0.16-0.16	0-0.2	
pH		6.4	6.4-6.4	6-9 (Ross, 2000)	
ORP (mV)		124.7	124.7-124.7	300-500 mV (Horne and Goldman,1994)	
Secchi(m)		0.1		0.35-0.5 (Berveredge, 2004, Aura et al., 2021)	Low Secchi an indication of enhanced turbidity due to high siltation
Nitrites (µgL^{-1})		2.33		0.75-5mg L^{-1}	
Nitrates (µgL^{-1})		14.76		0 – 40 mgL^{-1}	
Ammonium (µgL^{-1})		84.69		60 µgL-1at pH 9 and temperature of 25 oC L-Shafey (1998) (El - Shafey,1998)	The value recorded is above the reference value
TN (µgL^{-1})		182.32			
SRP (µgL^{-1})		85.33		10-50 µg L^{-1}	The value recorded is above the reference value
TP (µgL^{-1})		347.57		0.3-0.5mgL^{-1}	Range of values recorded for nutrient species favourable for growth of fish
TN:TP		0.52		<15	There was nitrogen deficient in the dam
Silicate(mgL-¹)		26.49		4–20 mg L^{-1}	Value recorded was above the reference point
Alk (mgL-¹)		54.00			
Hard(mgL-¹)		68.00			
Chlorophyll a (µgL^{-1})		36.04		7.5 - <40	
Fish condition (Relative condition factor of stocked *O. niloticus)*		1.31	0.59-3.17	1.01±0.17 to 1.05±0.5 (Daliri et al., (2012), Lloret et al., (2014))	Species performance good
Total Coliforms		29 x10^3		<1000 cfu/100ml	Water contamination mitigation measures to improve water quality.
E. coli		4 x10^3		<10 cfu/100ml	
Phytoplankton Shannon Index		2.33			Suitable for small fish farming but needs feed enhancement
Phytoplankton Abundance (IndL^{-1})		405		300	

Zooplankton Shannon Index		0.9469			
Zooplankton Abundance		27.1			

Conclusion and recommendations

Aquaculture operations have been hampered by several challenges, including crop farming dominance, lack of fishing equipment, and youth interest in the intervention. The dam has low natural productivity therefore not able to sustain optimal fish growth.

The following are recommended to improve utilization and management of the dam:

- There is need for supplementary feeding in the dam
- Provision of fishing gears and inclusion of youths in decision making for dam management through sensitization and training
- Fencing of the dam to limit animal defecation and controlled human water abstraction

2. Lusoi Dam

Plate 24. Aerial View of Lusoi Dam, Source: Google Earth®

Lusoi dam is found in Kieni East subcounty at an altitude of 1942 m around the GPS points (Latitude,Longitude), 027633, 37.05178. The appearance of the dam is milky from clay/ rock sediments. The water source is through underground seepage and runoff.

Table 20. Means and ranges of Socio-economics impact index, water quality physical and chemical variables and nutrient species measured at Luisoi dam in Nyeri County (EL = Endline, BL = Baseline, mgL^{-1} = Milligram per litre, μScm^{-1} – Micro-Siemens per cm, μgL^{-1} = Microgram per litre, ppm = Parts per million, cfu = Colony forming unit).

Parameter	**Mean**		**Range**	**Discussion**	
	BL	**EL**	**EL**	**Reference value**	**Interpretation**

Socio economics Status index		2.48	1-3	≤2.34 High <3.00	Restocking had an effect of socioeconomic enhancement to the community
Temp (⁰C)		21.7	21.7-21.7	20-31 for fish adapted to higher temperatures, <20 for fish adapted to low temperatures Mires, (1995	Normal temperature for fish growth
DO (mgL^{-1})				$5mgL^{-1}$ and above (Ross, 2000)	
Cond(μScm^{-1})		386.4	386.4-386.4		Falling within normal range but with enhanced alkalinity. Ranges are favourable for fish growth
TDS (mgL^{-1})		263.9	263.9-263.9		
Sal (ppm)		0.19	0.19-0.19	Range from 0-0.2ppm for freshwater	
pH		6.96	6.96-6.96	6-9 (Ross, 2000)	
ORP (mV)		97.9	97.9-97.9	300-500 mV (Horne and Goldman,1994)	Low value an indication of lots of dead and decaying material in the water column that cannot be easily decomposed
Secchi(m)		0.2	0.2-0.2	0.35- 0.5m (Berveredge, 2004, Aura et al., 2021)	Low Secchi an indication of enhanced turbidity due to high siltation
Nitrites (μgL^{-1})		7.182		$0.75\text{-}5mgL^{-1}$	Values recorded fall within tolerable ranges for growth of fish
Nitrates (μgL^{-1})		14.455		0 – 40 mgL^{-1}	
Ammonium (μgL^{-1})		29.063		0.06 ppm at pH 9 and temperature of 25^0C to 160 ppm at pH 6 and temperature of 5^0C	Elevated ammonium due to increased metabolism of higher fish biomass
TN (μgL^{-1})		114.947			Range of values recorded for nutrient species is favourable for growth of fish
SRP (μgL^{-1})		18.667		10-50 μgL^{-1}	
TP (μgL^{-1})		153.286		$0.3\text{-}0.5mgL^{-1}$	
TN:TP		0.75		<15	There is nitrogen deficiency which affects primary production
Silicate(mgL^{-1})		32.570		4–20 mgL^{-1}	The value recorded was above the

					reference point, this inturns enhances the growth of phytoplanktons like diatoms
Alk (mgL-¹)		170.000		20-200 ppm	
Hard(mgL-¹)		94.000			
Chlorophyll a (µgL^{-1})		24.73		7.5 - <40 (Aura et al., 2021, Kashindye et al., 2015, Aura et al., 2016)	High primary productivity. Favourable for aquaculture
Fish condition (Relative condition factor of stocked *O. niloticus)*		1.30	0.91-2.70	1.01±0.17 to 1.05±0.5 (Daliri et al., (2012), Lloret et al., (2014))	Species performance good
Total Coliforms		48 x10^3		<1000 cfu/100ml	Water contamination mitigation measures to improve water quality.
E. coli		25 x10^3		<10 cfu/ 100ml	
Phytoplankton Shannon Index		1.921			Suitable for aquaculture
Phytoplankton Abundance (IndL^{-1})		387		300	Improved plankton abundance from BL, suitable for aquaculture practices.
Zooplankton Shannon Index		1.725			
Zooplankton Abundance (Indiv.L^{-1})		12.7			

Conclusion and recommendations

The dam was harvested, and the proceeds were used to fund aquaculture operations and infrastructure, indicating its suitability and a moderate impact on the community. The occurrence of the diatoms, chlorophytes, euglenophytes and Zygenemetepheae are favourite prey to rotifer. They are indication of predation pressure from fish or macro-invertebrates in dams. Zooplankton diversity index and abundance indicate low secondary production thus not very conducive for sustainable fish production except through supplementary feeding.

The following are the recommendations from the findings:

- There is need for supplemental feeding in the dams
- Control of pathogens through fencing of the dams and excessive water abstraction
- There is a need to implement integrated fish farming
- It is necessary to implement integrated management practices around dams to reduce soil erosion.

3.2.2 Kirinyaga County

1. Kangai Dam

Plate 25. Aerial View of Kangai Dam, Source: Google Earth®

Kangai dam is found in Mwea west Subcounty at an altitude of 1184m with GPS point (Latitude, Longitude) -0.6401, 137.3000. Semi-arid region, Dam under rehabilitation, clay soil, physico-chemical parameters taken from the water source drainage, intense agricultural activities in the catchment including rice and horticultural farming, the dam water is also used for irrigation.

Table 21. Means and ranges of Socio-economics impact index, water quality physical and chemical variables and nutrient species measured at Kangai dam in Kirinyaga County (EL = Endline, BL = Baseline, mgL^{-1} = Milligram per litre, μ/cm^{-1} = Micro-Siemens per cm, μgL^{-1} = Microgram per litre, ppm = Parts per million, cfu = Colony forming unit).

Parameter	Mean		Range	Discussion	
	BL	EL	EL	Reference value	Interpretation
Socio economics Status index	0.55	2.88	1-3	≤2.34 High<3.00	Restocking had improved impact to the community
Temp (ºC)	20.9			20-31 fish adapted to higher temperatures, <20 fish adapted to low temperatures	

				fish sarig (1969), Morgan (1992), and Mires, (1995)	
DO (mgL^{-1})	6.7			5mgL^{-1} and above (Ross, 2000)	
Cond(µS/cm-1)		66.1	66.1-66.1		The value recorded for this parameter fall within tolerable ranges for fish growth
TDS (mgL^{-1})					
Sal (ppm)					
pH	7.3			6-9 (Ross, 2000)	
ORP (mV)		108.7	108.7^{-1}08.7	300-500 mV (Home and Goldman,1994)	Low value an indication of lots of dead and decaying material in the water column that cannot be easily decomposed
Secchi(m)		0.1		0.35-0.5 (Berveredge, 2004, Aura et al., 2021)	Low Secchi depth, an indication of enhanced turbidity due to high siltation rates
Nitrites (μgL^{-1})		1.88	1.73- 2.03	0.75-5mgL^{-1}	The values recorded are within the range for fish growth
Nitrates (μgL^{-1})		6.58		0 – 40 mgL^{-1}	
Ammonium (μgL^{-1})	87.1	32.50		0.06 ppm at pH 9 and temperature of 25 degrees to 160 ppm at pH 6 and temperature of 5^{0}C	Elevated ammonium due to increased metabolism of higher fish biomass
TN (μgL^{-1})		86.53		0.62-0.76 mgL^{-}	Values are within the optimal ranges. Suitable for aquaculture practices
SRP (μgL^{-1})		56.17		10-50 μgL^{-1}	
TP (μgL^{-1})		243.29		0.3-0.5mgL^{-1}	
TN:TP	1.9	0.36		<15	
Silicate(mgL-¹)		10.85		4–20 mgL^{-1}	
Alk (mgL-¹)		49.00			
Hard(mgL-¹)		55.00			
Chlorophyll a (μgL^{-1})		1.88		7.5 - <40 (Aura et al., 2021, Kashindye et al., 2015, Aura et al., 2016)	

Fish condition (Relative condition factor of stocked *O. niloticus)*		1.29	0.77-2.07	1.01±0.17 to 1.05±0.5 (Daliri et al., (2012), Lloret et al., (2014))	Species performance good
Total Coliforms		49 x10^3		<1000 cfu/100ml	Mitigate water contamination from point and non-point sources.
E. coli	70 x10^3	27 x10^3		<10 cfu/100ml	
Phytoplankton Shannon Index	1.346	2.183		H' ≥ 2.5 (Aura et al., 2021)	Suitable for aquaculture but needs feeds enhancement
Phytoplankton Abundance (IndL^{-1})	827	432		300	
Zooplankton Shannon Index		2.123			
Zooplankton Abundance (Indiv.l^{-1})		112.3			

Conclusion and recommendations

The dam had been harvested, and the proceeds reinvested in fisheries operations, crop/livestock operations, and asset purchases. Overall, phytoplankton species distribution and abundance in the study is influenced by various environmental factors such as water transparency and chlorophyll-a content. Fisheries production can be enhanced through supplementary feeding to boost the natural food.

The following management steps are recommended:

- Community sensitization on aquaculture be enhanced.
- More fingerlings should be provided for subsequent restocking
- Fencing of the dam to limit unauthorised access
- Controlled human water abstraction
- Monitoring the water inflow points to reduce runoff from pollution zones.

2. Karura Dam

Plate 26. Aerial View of Karura Dam, Source: Google Earth®

Karura dam is situated in Kirinyaga west Sub County with a GPS of – (Latitude, Longitude)06.3593, 37.1781. The g=has a dry climatic condition, densely populated, shrub vegetation in the catchment, closed basin with seasonal recharge from surface run-offs and spring water, highly turbid from algal biomass, fringing wetland vegetation cover.

Table 22. Means and ranges of Socio-economics impact index, water quality physical and chemical variables and nutrient species measured at Karura dam.in Kirinyaga County (EL = Endline, BL = Baseline, mg L^{-1} = Milligram per litre, μScm^{-1} – Micro- Siemens per cm, μgL^{-1} = Microgram per litre, ppm = Parts per million, cfu = Colony forming unit).

Parameter	Mean		Range	Discussion	
	BL	EL	EL	Reference value	Interpretation
Socio economics Status index	**0.520**	2.28	1-3	≤1.67 Moderate <2.33	Restocking had moderate impact to the community
Temp (ºC)	24.4			20-31 fish adapted to higher temperatures, <20 fish adapted to low temperatures fish(sarig (1969), Morgan (1992), and Mires, (1995)	

DO (mgL^{-1})	6.4			5mgL^{-1} and above (Ross, 2000)	
Cond(µScm^{-1})					
TDS (mgL^{-1})					
Sal (ppm)					
pH	7.4			6-9 (Ross, 2000)	
ORP (mV)				300-500 mV (Horne and Goldman,1994)	
Secchi(m)		0.1		0.35-0.5 (Berveredge, 2004, Aura et al., 2021)	Low Secchi depth observed, an indication of enhanced turbidity due to high siltation.
Nitrites (µgL^{-1})		2.33		0.75-5mgL^{-1}	Nutrient species within optimal ranges
Nitrates (µgL^{-1})		6.24		0 – 40 mgL^{-1}	
Ammonium (µgL^{-1})	18.6	32.19		0.06 ppm at pH 9 and temperature of 25 degrees to 160 ppm at pH 6 and temperature of 5^{0}C	Elevated ammonium due to increased metabolism of higher fish biomass
TN (µgL^{-1})		70.74			Nutrient species within optimal ranges
SRP (µgL^{-1}		28.67		10-50 µgL^{-1}	Low silicate level, a disadvantage to the growth of essential phytoplankton like diatoms. This in turn staggers fish growth.
TP (µgL^{-1})		163.29		0.3-0.5mgL^{-1}	
TN:TP	7.4	0.43		<15	
Silicate(mgL-^{1})		19.78		4–20 mgL^{-1}	
Alk (mgL-^{1})		50.00			Chemical attributes of the water indicate tolerable levels
Hard (mgL-^{1})		56.00			
Chlorophyll a (µgL^{-1})		80.97		>7.5 and <40 for Lake Victoria (Aura et al., 2021, Kashindye et al., 2015, Aura et al., 2016)	High primary productivity. Favourable for aquaculture

Fish condition (Relative condition factor of stocked *O. niloticus*)		0.92	0.51-1.61	1.01±0.17 to 1.05±0.5 (Daliri et al., (2012), Lloret et al., (2014))	Species performance good
Total Coliforms		32 x10^3		<1000 cfu/100ml	Mitigate water contamination from point and non-point sources.
E. coli	30 x10^3	5 x10^3		<10 cfu/100ml	
Phytoplankton Shannon Index	1.863	2.206		H' ≥ 2.5 (Aura et al., 2021)	Suitable for aquaculture
Phytoplankton Abundance (IndL^{-1})	152	270		300	Enough natural food was recorded hence the dam supports aquaculture. Potentially supports aquaculture practices because chlorophytes were abundant and acts as food for zooplankton
Zooplankton Shannon Index		1.092			
Zooplankton Abundance (Indiv.l^{-1})		5.0			Low record of zooplankton abundance which is an indication of poor secondary productivity.

Conclusion and recommendations

There is little fishing activity in the dam, which translates to moderate impact to the community. This was primarily due to a lack of fishing equipment and technical knowledge. The dam is suitable for aquaculture with diversity and abundance of phytoplankton which acts as food for fish. Primary and secondary productivity was high suggesting that there is enough food for other aquatic organisms. The dam has no limiting nutrient type hence can support a diverse range of algae to sustain fish farming.

The following are recommended to boost utilization and management of the dam:

- Sensitization of the community on the benefits of fish farming and management practice
- Increased funding to aid in the acquisition of fishing equipment.
- Fencing of the dam to limit trespass
- Monitoring the water inflow points to reduce runoff from pollution zones.

3.2.3 Meru County

1. Kiambogo Dam

Plate 27. Aerial View of Kiambogo Dam, Source: Google Earth®

Kiambogo dam is found in, Kwene Sub- County at an altitude 1383m and (Latitude and Longitude) -0.0848426, 37.6806498. The dam is found within an abandoned quarry and within an agricultural area. The source of water is through underground seepage and surface run-offs.

Table 23. Means and ranges of Socio-economics impact index, water quality physical and chemical variables and nutrient species measured at Kiambogo dam in Meru County (EL = Endline, BL = Baseline, mgL^{-1} = Milligram per litre, μScm^{-1} = Micro-Siemens per cm, μgL^{-1} = Microgram per litre, ppm = Parts per million, cfu = Colony forming unit).

Parameter	**Mean**		**Range**		
	BL	**EL**	**EL**	**Reference value**	**Interpretation**
Socio economics Status index		**2.23**	**1-3**	≤1.67 moderate <2.33	Restocking had moderate impact to the community
Temp (ºC)		27.2	27.2-27.2	20-31 fish adapted to higher temperatures, <20 fish adapted to low temperatures (sarig (1969), Morgan (1992), and Mires, (1995)	The temperature recorded was within the favourable range for fish growth

DO (mgL^{-1})				5mg**L**$^{-1}$and above (Ross, 2000)	
Cond(μScm^{-1})		386.4	386.4-386.4	200-1000μScm^{-1} (Horne and Goldman,1994)	Values recorded for these parameters fall within tolerable ranges for fish growth
TDS (mgL^{-1})		240.5	240.5-240.5		
Sal (ppm)		0.18	0.18-0.18	0.02-0.2	
pH		6.05	6.05-6.05	6-9 (Ross, 2000)	
ORP (mV)				300-500 mV (Horne and Goldman,1994)	
Secchi(m)		0.1		0.35-0.5 (Berveredge, 2004, Aura et al., 2021)	Low Secchi depth an indication of enhanced turbidity due to high siltation rates
Nitrites (µgL-1)		0.52	0.52- 0.52	0.75-5mg**L**$^{-1}$	Values recorded for these parameters fall within tolerable ranges for fish growth
Nitrates (µgL-1)		2.33	2.33- 2.33	0 – 40 mg**L**$^{-1}$	
Ammonium (μgL^{-1})		24.06	24.06- 24.06	60 μgL^{-1} at pH 9and temperature of 25^{0}C	Value recorded was within the recommended range
TN (µgL-1)		67.58			Range of values recorded for nutrient species is favourable for growth of fish
SRP (μgL^{-1})		13.67		10-50 μgL^{-1}	
TP (μgL^{-1})		40.43		0.3-0.5mgL^{-1}	
TN:TP		1.67		<15	
Silicate(mgL^{-1})		31.49		4–20 mgL^{-1}	High levels of silicate is essential for the growth of diatoms which in turn helps in fish growth.
Alk (mgL^{-1})		42.00			The values recorded are tolerable to fish growth.
Hard(mgL^{-1})		162.00			
Chlorophyll a (μgL^{-1})		16.03		>7.5 and <40 for Lake Victoria (Aura et al., 2021, Kashindye et al., 2015, Aura et al., 2016)	Moderate primary productivity favourable for fish
Fish condition (Relative condition factor of stocked *O. niloticus*)		1.11	0.11-2.19	1.01±0.17 to 1.05±0.5 (Daliri et al., (2012),	Species performance good

				Lloret et al., (2014))	
Total Coliforms		16 x10^3		<1000 cfu/100ml	Water quality suitable for aquaculture with continued monitoring interventions.
E. coli		0	0	<10 cfu/100ml	
Phytoplankton Shannon Index		1.312		H' ≥ 2.5 (Aura et al., 2021)	Suitable for aquaculture, most of species like *Aulacoseira* species. are food for fish
Phytoplankton Abundance (IndL^{-1})		3725		300	Abundance natural food was recorded an indication of aquaculture viability in the dam.
Zooplankton Shannon Index		N/A			
Zooplankton Abundance (Indiv.l^{-1})		N/A			

Conclusion and recommendations

The growth performance of the stocked fish in this dam was good although the community had not harvested fish due to factors such as preoccupation with crop farming, lack of technical support since restocking, and lack of a proper fishing gear and an existing deterrence from fishing until the fisheries department grants permission. The dam's seasonality was identified as a significant challenge. The dam has a high diversity of primary producers which are potential sources of fish food in the natural environment.

The following are recommended following the observations during the assessment:

- Sensitization of the community to the importance of aquaculture as an alternative source of food and income.
- Extension services should be provided by the appropriate authorities.
- Defining regular fishing for the benefit of the locals.
- Provision of fishing equipment
- Advanced construction techniques to ensure that the dam can store water for an extended period.

2. Nguthiru elain'go Dam

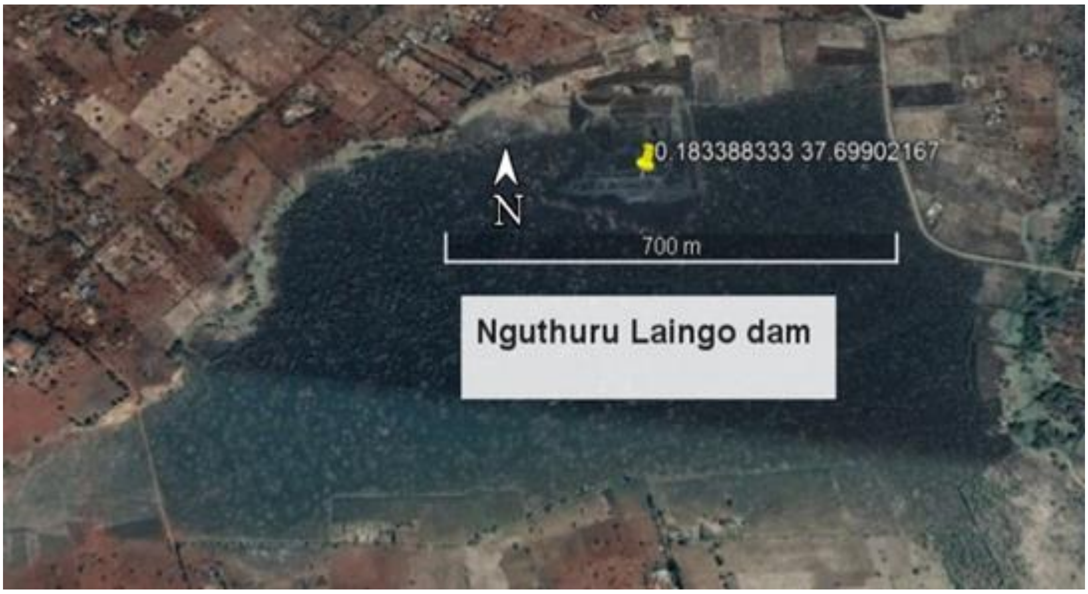

Plate 28. Aerial View of Nguthiru elain'go Dam, Source: Google Earth®

Nguthiru elaing'o dam is found in Imenti South Subcounty at an altitude of 1342m around GPS point 0.1833, 37.6990 in a semi-arid area. The climate is semi-arid, characterized by acacia trees, black clay soil, limited agricultural activities, plain landscape, open basin with river recharge and discharge, new dam (1 year old), stocked with about 50 *C. gariepinus* borrowed from a farmer.

Table 24. Means and ranges of Socio-economics impact index, water quality physical and chemical variables and nutrient species measured at Nguthiru elain'go dam in Meru County (EL = Endline, BL = Baseline, mgL^{-1} = Milligram per litre, μScm^{-1} – Micro-Siemens per cm, μgL^{-1} = Microgram per litre, ppm = Parts per million, cfu = Colony forming unit).

Parameters	**Mean**		**Range**	**Discussion**	
	BL	**EL**	**EL**	**Reference value**	**Interpretation**
Socio-economics impact index	0.53	2.33	1-3	≤1.67Moderate <2.33	Restocking had moderate impact to the community
Temp (ºC)	22.3	24.3	24.3-24.3	20-31 fish adapted to higher temperatures, <20 fish adapted to low temperatures (sarig (1969), Morgan (1992), and Mires, (1995)	
DO (mg L^{-1})	7.2			5mgL^{-1} and above (Ross, 2000)	
Cond (μScm^{-1})		386.5	386.5-386.5	200-1000μScm^{-1} (Horne and Goldman,1994)	Values recorded for these parameters fall within tolerable ranges for fish growth
TDS (mg L^{-1})		254.8	254.8-254.8		
Sal (ppm)		0.19	0.19-0.19	0.02-0.2	

pH	8.6	6.35	6.35-6.35	6-9 (Ross, 2000)	
ORP (mV)		87.3	87.3-87.3	300-500 mV (Horne and Goldman,1994)	
Secchi(m)		0.38	0.38-0.38	0.35-0.5 (Berveredge, 2004, Aura et al., 2021)	
Nitrites (µgL-1)		3.85	3.85- 3.85	0.75-5mgL^{-1}	Low values of nutrient recorded which is suitable for fish in water
Nitrates (µgL-1)		7.76	7.76- 7.76	0 – 40 mg L^{-1}	
Ammonium (µgL^{-1})	33.6	26.56	26.56-26.56	60 µgL^{-1} at pH 9and temperature of 25^{0}C	Value recorded was within the recommended ran
TN (µgL-1)		72.32		0.62-0.76 mgL^{-1}	The values recorded are tolerable to fish growth
SRP (µgL^{-1})		5.33		10-50 µgL^{-1}	
TP (µgL^{-1})		69.00		0.3-0.5mg L^{-1}	
TN:TP	43.6	1.05		<15	
Silicate (mgL-¹)		36.17		4–20 mgL^{-1}	High levels of silicate is essential for the growth of diatoms which in turn helps in fish growth.
Alk (mgL-¹)		28.00			The values recorded are tolerable to fish growth.
Hard (mgL-¹)		334.00			
Chlorophyll a (µgL^{-1})		55.47		>7.5 and <40 for Lake Victoria (Aura et al., 2021, Kashindye et al., 2015, Aura et al., 2016)	High primary productivity. Favourable for aquaculture
Fish condition (Relative condition factor of stocked *O. niloticus)*		2.21	0.95-4.81	1.01±0.17 to 1.05±0.5 (Daliri et al., (2012), Lloret et al., (2014))	Species performed well
Total Coliforms	20 x10^{3}	19 x10^{3}		<1000 cfu/100ml	Water quality suitable for aquaculture with continued monitoring interventions.
E. coli		0		<10 cfu/100ml	
Phytoplankton Shannon Index	2.344	1.083		H' ≥ 2.5 (Aura et al., 2021)	Water Quality is favourable for aquaculture since most species like *Fragillaria* spp. are food for fish
Phytoplankton Abundance (IndL^{-1})	198	11657		300	Enough natural food was recorded hence the dam supports aquaculture. Potentially supports aquaculture practices because chlorophytes were
Zooplankton Shannon Index	1.3	2.048			
Zooplankton Abundance (Indiv.l^{-1})	247.6	118.9			

					abundant and acts as food for zooplankton

Conclusion and recommendations

Due to lack of fishing equipment, the community had not harvested fish hence registering a moderate impact to the community. The phytoplankton community in the littoral and towards the open are attributed to dominance of diatoms which are relatively photosynthetic and have capacity to thrive towards the open of the dam. It was noted that Macrophytes plays an important role since some species like *Fragilaria intermedia* tend to thrive hence they act as food for aquatic organisms.

The following measures are recommended in order to enhance the use of the dam:

- Provision of fishing equipment, such as boats and fishing nets.
- Sensitization of the community on the importance of aquaculture.
- Extension services should be provided by the appropriate authorities.
- Relevant stakeholders to reduce some macrophytes for primary productivity to occur.

3.2.4 Embu County

1. Ithatha Dam

Plate 29. Aerial View of Ithatha Dam, Source: Google Earth®

Ithatha dam is found around (Latitude, Longitude)-0.4881, 37.6190 at an altitude of 1236.9 m. The dam is heavily infested with both submerged and emergent Macrophytes. The shores of the dam are surrounded by macrophytes, mostly *Typha species*, with agricultural farms surrounding the dam. There's the risk of erosion and contamination through use of pesticides and herbicides. There was a high bird population during the study and the dam was generally shallow.

Table 25. Means and ranges of Socio-economics impact index, water quality physical and chemical variables and nutrient species measured at Ithatha dam, Embu County (EL =

Endline, BL = Baseline, mgL^{-1} = Milligram per litre, μScm^{-1} = Micro-Siemens per cm, μgL^{-1} = Microgram per litre, ppm = Parts per million, cfu = Colony forming unit)

Parameter	Mean		Range	Discussion	
	BL	**EL**	**EL**	**Reference value**	**Interpretation**
Socio-economics impact index	0.47	2.28	1-3	Moderate ≥1.67 Moderate <2.33	Restocking had moderate impact to the community
Temp (ºC)	23.7	25.45	22.6-29	20-31 fish adapted to higher temperatures, <20 fish adapted to low temperatures (Mires, 1995)	The values recorded were within recommended ranges fouvarable for fish farming
DO (mgL^{-1})	4.81	4.18	2.41-6.23	$5mgL^{-1}$ and above (Ross, 2000)	
Cond (μScm^{-1})		667.66	651.1-687.4	$200\text{-}1000\mu Scm^{-1}$ (Horne and Goldman,1994)	
TDS (mgL^{-1})		58.40	55.9-60.45		The values recorded were within the parameters recommended ranges fouvarable for fish farming
Sal (ppm)		0.04	0.04-0.04		
pH	7.6	8.38	7.81-8.52	6-9 (Ross, 2000)	
ORP (mV)		9.45	15.9-30.2	300-500 mV (Horne and Goldman,1994)	
Secchi (m)	0.3	0.37	0.37-0.38	0.35-0.5 (Berveredge, 2004, Aura et al., 2021)	
Nitrites (µgL-1)		7.28	6.27- 8.39	$0.75\text{-}5mgL^{-1}$	
Nitrates (µgL-1)		11.32	9.30- 12.64	0 – 40 mgL^{-1}	
Ammonium (μgL^{-1})	30.9	23.02	7.19- 35.94	60 µgL-1at pH 9 and temperature of 25^0C	Elevated ammonium due to increased metabolism of higher fish biomass
TN (µgL-1)		86.00	78.63- 96	0.62-0.76 mgL^{-1}	Values recorded are within the optimal ranges. Suitable for aquaculture practices
SRP (μgL^{-1})		12.56	8.67- 15.33	10-50 μgL^{-1}	
TN:TP	239.6	1.65	1.45- 1.9	<15	
TP (μgL^{-1})		52.33	49- 57.57	0.3-0.5mg L^{-1}	
Silicate (mgL-¹)		23.60	23.27- 23.91	4–20 mgL^{-1}	
Alk (mgL-¹)		34.00	30- 40		
Hard (mgL-¹)		19.33	18- 22		
Chlorophyll a (μgL^{-1})		8.31	4.64- 13.34	>7.5 and <40 for Lake Victoria (Aura et al., 2021,	High primary productivity.

				Kashindye et al., 2015, Aura et al., 2016)	Favourable for growth of fish
Fish condition (Relative condition factor of stocked *O. niloticus)*	2.7	0.02	0.01-0.1	1.01±0.17 to 1.05±0.5 (Daliri et al., (2012), Lloret et al., (2014))	Stocked species performed lowly under natural growth; supplemental feeding recommended.
Total Coliforms		49 x10^3		<1000 cfu/100ml	Mitigate water contamination from point and non-point sources to improve water quality.
E. coli	40 x10^3	27 x10^3		<10 cfu/100ml	
Phytoplankton Shannon Index	4.609	1.81		H' ≥ 2.5 (Aura et al., 2021)	Suitable for aquaculture activities
Phytoplankton Abundance (IndL^{-1})	301	251		300	Improved plankton abundance favourable for aquaculture
Zooplankton Shannon Index	1.150	1.237			
Zooplankton Abundance (Indiv.l^{-1})	294.3	11.1			

Conclusion and recommendations

The prevalence of crop farming in the region led to poor inception of aquaculture thus the moderate socio-performance indicated. There was a lack of fish farming inputs like fishing gears combined with limited access to training and extension services. Ithatha dam is eutrophic, suggestive of the fact that it is highly productive and can support aquaculture. The phytoplankton abundance and diversity were equally high which can reliably support primary productivity of the dam.

The following measures are recommended:

- Community sensitization and awareness creation on aquaculture development as an alternative source of income
- Training on fish management/aquaculture best practices and provision of basic fish farming inputs
- Fencing of the dam to enhance security
- Monitoring the water inflow points to reduce runoff from pollution zones.
- Cleaning and dredging of the dam are recommended to enable fish recruitment, growth and the surrounding community to make proper use of the water since there is very heavy agricultural activity involving irrigation of the farms from the dam.

2. Masinga Dam

Plate 30. Aerial View of Masinga Dam, Source: Google Earth®

Masinga dam is found in Mbere South subcounty at (Latitude, Longitude) -0.8496, 37.3999 at an altitude of 1055.9 m. The climate is semi-arid with patches of thick forest cover which were planted by TARDA. The dam's water was clear. This is the biggest and most productive among the Seven Fork dams. The dam harbors dangerous aquatic wildlife like the crocodiles and hippopotamuses.

Table 26. Means and ranges of Socio economics Status index, water quality physical and chemical variables and nutrient species measured at Masinga dam in Embu county (EL = Endline, BL = Baseline, mgL^{-1} = Milligram per litre, μScm^{-1}= Micro-Siemens per cm, μgL^{-1} = Microgram per litre, ppm = Parts per million, cfu = Colony forming units).

Parameter	**Mean**		**Range**	**Discussion**	
	BL	**EL**	**EL**	**Reference value**	**Interpretation**
Socio economics Status index	0.52	2.37	1-3	≤2.34 High <3.00	Restocking improved social index of the community
Temp (ºC)	25.8	28.58	26.7-30.2	20-31 fish adapted to higher temperatures, <20 fish adapted to low temperatures (Mires, 1995)	The values recorded were within recommended ranges favourable for fish farming
DO ($mg L^{-1}$)	5.7	5.65	4.83-6.41	$5mgL^{-1}$ and above (Ross, 2000)	
Cond (μScm^{-1})		668.86	668.8-668.9		
TDS ($mg L^{-1}$)		110.38	107.9-114.4		
Sal (ppm)		0.08	0.08-0.08		
pH	8.5	8.87	8.72-9	6-9 (Ross, 2000)	
ORP (mV)		102.39	12.9-209.2	300-500 mV (Horne and Goldman,1994)	

Secchi (m)	0.7	0.10	0.1-0.1	0.35-0.5 (Berveredge,2004, Aura et al., 2021)	Low Secchi depth an indication of enhanced turbidity due to high siltation
Nitrites (μgL^{-1})		13.34	12.94-13.55	0.75-5mgL^{-1}	Values recorded fall within tolerable ranges for growth of fish
Nitrates (µgL-1)		18.90	15.97-22.03	0 – 40 mgL^{-1}	
Ammonium (μgL^{-1})	38.4	25.10	20.94-28.44	60 µgL-1at pH 9 and temperature of 25 oC L-Shafey (1998)	Elevated ammonium due to increased metabolism of higher fish biomass
TN (µgL-1)		133.37	107.05- 156	0.62-0.76 mgL^{-1}	Range of values recorded for nutrient species is favourable for growth of fish
SRP (μgL^{-1})		29.78	27- 33.67	10-50 μgL^{-1}	
TP (μgL^{-1})		76.62	30.43-113.29	0.3-0.5mgL^{-1}	
TN:TP	57.7	2.42	0.94- 4.50	<15	
Silicate(mgL^{-1})		18.68	18.59-18.82	4–20 mgL^{-1}	
Alk (mgL^{-1})		50.00	48- 52		
Hard(mgL^{-1})		70.00	66- 76		
Chlorophyll a (μgL^{-1})		20.88	15.66-27.76	>7.5 and <40 for Lake Victoria (Aura et al., 2021, Kashindye et al., 2015, Aura et al., 2016	High primary productivity. Favourable for aquaculture
Fish condition (Relative condition factor of stocked *O. niloticus)*	3.16-	-	-	1.01±0.17 to 1.05±0.5 (Daliri et al., (2012), Lloret et al., (2014))	*O. niloticus* was not reported in the catch
Total Coliforms		32 x10^3		<1000 cfu/100ml	Mitigate water contamination from point and non-point sources.
E. coli	80 x10^3	5 x10^3		<10 cfu/100ml	
Phytoplankton Shannon Index	4.397	2.967		H' ≥ 2.5 (Aura et al., 2021)	Suitable for aquaculture activities
Phytoplankton Abundance ($IndL^{-1}$)	214	667		300	Improved plankton abundance favourable for aquaculture
Zooplankton Shannon Index	0.9982	1.078			
Zooplankton Abundance ($Indiv.l^{-1}$)	186.3	256.3			

Conclusion and recommendations

The water level was significantly lower than it was during the baseline survey. There were no macrophytes present. There was a lot of irrigation all around the dam. The community makes extensive use of the resources by harvesting on a regular basis, which has since been used to cover household expenses such as food, medical, and school fees, among other things. Phytoplankton community structure populations were supported by the well-established primary productivity and conducive waters. The good biological productivity is attributed to support the fisheries without supplementary feeding. The dam is suitable for aquaculture and other Integrated Resource Management approaches

The following are recommended to improve the dam utilization:

- Provide more fingerlings for subsequent restocking to increase production.
- Incorporate integrated management to incorporate other resource uses and reduce potential conflicts.
- Monitoring the water inflow points to reduce runoff from pollution zones.

3.2.5 Tharaka-Nithi

1. Kaiboshe

Plate 31. Aerial View of Kaiboshe Dam, Source: Google Earth®

The dam is found in Tharaka Nithi County in Chiakariga Sub- County at -0.2915195, 37.9241938. It lies in a semi-arid area with shrub vegetation and small-scale agricultural activities taking place around the dam.

Table 27. Means and ranges of Socio economics Status index , water quality physical and chemical variables and nutrient species measured at Kaiboche dam, Tharaka Nithi county (EL =Endline, BL = Baseline, mgL^{-1} = Milligram per litre, μScm^{-1} = Micro-Siemens per cm, μgL^{-1} = Microgram per litre, ppm = Parts per million, cfu = Colony forming unit).

Parameter	Mean		Range	Discussion	
	BL	EL	EL	Reference value	Interpretation
Socio economics Status index		2.13	1-3	≤1.67 Moderate <2.33	Restocking had moderate impact to the community
Secchi(m)		0.1	0.1-0.1	0.35- 0.5 (Berveredge, 2004, Aura et al., 2021)	
Nitrites (µgL-1)		5.97		0.75-5mgL^{-1}	
Nitrates (µgL-1)		9.58		0 – 40 mgL^{-1}	
Ammonium (µgL^{-1})		21.56		0.06 ppm at pH 9 and temperature of 25^{o}C	
TN (µgL-1)		77.05			
SRP (µgL^{-1})		88.67		10-50 µgL^{-1}	Values above optimal ranges for aquaculture production
TP (µgL^{-1})		456.14		0.3-0.5mgL^{-1}	
TN:TP					
Silicate(mgL-^{1})		10.33		4–20 mgL^{-1}	
Alk (mgL-^{1})		68.00			
Hard(mgL-^{1})		64.00			
Chlorophyll a (µgL^{-1})		5.97		>7.5 and <40 for Lake Victoria (Aura et al., 2021, Kashindye et al., 2015, Aura et al., 2016)	Adequate primary productivity
Fish condition (Relative condition factor of stocked *O. niloticus)*		1.22	0.76-2.93	1.01±0.17 to 1.05±0.5 (Daliri et al., (2012), Lloret et al., (2014))	*Fish* Species performance good
Total Coliforms		28 x10^{3}		<100 cfu/100ml	Water contamination mitigation measures to improve water quality
E. Coli		7 x10^{3}		<1 cfu/100ml	
Phytoplankton Shannon Index		2.209		H’ ≥ 2.5 (Aura et al., 2021)	Primary productivity favourable for aquaculture
Phytoplankton Abundance (IndL^{-1})		293		300	
Zooplankton Shannon Index		1.481			

Zooplankton Abundance (Indiv.l^{-1})		60.6			

Conclusion and recommendations

The performance of the stocked *O. niloticus* was very good despite a moderate social index recorded for the dam. This is partly attributed to the preoculation with crop farming while the lack of fishing gears and limited access to extension services may have derailed the desired exploitation of available fisheries resources. The dam is favourable for aquaculture activities with an abundance of natural food sources like *Synedra cunningtonii* and *Surillella* spp. Notable high turbidity associated with siltation and algal growth.

Below are the recommendations for sustainable aquaculture and community development of the dam:

- Awareness creation and sensitization on aquaculture commercialization for community empowerment and diversification of income sources.
- Provide fish farming inputs like fishing gears and other harvesting equipment.
- Desilting the dam.
- Monitoring the water inflow points to reduce runoff from pollution zones.

2. Ndetha Dam

Plate 32. Aerial View of Ndetha Dam, Source: Google Earth®

Ndetha dam is a water pan for livestock located at around GPS reading 0.3450, 34. 8388 at an altitude of 747.6 m. The area is semi-arid with shrub vegetation in the catchment, most water comes from seasonal recharge and discharge from surface run-offs. The run-off comes with heavy nutrient loading making the dam highly turbid due to proliferation of algae/primary production

Table 28. Means and ranges of Socio economics Status index, water quality physical and chemical variables and nutrient species measured at Ndetha dam in Thraka-Nithi County (EL = Endline, BL = Baseline, mgL^{-1} = Milligram per litre, μScm^{-1} – Micro-Siemens per cm, μgL^{-1} = Microgram per litre, ppm = Parts per million, cfu = Colony forming unit).

Parameter	**Mean**		**Range**	**Discussion**	
	BL	**EL**	**EL**	**Reference value**	**Interpretation**
Socio economics Status index	0.47	2.30	1-3	≤1.67 Moderate <2.33	Restocking had moderate impact to the community
Temp (°C)	29.4				
DO (mgL^{-1})	5.2				
Cond(μScm^{-1})					
TDS (mgL^{-1})					
Sal (ppm)					
pH	8.7				
Secchi(m)	0.4	0.4	0.4-0.4	0.35- 0.5 (Berveredge, 2004, Aura et al., 2021)	Secchi depth levels within acceptable range
Nitrites (µgL-1)		1.42		0.75-5mgL^{-1}	Parameter values safe for fish
Nitrates (µgL-1)		2.33		0 – 40 mgL^{-1}	
Ammonium (μgL^{-1})	40.0	20.94		0.06 ppm at pH 9 and temperature of 25^{0}C	Decrease ammoniam levels from BL
TN (µgL-1)		54.95			
SRP (μgL^{-1})		25.33		10-50 μgL^{-1}	Values within optimal ranges for aquaculture practices
TP (μgL^{-1})		96.14		0.3-0.5mgL^{-1}	
TN:TP		0.57		<15	
Silicate(mgL^{-1})		36.06		4–20 mgL^{-1}	High silicate levels favourable for growth of diatoms
Alk (mgL^{-1})		42.00			
Hard (mgL^{-1})		294.00			
Chlorophyll a (μgL^{-1})		95.47		>7.5 and <40 for Lake Victoria (Aura et al., 2021, Kashindye et al., 2015, Aura et al., 2016)	High primary productivity. Favourable for aquaculture
Fish condition (Relative condition factor of stocked *O. niloticus)*		2.13	1.48-3.56	1.01±0.17 to 1.05±0.5 (Daliri et al., (2012), Lloret et al., (2014))	*Oreochromis niloticus* performing very well.

(Relative condition factor of stocked *O. niloticus*)					
Total Coliforms		64 x10^3		<1000 cfu/100ml	Water contamination mitigation measures to improve water quality.
E. coli	140 x10^3	41 x10^3		<10 cfu/100ml	
Phytoplankton Shannon Index	4.071	1.921			Not suitable for aquacture (Presence of micro inhbitive species like Microcystis and *M erismopedia* spp known to inhibit growth of fish
Phytoplanktons Abundance (IndL^{-1})	467	1501		300	
Zooplankton Shannon Index	1.495	0.9393			
Zooplankton Abundance (Indiv.l^{-1})	81.1	123.1			

Conclusion and recommendations

Socioeconomic impact for restocking for fisheries and aquaculture within the dam had been moderate. Aquaculture operations have faced some challenges including: a lack of basic fishing inputs/equipment, and limited access to training and extension services as per the socio-performance index. The availability of natural food sources was low which makes it necessary to consider supplementary feeding for good fish growth, and sustainable fish production. The poor zooplankton abundance was indicative low or moderate secondary production.

We recommend the following measures aimed towards enhancing the benefits of the stocked fish to the communities:

- Awareness creation and community sensitization on aquaculture development and aquaculture best practices.
- Provision of fish farming inputs/fishing equipment.
- The dam should be desilted.
- Monitoring the water inflow points to reduce runoff from pollution zones.

3.2.6 Kiambu County

1.Rungiri

Plate 33. Google Earth Image of Rungiri Dam, Kiambu County

Located around GPS point, -1.24258, 36.67017, sitting at an altitude of 1981.5 m a.s.l. the dam came about after the construction company was fetching raw materials finished and it was filled by runoff The catchment has some agricultural activities, fringing macrophytes and with very clear waters

Table 29. Means and ranges of Socio-economics impact index, water quality physical and chemical variables and nutrient species measured at Rungiri dam, Kiambu county (EL = Endline, BL = Baseline, mgL^{-1} = Milligram per litre, μScm^{-1} – Micro-Siemens per cm, μgL^{-1} = Microgram per litre, ppm = Parts per million, cfu = Colony forming unit).

Parameter	**Mean**		**Range**	**Conclusion**	
	BL	**EL**	**EL**	**Reference value**	**Interpretation**
Socio economics Status index	0.51	2.33	1-3	≤1.67 Moderate <2.33	Restocking had moderate impact on the community
Temp (ºC)	20.8	24.07	23.3-25.6	20-31 for fish adapted to higher temperatures, <20 for fish adapted to low	The values recorded fall within tolerable ranges for fish growth

				temperatures. Mires (1995)	
DO (mgL^{-1})	7.6	7.82	7.78-7.84	5mg L^{-1} and above	
Cond(μScm^{-1})		601.37	601.3-601.4	200-1000μScm^{-1} (Horne and Goldman, 1994)	The values recorded were within the range that will support fish growth
TDS (mgL^{-1})		224.47	223.6-224.9		
Sal (ppm)		0.17	0.16-0.17	0.02- 0.2 ppm for freshwater	
pH	8.9	8.71	8.68-8.72	6-9 (Ross 2000)	
ORP (mV)		19.67	19-21	300-500 Horne and (Goldman 1994)	The value is below the required minimum an indication of dead decaying matter which is hard to decompose in less volume of water
Secchi(m)	1.1	0.10	0.1-0.1	0.35- 0.5 (Berveredge, 2004, Aura et al., 2021)	The Secchi depth reduced due to the siltation of the dam from runoff
Nitrites (μgL^{-1})		19.91		0.75-5mgL^{-1}	The parameters recorded were within the tolerable range which supports fish growth
Nitrates (μgL^{-1})		23.85		0 – 40 mgL^{-1}	
Ammonium (μgL^{-1})	50.9	12.81		60μgL^{-1} at pH 9 and temperature of 25 degrees to 160 ppm L-Shafey (1998)	
TN (μgL^{-1})		140.21			
SRP (μgL^{-1})		10.33		10-50 μgL^{-1}	
TP (μgL^{-1})		51.86		0.3-0.5mgL^{-1}	
TN:TP	1770.7	2.70		<15	
Silicate(mgL-¹)		43.24		4–20 mgL^{-1}	High levels of silicate is essential for the growth of a species of phytoplankton known as diatoms which in turn helps in fish growth
Alk (mgL-¹)		58.00			
Hard(mgL-¹)		72.00			

Chlorophyll a (μgL^{-1})		25.17		60 μgL^{-1} at pH 9 and temperature of 25ºC . L-Shafey (1998)	Values recorded were within the range which supports the fish growth
Fish condition (Relative condition factor of stocked *O. niloticus)*		1.35	0.61-1.82	1.01±0.17 to 1.05±0.5 (Daliri et al., (2012), Lloret et al., (2014))	Species performed very well
Total Coliforms		15 $x10^3$		<1000 cfu/100ml	Mitigate water contamination from point and non-point sources.
E. coli	20 $x10^3$	1 $x10^3$		<10 cfu/100ml	
Phytoplankton Shannon Index	1.585	0.4171			Suitable for aquaculture since some since species like *Ampora* spp. are thriving and act has prey for fish
Phytoplankton Abundance ($IndL^{-1}$)	918	2818		300	
Zooplankton Shannon Index	1.22	1.148			
Zooplankton Abundance ($Indiv.l^{-1}$)	237.4	23.1			

Conclusion and recommendations

Business and entrepreneurship were the primary economic activity around the dam; combined with recreational use of the site, shifted the focus away from aquaculture practice, hence moderate impact due to restocking. Due to a lack of fishing equipment, the community had not harvested extensively such that a moderate impact was registered. There was abundant food and diverse species of phytoplankton to prey on both in the baseline and endline. Diatoms were the most predominant and are the species most preferred by juvenile fish and other aquatic fauna, both in lotic and lentic waters as they are the chief primary producers. The dam can continue to support fish production through enhanced dam management by providing food supplements.

The following are recommendations for the management of the dam:

- An integrated resource management approach is required to support the fishery
- The community requires aggressive training in aquaculture and fisheries operations.
- Fencing of the dam to eliminate threats of encroachment, trespass and introduction of contaminants.
- Controlled human water abstraction
- Monitoring the water inflow points to reduce runoff from pollution zones.

2.Twiga

Plate 34. Google Earth Image of Twiga 1 Dam, Kiambu County: Google Earth®

Twiga 1 dam is located in Ruiru sub county at latitude (- 1.12168) and longitude (36.98482) sitting at an altitude of 1524 m a.s.l. The catchment has dense settlement, rocky, and with some agricultural activities.

Table 30. Means and ranges of Socio-economics impact index, water quality physical and chemical variables and nutrient species measured at Twiga dam, Kiambu county (EL = Endline, BL = Baseline, mgL^{-1} = Milligram per litre, μScm^{-1} = Micro-Siemens per cm, μgL^{-1} = Microgram per litre, ppm = Parts per million, cfu = Colony forming unit).

Parameter	**Mean**		**Range**	**Conclusion**	
	BL	**EL**	**EL**	**Reference value**	**Interpretation**
Socio economics Status index	0.48	2.73	1-3	≤2.34 High <3.00	Restocking had an improvement to the community
Temp (ºC)	22.4	24.58	23.3-26.3	20-31 for fish adapted to higher temperatures, <20 for fish adapted to low temperatures. Mires (1995)	The value recorded fall within tolerable ranges for fish growth
DO (mg/L)	7.0	5.54	2.45-6.54	$5mgL^{-1}$ and above	Some values in the sites showed anoxic environment while other sites were within the range
Cond(μScm^{-1})		635.74	635.3-636.9	200- 1000μScm^{-1}	The values recorded are

TDS (mgL^{-1})		129.44	125.75- 132.6		within the range that can support fish growth
Sal (ppm)		0.09	0.09-0.1	0- 0.2 ppm	
pH	8.2	9.03	8.73-9.17	6-9 (Ross, (2000)	
ORP (mV)		18.39	7.1-38.2	300- 500 (Horne and Goldman, 1994)	The value is below the required minimum an indication of dead decaying matter which is hard to decompose in less volume of water
Secchi(m)	1.1	1.12	0.85-1.3	0.35- 0.5 (Berveredge, 2004, Aura et al., 2021)	The value recorded were far much higher to the range an indication of high photic depth which increases primary production
Nitrites (μgL^{-1})		3.75	3.24- 4.15	0.75-5mgL^{-1}	Values recorded were within the range that can support fish growth
Nitrates (μgL^{-1})		9.49	5.67- 14.45	0 – 40 mgL^{-1}	
Ammonium (μgL^{-1})	36.6	45.31	25.94- 80.31	60μg^{-1} at pH 9 and temperature of 25^{o}C L-Shafey (1998)	
TN (μgL^{-1})		94.95	84.95- 100.74		
SRP (μgL^{-1})		4.78	2- 8.67	10-50 μgL^{-1}	
TP (μgL^{-1})		19.48	17.57- 23.29	0.3-0.5mgL^{-1}	
TN:TP	42.4	4.93	4.33- 5.64	<15	
Silicate(mgL^{-1})		26.16	25.88- 26.73	4–20 mgL^{-1}	High levels of silicate is essential for the growth of a species of phytoplankton known as diatoms which in turn helps in fish growth
Alk (mgL^{-1})		57.33	54- 60		Values recorded were within the range that can support fish growth
Hard (mgL^{-1})		37.33	36- 40		
Chlorophyll a (μgL^{-1})		0.75	0- 2.24	>7.5 and <40 for Lake Victoria	

				(Aura et al., 2021, Kashindye et al., 2015, Aura et al., 2016)	
Fish condition (Relative condition factor of stocked *O. niloticus)*	-	1.23	0.62-1.70	1.01±0.17 to 1.05±0.5 (Daliri et al., (2012), Lloret et al., (2014))	Species performed very well.
Total Coliforms		18 x10^3		<1000 cfu/100ml	Mitigate water contamination from point and non-point sources.
E. coli	20 x10^3	1 x10^3		<10 cfu/100ml	
Phytoplankton Shannon Index	1.796	1.151			Suitable for small aquaculture business
Phytoplankton Abundance (IndL^{-1})	193	110		300	
Zooplankton Shannon Index	1.08	1.168			
Zooplankton Abundance (Indiv.l^{-1})	289	23.5			

Conclusion and recommendations

It is notable that the community had been fishing and utilizing the restocked fish for socioeconomic wellbeing. However, fishing was done using rudimentary fishing techniques and equipment which are not cost effective for maximum economic benefits. The trophic state index of the dam showed that the dam is mesotrophic both in the baseline and end line studies and could be attributed to relatively increased biological productivity which also reflected on the phytoplankton data.

The following recommendations should be considered to improve the socioecological status of the dam and promote the positive benefits of the stocked fish to the community:

- Supplemental feeding and training in fish management practices
- Further research on a potent algal toxin noted during the assessment.
- Fencing of the dam to enhance security
- Controlled human water abstraction
- Monitoring the water inflow points to reduce runoff from pollution zones.

3.2.7 Kajiado County

1. Endiro Dam

Plate 35. Google Earth Image of Endiro Dam, Kajiado county

Located around GPS point, 1.7583, 36.96198 previously, the dam was used as gypsum mining sites. After the minerals were depleted, they were filled with rainwater. The dam had little macrophytes (papyrus) and extremely turbid water mainly used as animals watering pans. The dams are found in a region with black cotton soils.

Table 31. Means and ranges of Socio-economics impact index, water quality physical and chemical variables and nutrient species measured at Endiro dam, Kajiado county (EL = Endline, BL = Baseline, mg L^{-1} = Milligram per litre, µScm^{-1} – Micro- Siemens per cm, µgL^{-1} = Microgram per litre, ppm = Parts per million, cfu = Colony forming units).

Parameter		**Mean**		**Range**	**Discussion**	
		BL	**EL**	**EL**	**Reference value**	**Interpretation**
Socio economics Status index			2.27	1-3	≤1.67 Moderate <2.33	Restocking had moderate impact on the community
Temp (ºC)			24.00	24-24	20-31 for fish adapted to higher temperatures, <20 for fish adapted to low temperatures. Mires (1995)	Values recorded for these parameters fall within tolerable ranges for fish growth
DO (mgL^{-1})			9.60	9.6-9.6	5mgL^{-1} and above	
Cond (µScm^{-1})			675.10	675.1-675.1		Elevated values due to gypsum mining and high turbidity brought about by runoff
TDS (mgL^{-1})			455.00	455-455		

Sal (ppm)			0.34	0.34-0.34	0- 0.2 ppm	High salinity values due to previous mining activity in the dam
pH			4.50	4.5-4.5	6-9 (Ross, 2000)	Low pH value possibly due to mineral rocks and immense water abstraction
ORP (mV)			430.40	430.4-430.4	200- 500	This is an indication the dam does not have much organic matter hence easily replenish itself
Secchi (m)			0.18	0.18-0.18	0.35-0.5 (Berveredge, 2004, Aura et al., 2021)	Low Secchi depth, an indication of enhanced turbidity due to high siltation
Nitrites (μgL^{-1})			2.03		0.75-5mgL^{-1}	Values recorded for these parameters fall within tolerable ranges for fish growth
Nitrates (μgL^{-1})			8.39		0 – 40 mgL-1	
Ammonium (μgL^{-1})			47.19		60 μgL^{-1}at pH 9 and temperature of 25 °C L-Shafey (1998)	Elevated ammonium due to increased metabolism of higher fish biomass
TN (μgL^{-1})			67.58			Values are within the optimal ranges. Suitable for aquaculture practices
SRP (μgL^{-1})			5.33		10-50 μgL^{-1}	
TP (μgL^{-1})			150.43		0.3-0.5mgL^{-1}	
TN:TP			0.45		<15	
Silicate (mgL^{-1})			47.48		4–20 mgL^{-1}	High levels of silicate is essential for the growth of a species of phytoplankton known as diatoms which in turn helps in fish growth
Alk (mgL^{-1})			98.00			Values observed for the chemical parameters tolerable for fish
Hard(mgL^{-1})			220.00			
Chlorophyll a (μgL^{-1})			79.52		>7.5 and <40 for Lake Victoria (Aura et al., 2021, Kashindye et al., 2015, Aura et al., 2016)	Elevated concentrations of chlorophyll-a could signal a rapid growth of algae an indication of algal bloom a problem for aquatic ecosystems, once death they sink to the bottom and decompose, using up the dissolved oxygen which organisms need to live.
Fish condition (Relative condition factor of stocked *O. niloticus*)			1.36	0.95-1.60	1.01±0.17 to 1.05±0.5 (Daliri et al., (2012), Lloret et al., (2014))	Fish condition is good
Total Coliforms			21 x10^3		<1000 cfu/100ml	

E. coli			0		<10 cfu/100ml	Water quality suitable for aquaculture with monitoring interventions.
Phytoplankton Shannon Index			1.908		H’ ≥ 2.5 (Aura et al., 2021)	The dam is suitable for aquaculture however supplemental feeding is required
Phytoplankton Abundance (IndL^{-1})			274		300	
Zooplankton Shannon Index			0.8731			
Zooplankton Abundance (IndL-1)			133.4			

Conclusion and recommendations

With good water quality, fish growth performance in this dam was quite good. However, owing to poor/indigenous opinions about fish eating and farming, aquaculture exploitation did not have the expected high impact. Therefore, other primary sources of income for the community, resulting in a moderate score on the aquaculture socio-performance index. This, along with a lack of information about fish farming processes, makes aquaculture development challenging. The dam has a plentiful supply of natural food sources that can maintain a fishery with proper management. If intensive aquaculture takes root in the dam, it will be necessary to improve natural production to suggested reference levels in the future. The absence of fecal coliforms indicates that the water is not polluted.

In order to ensure maximum benefits to the community from the stocked fish, it is recommended that:

- Communities be sensitized on aquaculture and its economic potential in improving the livelihood.
- Raise awareness about the advantages of fish as a nutritious alternative food
- Provision of farm inputs like fishing gears.

2. Jerusalem Dam

Plate 36. Google Earth Image of Jerusalem Dam, Kajiado County

Located around GPS point, 1.62618, 36.98567, the dam was covered with macrophytes, particularly water lilies. On the dam's outskirts, livestock were grazing. The soil is black cotton, and there is a quarry ballast mining site nearby. There was no inflow and outflow water since it was a dry season. Desiltation of the dams is required.

Table 32. Means and ranges of Socio-economics impact index, water quality physical and chemical variables and nutrient species measured at Jerusalem dam, Kajiado county. (EL = Endline, BL = Baseline, mgL^{-1} = Milligram per litre, μScm^{-1} = Micro-Siemens per cm, μgL^{-1} = Microgram per litre, ppm = Parts per million, cfu = Colony forming unit)

	Mean		**Range**	**Discussion**	
Parameter	**BL**	**EL**	**EL**	**Reference value**	**Interpretation**
Socio economics Status index		2.50	1-3	≤2.34 High <3.00	Restocking had an improvement to the community.
Temp (ºC)		21.95	20.8-23.4	20-31 for fish adapted to higher temperatures, <20 for fish adapted to low temperatures. Mires (1995)	The value recorded fall within tolerable ranges for fish growth
DO (mgL^{-1})		3.53	1.7-4.39	5mgL^{-1} and above	Low values an indication of hypoxic environment which cannot sustain fish
Cond (μScm^{-1})		679.53	629.1-829.8		Elevated values due to ballast quarry mining and high turbidity brought about by runoff
TDS (mgL^{-1})		103.35	102.05-105.95		
Sal (ppm)		0.073	0.07-0.08	0- 0.2 ppm	Low salinity

pH		4.69	3.19-7.9	6-9 (Ross,2000)	pH values below the required minimum at the point where animals are watered but within the range where vegetation acts as a buffer
ORP (mV)		239.43	51.6-317.7		
Secchi (m)		0.15	0.1-0.2	0.35- 0.5 (Berveredge, 2004, Aura et al., 2021)	Secchi depth readings record below the reference value. Reduced photic depth indicating increased turbidity
Nitrites (μgL^{-1})		9.51	8.39- 11.42	0.75-5mgL^{-1}	Values are within the optimal ranges. Suitable for aquaculture practices
Nitrates (μgL^{-1})		15.97	9.61- 21.12	0 – 40 mgL^{-1}	
Ammonium (μgL^{-1})		45.10	35.94- 63.44	0.06 ppm at pH 9 and temperature of 25°C to 160 ppm at pH 6 and temperature of 5°C L-Shafey (1998)	Elevated ammonium due to increased metabolism of organisms and defecation of animal wastes during watering
TN (μgL^{-1})		80.74	67.58-103.89		
SRP (μgL^{-1})		39.78	35.33- 43.67	10-50 μgL^{-1}	Values are within the optimal ranges. Suitable for aquaculture practices
TP (μgL^{-1})		265.67	216.14-296.14	0.3-0.5mgL^{-1}	
TN:TP		0.31	0.24- 0.35	<15	Nitrogen deficient in the dam
Silicate(mgL^{-1})		26.38	25.94- 26.76	4–20 mgL^{-1}	High levels of silicate is essential for the growth of a species of phytoplankton known as diatoms which in turn helps in fish growth
Alk (mgL^{-1})		54	52- 58		The values are within the range for fish growth
Hard(mgL^{-1})		54	52- 56		
Chlorophyll-a (μgL^{-1})		96.58	51.91-130.06	>7.5 and <40 for Lake Victoria (Aura et al., 2021, Kashindye et al., 2015, Aura et al., 2016)	Elevated concentrations of chlorophyll-a could signal a rapid growth of algae an indication of algal bloom a problem for aquatic ecosystems, once death they sink to the bottom and decompose, using up the dissolved oxygen which organisms need to live.
Fish condition (Relative condition factor of stocked *O. niloticus)*		-	-	1.01±0.17 to 1.05±0.5 (Daliri et al., (2012), Lloret et al., (2014))	-
Fecal Coliform		25 x10^3		<1000 cfu/100ml	Mitigate contamination from point and non-point sources to improve water quality.
E. coli		1 x10^3		<10 cfu/100ml	
Phytoplankton Shannon Index		2.741		H' ≥ 2.5 (Aura et al., 2021)	The values are within the tolerance for fish farming

Phytoplankton Abundance (IndL^{-1})		350		300	
Zooplankton Shannon Index		0.9539			
Zooplankton Abundance (Indiv.l^{-1})		1087.1			

Conclusion and recommendations

Despite the community harvesting fish from the dam, there were issues on sharing of the resource mainly as employees (Salary/Wages). The main economic activity is cattle rearing, and the community has scanty information on aquaculture and fisheries issues. Furthermore, fish intake has been minimal due to Maasai traditional beliefs that they do not consume fish or fowl. We therefore recommend:

- For more fish farming, handling, and preparation training
- Sensitization of the community about the nutritional benefits of fish
- Fencing of the dam to limit animal defecation
- Controlled human water abstraction
- Monitoring the water inflow points to reduce runoff from pollution zones.

3.2.8 Machakos County

1. Kikambuani

Plate 37. Google Earth Image of Kikambuani Dam, Machakos County

Located around GPS point, 1.29795, 37.37705, at an altitude of 1600 m because of the rainy season, the dams had few macrophytes (potamogeton) and severely turbid water which brought about reduced photic depth. Water was constantly streaming in and out of the dam an indication of replenishment and high dissolved oxygen value which may sustain fish growth.

Table 33. Means and ranges of Socio-economics impact index, water quality physical and chemical variables and nutrient species measured at Kikambuani dam in Machakos County (EL = Endline, BL = Baseline, mgL^{-1} = Milligram per litre, μScm^{-1} = Micro-Siemens per cm, μgL^{-1} = Microgram per litre, ppm = Parts per million, cfu = Colony forming unit).

	Mean		Range		
Parameter	**BL**	**EL**	**EL**	**Reference value**	**Interpretation**
Socio economics Status index		2.28	1-3	≤1.67 Moderate <2.33	Restocking had moderate impact on the community
Temp (°C)		22.90	21.4-25.6	20-31 for fish adapted to higher temperatures, <20 for fish adapted to low temperatures. Mires (1995)	Values recorded for these parameters fall within tolerable ranges for fish growth
DO (mg L^{-1})		5.85	5.32-6.61	5mg L^{-1} and above	
Cond (μScm^{-1})		630.06	629.2-630.3		Elevated values due to mineral turbidity brought about by runoff from agricultural activities
TDS (mgL^{-1})		52.00	51.35-52.65		
Sal (ppm)		0.04	0.04-0.04	0- 0.2 ppm	Reduced values of salinity
pH		6.87	5.47-8.44	6-9 (Ross 2000)	The value recorded is within the range of the required pH for fish growth
ORP (mV)		180.64	12.4-510.5	300- 500mV (Horne and Goldman, 1994)	The value is below the required minimum an indication of dead decaying matter which is hard to decompose in less volume of water
Secchi(m)		0.11	0.08-0.14	0.35- 0.5 (Berveredge, 2004, Aura et al., 2021)	Reduced photic depth and light intensity is low hindering primary production
Nitrites (μgL^{-1})		11.93	11.12- 12.33	0.75-5mgL^{-1}	Values are within the optimal ranges. Suitable for aquaculture practices
Nitrates (μgL^{-1})		14.96	12.64- 17.18	0 – 40 mgL^{-1}	
Ammonium (μgL^{-1})		40.31	32.81- 46.56	0.06 ppm at pH 9 and temperature of 25 degrees to 160 ppm at pH	Elevated ammonium due to increased metabolism of higher fish biomass

				6 and temperature of 5 oC L-Shafey (1998)	
TN (μgL^{-1})		100.21	92.84- 105.47		Values recorded in these parameter are within the optimal ranges. Suitable for aquaculture practices
SRP (μgL^{-1})		16.44	12- 20.33	10-50 μgL^{-1}	
TP (μgL^{-1})		102.33	70.43- 131.86	0.3-0.5mgL^{-1}	
TN:TP		1.05	0.78- 1.50	<15	
Silicate(mgL^{-1})		5.94	6.20- 5.88	4–20 mg L^{-1}	
Alk (mgL^{-1})		28.00	26- 30		
Hard(mgL^{-1})		36.33	32- 44		
Chlorophyll a (μgL^{-1})		15.59	6.67- 27.18	>7.5 and <40 for Lake Victoria (Aura et al., 2021, Kashindye et al., 2015, Aura et al., 2016)	
Fish condition (Relative condition factor of stocked *O. niloticus)*		0.85	0.53-1.22	1.01±0.17 to 1.05±0.5 (Daliri et al., (2012), Lloret et al., (2014))	There was low performance for the species
Total Coliforms		39 $x10^3$		<1000 cfu/100ml	Mitigate water contamination from point and non-point sources to improve water quality.
E. coli		17 $x10^3$		<10 cfu/100ml	
Phytoplankton Shannon Index		1.151		H' ≥ 2.5 (Aura et al., 2021)	Suitable for aquaculture related activities
Phytoplankton Abundance ($IndL^{-1}$)		110		300	
Zooplankton Shannon Index		0.8731			
Zooplankton Abundance		133.4			

Conclusion and recommendations

The community had not harvested restocked fish from the dam because of several factor; including crop farming dominance, and lack of fishing gear. Some of the challenges the dam management faces include the withdrawal of some members of the group because there is no streaming of income and also due to the seasonality of dam. These recommendations are aimed at raising the communities' socioeconomic benefits from the stocked fish:

- Raising awareness about the importance of aquaculture as a source of income.
- Ensuring community extension services are provided.
- Prevention of group dynamics requires training on the importance of cohesion.
- In order to provide direct benefit to the community, relevant authorities and partners should allow for periodic intermittent fishing.
- There is need to enhance the food through improvement of primary productivity

- Fencing of the dam to limit animal defecation
- Controlled human water abstraction
- Monitoring the water inflow points to reduce runoff from pollution zones.

2. Kwa Mutia

Plate 38. Google Earth Image of Kwa Mutia Dam, Machakos County

Located around GPS point, 1.3862, 37.25412 at an altitude of 1561 m the dam is surrounded by agricultural activities, it is surrounded by exotic trees (graverier) planting of crops and rearing of domestic livestock. The dam is used to water the livestock and doing some irrigation for domestic use.

Table 34. Means and ranges of Socio-economics impact index, water quality physical and chemical variables and nutrient species measured at Kwa Mutia dam, Machakos County (EL = Endline, BL = Baseline, mg L^{-1} = Milligram per litre, μScm^{-1} – Micro- Siemens per cm, μgL^{-1} = Microgram per litre, ppm = Parts per million, cfu = Colony forming unit).

Parameter	**Mean**		**Range**		
	BL	**EL**	**EL**	**Reference value**	**Interpretation**
Socio economics Status index		2.05	1-3	≤1.67 Moderate <2.33	Restocking had moderate impact on the community
Temp (ºC)		24.13	20.7-30.4	20-31 for fish adapted to higher temperatures, <20 for fish adapted to low temperatures. Mires (1995)	Values recorded for these parameters fall within tolerable ranges for fish growth

DO (mgL^{-1})		6.52	$3.25^{-1}0.04$	5mg L^{-1} and above (Ross 2000)	
Cond (μScm^{-1})		631.35	631.2-631.6		Elevated values due to mineral turbidity brought about by runoff from agricultural activities
TDS (mgL^{-1})		105.79	$80.6^{-1}18.95$		
Sal (ppm)		0.08	0.06-0.08	0- 0.2	Reduced photic depth hindering light penetration for efficient primary production
pH		9.39	8.92-9.82	6-9 (Ross,2000)	The value recorded was higher an indication of an alkaline environment if buffered will be good for fish growth
ORP (mV)		32.09	-15.8-214.8	300- 500mV (Horne and Goldman, 1994)	Low value an indication of lots of dead and decaying material in the water column that cannot be easily decomposed
Secchi(m)		0.18	0.16-0.2	0.35- 0.5 (Berveredge, 2004, Aura et al., 2021)	Reduced photic depth and light intensity is low hindering primary production
Nitrites (μgL^{-1})		4.05	2.64- 5.06	$0.75\text{-}5mgL^{-1}$	Appropriate for fish growth
Nitrates (μgL^{-1})		11.53	6.58- 15.97	0 – 40 mgL^{-1}	
Ammonium (μgL^{-1})		29.48	22.81- 34.69	60 μgL^{-1}at pH 9 and temperature of 25 ºC L-Shafey (1998)	Elevated ammonium due to increased metabolism of higher fish biomass
TN (μgL^{-1})		71.26	61.26- 80.21		Values are within the optimal ranges. Suitable for aquaculture practices
SRP (μgL^{-1})		8.67	5.33- 12	10-50 μgL^{-1}	
TP (μgL^{-1})		139.95	96.14-176.14	$0.3\text{-}0.5mgL^{-1}$	
TN:TP		0.54	0.42- 0.75	<15	
Silicate(mgL^{-1})		14.34	14.02- 14.84	4–20 mgL^{-1}	

Alk (mgL^{-1})		56.67	54- 60		
Hard(mgL^{-1})		50	44- 58		
Chlorophyll a (μgL^{-1})		50.60	46.80- 54.84	>7.5 and <40 for Lake Victoria (Aura et al., 2021, Kashindye et al., 2015, Aura et al., 2016)	Elevated concentrations of chlorophyll-a could signal a rapid growth of algae an indication of algal bloom a problem for aquatic ecosystems, once death they sink to the bottom and decompose, using up the dissolved oxygen which organisms need to live.
Fish condition (Relative condition factor of stocked *O. niloticus)*		1.01	0.76-1.42	1.01±0.17 to 1.05±0.5 (Daliri et al., (2012), Lloret et al., (2014))	There was low performance for the species, supplemental feeding recommended
Total Coliforms		30 x10^3		<1000 cfu/100ml	Monitoring of point and non-point sources to improve water quality.
E. coli		5 x10^3		<10 cfu/100ml	
Phytoplankton Shannon Index		3.5		H’ ≥ 2.5 (Aura et al., 2021)	Suitable for aquaculture activities
Phytoplankton Abundance ($IndL^{-1}$)		833		300	
Zooplankton Shannon Index		0.8337			
Zooplankton Abundance ($Indiv.l^{-1}$)		121.1			

Conclusion and recommendations

The community had not harvested restocked fish primarily due to a lack of fishing equipment and insufficient skills to undertake the activity. Furthermore, crop farming is the dominant economic activity with emerging interest in fisheries and aquaculture. The phytoplankton composition was largely dominated by diatoms followed by chlorophytes and cyanophytes. High abundance of these blue green and green species is a sign of nutrient enrichment that supports proliferation of these species. Diatoms act as a supplemental source of protein hence it can support a fishery because it is available for juvenile fish and other aquatic organisms.

The following management recommendations are geared towards enhanced benefits to the community from the stocked fish:

- Community education and sensitization about the importance of aquaculture.

- A periodic fishing technique should be defined by relevant authorities and implementing partners.
- Fencing of the dam to limit animal defecation, controlled human water abstraction because during drought the water depth recedes
- Monitoring the water inflow points to reduce runoff from pollution zones.

GENERAL CONCLUSION AND RECOMMENDATIONS

The average relative condition factor (Kn) of tilapia in restocked SWBs was 1.24±0.53 SD, suggesting that the fish were in excellent growth condition. Water conditions also revealed that the studied SWBs had good primary and secondary production necessitating the need to invest in such systems through fish restocking. Additionally, most dams registered moderate to high socioeconomic impact on riparian communities. These findings indicate that (re)stocking the SWBs with tilapia was beneficial to the riparian communities, since the species rapidly established itself and is currently fished for household and commercial purposes at varying scales. Given the limited exploitation of fish in some SWBs, additional community awareness and capacity building interventions are needed to realize the enormous potential identified during the baseline study and in this survey. Riparian communities will benefit from improved livelihoods as well as food and nutrition security.

RECOMMENDATIONS

It is recommended that the county governments and the communities whose jurisdictions the SWBs fall adopt the recommendation listed for each SWB. Overall, it is recommended that additional SWBs be (re)stocked with tilapia in order to broaden the geographic scope and community coverage of aquaculture business enterprises. The suggested actions to respond to the unfavorable elements noted for each dam vary from:

- Provision of fishing equipment (crafts and gear) to SWB communities in order to encourage them to explore fishing as a form of income diversification.
- Dam fencing to prevent encroachment and possible pollution from dispersed sources.
- Desilting and reengineering dam structures and nearby ecosystems to reduce sediment and pollutant loading
- Future (re)stocking to be undertaken after considering environmental and social characteristics of each SWB and its locality.

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ANNEXES

Annex I: List of the restocked SWBs under the ABDP program indicating the location, numbers of fingerlings restocked with, and availability or none of the baseline information from the initial carrying capacity assessment.

County	Name of the Dam	Sub-county	Ward	Quantity of Fingerings	Baseline info. availability
Meru	Kathagara	Imenti South	Mitunguu	22,000	No
	Mutethia II	Buuri	Timau	22,000	No
	Kaliati	Tigania West	Nkomo	22,000	No
Tharaka Nithi	Kaiboche	Tharaka South	Chiakariga	22,000	No
	Ndetha	Igambangombe	Mariani	22,000	Yes
	Gatonto	Igambangombe	Kamwimbi	22,000	Yes
Embu	Ithatha	Runyenjes	Kagaari South	22,000	Yes
	Gitaru	Mbeere South	Mavuria	22,000	Yes
	Masinga	Mbeere South	Mwea	22,000	Yes
Kirinyaga	Kangai	Mwea West	Kangai	22,000	Yes
	Karura	Kirinyaga West	Kariti	22,000	Yes
	Njukiini	Kirinyaga East	Njukiini	22,000	No
Nyeri	Lusoi	Kieni East	Thegu	33,000	No
	Kamangura	Kieni East	Gakawa	33,000	No
Kiambu	Twiga 1	Juja	Mugutha	22,000	Yes
	Tigoni	Limuru	Tigoni/Ngecha	22,000	Yes
	Rungiri	Kikuyu	Kikuyu	22,000	Yes
Machakos	Kikambuani	Kangundo	Kangundo North	22,000	No
	Kwa Mutia	Kathiani	Mitaboni	22,000	No
	Ivovoani	Mavoko	Muthwani	22,000	No
Kajiado	Jerusalem	Kajiado East	Kaputie North	22,000	No
	Osewan	Kajiado East	Maroro	22,000	No
	Endiro	Kajiado Central	Dalat Lekutuk	22,000	No
Busia	Munana	Samia	Nangina	22,000	Yes
	Nyapera	Butula	Marachi North	22,000	No
	Bumula B. Dam	Butula	Marachi East	22,000	No
Siaya	Adhiri	Rarieda	West Uyoma	22,000	No
	Uranga	Alego Usonga	Siaya Township	22,000	Yes
	Nyandera Dam	Bondo	North Sales	22,000	No

Kisumu	Kere Women Group	Nyakach	South East Nyakach	22,000	No
	Buoye Community Dam	Kisumu East	East Kolwa	22,000	Yes
	Huma Self Help Group	Kisumu West	West Kisumu	22,000	Yes
Kisii	Ibeno Shallow Water Dam	Nyaribari Chache	Ibeno	22,000	Yes
	Nyamerako Shallow Water	Bonchari	Bogiakumu	22,000	No
	Rianyanchabera	Bomachoge Borabu	Bombaba	22,000	No
Homa Bay	Pap Orage Community	Rachuonyo South	South Kasipul	11,000	Yes
	Yonga	Suba South	Kaksingri East (Ruma)	11,000	Yes
	B1	Rachuonyo North	Kendu Bay Town	11,000	No
	Otok	Rachuonyo North	Central Ward	11,000	No
	Samanga	Rachuonyo North	Kibiri	11,000	No
	Kokeb	Rachuonyo North	Kibiri	11,000	No
Migori	Nyagesese	Kuria East	Tagare	22,000	No
	Nyamome	Suna West	Wasweta II	22,000	No
	Silanga	Suna East	Kakrao	22,000	Yes
Kakamega	Musembe	Lugari	Chekalini	22,000	Yes
	Lugulu	Likuyani	Sango	22,000	Yes
	Siyenga	Likuyani	Likuyani	22,000	No

Annex II: **Socio economic tool (Questionnaire) used in data collection for the SWB survey**

END LINE SURVEY FOR STOCKED SWBs QUESTIONNAIRE

Introduction

Good morning/afternoon! Top of Form

Kenya Marine and Fisheries Research Institute (KMFRI) in collaboration with Aquaculture Business Development Programme (ABDP), Kenya Fisheries Service (KeFS) and county governments are conducting a study to determine aquaculture economic efficiency and profitability assessment of small water bodies (SWB) in western and central regions of Kenya.

We would like to request your time, no more than 1(one) hour, to ask you a few questions. Your name will not appear in any data that is *made publicly available. The information you provide will be used purely for research purposes. Your participation* is *voluntary and will not affect any benefits or subsidies you may receive now or in the future. You may withdraw from the study at any time and if there are questions that you would prefer not to answer we respect your right not to answer them. However, we value your opinion and there are no right or wrong answers to the questions, we are interested to hear your views and ideas. Any information shared with us during the research will be kept confidential.*

*Do you consent to be part of th*is *study?*

[1] Yes [0] No

Part I: Background information

Region (dropdown) …………….. County (dropdown)…………………..…

Sub-County………………………………..………….
Ward………………..………………..… Location…………………………

Sub-location……………..………. Village ………………

Name of the SWB ………………………………………………………………

Name of enumerator …… ……Date…………………Contact……….Start time….….. GPS Location…………………………………

Name of respondent………………………..Contact (Phone)………………..

Part II: Socio-demographic characteristics

1. Gender [1] Female [0] Male

2. Age (Years) …………………………

3. Position in household [1] Head [2] Spouse [3] Dependent

4. Education level: [1] None [2] Primary [3] Secondary [4] Tertiary [5] University [6] Other, specify….

5. Main occupation

[1] Crop farming [2] Fish farming [3] Fishing [4] Fish trade [5] Employee (Salary/Wages) [6] Other trade

[7] Input provider [8] Transporter [9] Other, specify…………………………………………

6. Who owns this water body?

[1] Government [2] Community [3] Privately [4] Faith-based organization [5] Other, specify……

7a. Who manages this SWB?

[1] Individual [0] Group

7b. If group, what is the name of the group?...............................

7c. If group, indicate the segregation of membership as follows:

Men……… Women…. Youth….. VMGs……………………

8. Are there some activities mainly managed by women within this dam [1] Yes [0] No

If yes, please state them?

1. ____

2. ____

3. ____

4. ____

9.Are there some activities that involve the youths and PWDs in this SWB

1. ____

2. ____

3. ____

Part III: Level of community awareness of intervention and expectation

10. What are the major uses of this dam? [1] Irrigation (2) Power [3] Fisheries/Aquaculture [4] Domestic use [5] Other, specify

11a. Are you aware that this dam was stocked/restocked with fingerlings? 1=Yes, 0=No

11b. When was the dam stocked?

12. What species was stocked? …………………………………………………………………

13. What is the size of the dam in m^2? ………………………………………………………

14. Which fish species is the most preferred in the locality?

1. *Oreochrom*is *niloticus 2. Oreochrom*is *mossambicus 3. Lates niloticus 4.*Trout 5. *Labeo spp* 6. *Barbus spp* 7. Haplochromine 8. *Protopterus aethiopicus 9.* Clarias spp 10. Others (Specify)………………………………...........

15 Which fish species is cultured in this water body?

1. *Oreochrom*is *niloticus 2. Oreochrom*is *mossambicus 3. Lates niloticus 4.*Trout 5. Labeo spp 6. Barbus spp 7. Haplochromine 8. *Protopterus aethiopicus 9.*Clarias spp 10. Others (Specify)………………………………...........

16. Why have you embraced aquaculture/fisheries? (Select only one)

[1] Income [2] Food [3] Income & food [4] Hobby [5] Create employment [6] Benefit from ABDP [7] Utilize idle SWB [8] Other, specify ………………………………………………………

17. What were your expectations at the restocking of the dam?...

18. Which of those expectations have been achieved?...

Part IV: Synergies in project implementation

19. Have you had any kind of support in aquaculture farming since stocking of the SWB?

(1=Yes, 0=No)

20. If yes in question 19 above, state source/organization and type of support (Financial, inputs………..)

<u>Source/Organization</u> <u>Type</u>

i) ……………………………………………………… ……………………
ii) ………………………………………………………. …..…………
iii) ……………………………………………………… …………………
iv) ……………………………………………………… ………………………

Part V: Fish production

21a. Do you keep farm records? [1] Yes [0] No

21b. If yes, in what form? [1] Book [2] Loose Sheet [3] Computer [4] Other, Specify________________

21c. If no, give reasons………………..

22. What type of records do you keep?

[1] Stocking records [2] Feeding records [3] Production [4] Accounting records,

[5] Pond fertilization [6] Other records, specify_______________

23. Enumerator to Observe: How are the records?

[1] Minimal [2] Medium – some records [3] Good - up to date records [4] Excellent, comprehensive,

computer-based records [5] Notes (6) Missing

24. What is the main source of farm labour for this SWB aquaculture operation (Single response)

[1] Group members [2] Family [3] Other, specify

25. Are there any employees in this SWB? If yes, how many? Specify their roles

26. What is the skill level of the employees? How many are unskilled? Skilled?

27. Do women & youth form part of your employees? How many? What is their role?

28. What is the mode of employment

[1] Permanent [2] casual

29. What was the source of fingerlings for this SWB? Multiple response [1] Government hatchery [2] Private hatchery [3] Farmers [4] Self- production [5] Group/Cluster farm [6] Brought by ABDP County Coordinators [7] Other, specify________________

30. After how long did you harvest fish from this SWB?

[1] ≤4 months [2] 6 months [3] $6^{-1}2$ months [4] ≥ 1 year

31. What method did you use to harvest?

32. What quantities on average did you harvest from the SWB?

Feeds and feeding regimes

33. What were the sources of feed used

1=Purchased 2=Homemade feed 3=Both homemade and purchased 4=Trash feed/home remains 5=Freely provided 6=Other, specify

34. What are the methods used for administering feeds to fish?

[1] Hand feeding (ration broadcasted by hand for 15-30 minutes)

[2] Demand feeder (an equipment triggered by fish on demand)

[3]Automatic feed blower (automatically broadcast feed through electrically Powered blower)

35a. What is the frequency of feeding

[1] Once a day [2] Twice a day [3] Three times a day [4] Four times a day [5] >Five times a day [6] Other. Specify…………………

35b. Where do you store your feeds

[1] Farm stores [2] Individual homestead [3] others specify……………

35c. How do you store your feeds?

[1] Raised racks [2] On the ground [3] others specify…………….

Fish health

36. What biosecurity measures are applied in this SWB?

[1] Pond/farm has fencing [2]Farm uses sun-drying to disinfect nets [3] Farm uses chemicals to disinfect nets [4] Others, specify

37a. Have you experienced fish diseases/kills [yes] [no]

37b. What were the symptoms seen……………………….

38. Area you aware of fish disease management [Yes] [No]

39. How do you handle the sick fish

40. How do you dispose dead fish?………………..

41. Have you encountered fish predators in this SWB?..........Specify which one……………

Part VI: Inputs and Outputs/Costs and revenues

Please fill the table appropriately

	Item	Unit	Quantity	Unit Cost	Value (KES)	Total
Revenue/Incomes	Quantity harvested 1. Tilapia	Kg				
	(sales) Price 1. Tilapia	KES				
Total Income						
Variable Costs	Fingerlings/Seed 1. Tilapia	No.				
	Feeds (Varieties) 1.	Kg				
	2.	Kg				
	3.	Kg				
	4.	Kg				
	Hired Labor (production i.e feeding, predator control etc)	MD				
	Family Labor (production i.e feeding, predator control etc)	MD				
	Harvesting costs	MD				
	Security	MD/No.				
	Transportation	MD				
Total VC						
Fixed Costs	Store/building	No.				
	Jembes, Pangas, Shovels	No.				
	Assorted equipment/Equipment repair	No.				
	Farm Machinery	No.				
Interest	Long term Loans	%				
	Short term loans	%				
Dams	(lease/rent)	No.				
Total fixed costs						
Total Costs						

Fish trade and income

42. Who is your target consumer of harvested fish?

[1] Company [2] Small traders [3] Large scale traders [4] Hotels/restaurants [5] Community[6] Government [7] Other, specify

43. What did you use your last fish income for? (*two main)*

[1] Reinvest in fish farming operation [2] Invest in crop farming operation [3] Invest in livestock farming operation [4] Pay off debts [5] Purchase food [6] Medical expenses [7] Pay School fees

[8] Purchase assets like TV, motor vehicle, motorcycle, Radio, vehicle etc [9] Other: ____________

Part VII: Access To Extension And Advisory Services

44. Do you have access to extension services? ....……… (1=Yes, 0=No)

45. What's the source(s)/providers? .... (1=Government, 0= Other - Name them)

i) ……………………………………………………………………………………..……………

ii) ………………………………………………………………………………………………

iii) ………………………………………………………………………………………………

iv) ………………………………………………………………………………………………

46a. In future, are you willing to pay for your own training in aquaculture? [1] Yes [0] No

46b. If yes, why? (multiple response)

[1] For increased profits [2] For increased yields [3] For Adoption of new technologies [4] To Increase financial capability [5] Other (specify)____________________

47. Has the adoption of aquaculture affected women in any way in this area?

[1] Yes [0] No

If yes, how so? Please list

1. ____

2. ____

Part VIII: Fish consumption

48a. Do you or your household buy and eat fish and other fish products from the SWB? 1= Yes 2=No

48b.If yes, how regularly do you eat fish?

1=Daily 2= Once a week 3= Bi-weekly /fortnightly 4= Once a month 5=Periodically 6=Other, specify…….

49. Why do you consume fish (*please tick as many as apply to you*)

1= Easy to cook 2= Like the taste 3 = Cheaper than beef, chicken 4= Readily available 5 = Healthy

50. On average, how much do you spend on buying fish per month (Ksh)_________

51. what is the preferred size of fish in this area?

	Most preferred	Least Preferred	Not preferred
Whole big size fish			
Whole medium size fish			
Whole small size			
Fresh fillets			
Cut into pieces			

52. In which form do you consume the fish?

Product type: 1. Fresh, 2. Fried, 3. Smoked, 4. Dried. 5. Salted 6. Other(specify)

53. What is the source of fish consumed

Source of fish. 1=Farmed Fish, 2=Lake Victoria, 3= Other (Specify)____________________

54a. Have you consumed value added products? 1= Yes 2=No 3=Not available

54b. If yes which ones? 1=Fish samosas 2= Fish fingers 3= Fish balls 4=fish fillet 5= Smoked fish 6= Others, specify

54c. Of the products you have consumed which one do you prefer? 1=Fish samosas 2= Fish fingers 3= Fish balls 4=fish fillet 5= Smoked fish 6= Others, specify

54d. Why do you prefer them? 1= Delicious 2= Attractive 3= Other specify

55. Do you wish to incorporate these products in your diet? 1=Yes 2 = No

56. If no to qst 55. would you like to start consuming these products? 1= Yes 2=No

Part IX: Fish post-harvest preservation techniques and value addition technologies

57.What did you do to ascertain that your fish does not get spoilt? ………………………………

58. What happens to fish that is not sold at the end of the day? …………………………………

59a.Do you experience post-harvest loss? 1=Yes 2 = No

59b. If yes, what proportion?..

60.a Are you aware of fish post-harvest handling and preservation technologies: 1=Yes 2 = No

60b. Which ones do you know? 1=Smoking kiln 2=Improved fish display box3=Solar driers4=Other

61. Which ones are you currently using? 1=Smoking kiln 2=Improved fish display box3=Solar driers4=Other

Household Food Security Score (FCS) And Dietary Diversity Score (HDDS)

62. I now kindly ask you about the different types of food that your household has eaten in the past 7 days and last 24hours.

Food Group and Food list	L1. How **many days over the last 7 days** did your household eat these foods prepared	L2. What was the **main source of food** for the past 7days? **Source of food codes** [1] Own production [2] Purchase (cash)	L3. Did adults of your household eat these foods **yesterday** during the day and at night? [1] Yes [0] No

		and/or consumed at home *(Indicate number of days)*	[3] Purchase (credit) [4] Food assistance [5] Gifts [6] Exchange for labour [7] Beg [8] Others, specify	
1	**Cereals & grains:** Ugali, Githeri, mukimo, motokoi, noodles, spaghettis, biscuits, bread, mandazis and others			
2	**Roots & Tubers:** potatoes, yams, cassava, white flesh sweet potatoes,			
3	**Legumes & nuts:** Beans, soy, pigeon pea, peanuts, lentils (Kamande),			
4	**Orange veges (Rich in Vit. A):** Carrots, red/yellow pepper (hoho), pumpkin, orange sweet potatoes.			
5	**Greeny leafy veges:** Spinach, broccoli, amaranth, cassava leaves/other dark green leaves**.**			
6	**Other vegetables:** Onions, tomatoes, cucumber, radishes, green beans, peas (minji), French beans (muchiri), lettuce, cabbage			
7	**Orange fruits (Rich in Vit.A**): Mangoes, papaya, passion fruits, kiwi, apricot, peach, loquates, melon, guavas.			
8	**Other fruits:** Pears, banana, apple, lemon, tangerine, pineapple, plums, grapes, pears, others			
9	**Meat:** Goat, beef, chicken, pork (in large quantities, not as condiments)			
10	**Organ meat (Rich in hem iron**): Liver, kidney, heart and/or other organ meats			
11	**Fish/shellfish:** Fish (including canned tuna, in large quantities, not as condiments) **(Specify source) i.e Cultured, captured (Wild) or Imported fish**			
12	**Eggs**			
13	**Milk &dairy products:** Fresh milk, yoghurt, cheese and other dairy products (exclude margarine, butter /small amounts of milk for tea and coffee)			

14	**Oil/fat/butter:** Vegetable oil, margarine, palm oil, shea butter and other fats/oils.			
15	**Sugar/sweets:** Sugar, honey, jam, cakes, cookies, pastries and other sugary drinks.			
16	**Condiments/spice:** Tea, coffee, cocoa, salt, garlic, yeast /backing powder, tomato sauce, meat /fish condiments, others			

Part XI: Access to Institutional and Support Services & Collective Marketing

63a. Do you belong to a farmer's association /Co-operative? [1] Yes [0] No

63b. Name of the co-operative/association………………………..

Part XII: Climate risk factors

64a. What are some of your perceptions on the changing water levels and aquaculture/fisheries in this SWB?

64b. Do you think this SWB will be here permanently? [1] Yes [0] No

65. Have the following parameters involving aquaculture production been affected (degree of effect) by climate change in this area (i.e increasing water level, increasing temperatures etc? Use the scale 1= A little 2= Much 3= Very Much

a) Fish production
b) Income
c) livelihood

66. What do you think could be done to mitigate climate change and its impact on aquaculture in this SWB? ....

67. What are the potential climate smart aquaculture systems adaptable to communities around this SWB? ………………………………………………………………………………

Part XII: Challenges

68. What is the **main** challenge related to aquaculture/fisheries are you facing in this SWB?

1.Lack of water 2 Expensive feeds 3Scarce feeds 4 Lack of market 5 Predators of fish 6 Poor quality fingerlings 7Lack of extension services 8 Poor weather 9Thieves

10 Expensive labor 11 Lack of capital 12Flooding 13. Poor transport 14 Resource user conflicts 15.Other, specify

69. What do you think is a solution to those challenges?

70. Finally, Have the following parameters improved, decreased, or not changed since you started participating in aquaculture farming activities (tick appropriately); **probe and record only if associated with aquaculture**

Parameters	**Improved**	**Decreased**	**Low change**
Food security			
Access to good nutrition			
Adoption of aquaculture			
Improved market linkages			
Improved collaboration and partnership			
Housing or shelter			
Payment of school fee			
Initiation of other projects/diversification			
Family stability			
Improve social status			
Any other,(specify)			

71. Any additional comment?

Thank you for your time!