KENYA MARINE AND FISHERIES RESEARCH INSTITUTE

FRESH WATER SYSTEMS

A technical report on the economic potential (fisheries carrying capacity) of small water bodies in Siaya, Kakamega, Migori, Nyeri, Meru and Embu, and dissemination to stakeholders for development of blue economy

A TECHNICAL DRAFT REPORT

KMFRI/GOK/RES/C825(1)

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DOCUMENT CERTIFICATION

Certification by Director (Fresh Water Systems)

I hereby certify that this report has been done under my supervision and submitted to the Director.

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DECLARATION

We, Kenya Marine and Fisheries Research Institute (KMFRI), Kisumu and Aquaculture Business Development Programme (ABDP) participants herein submit a technical report for the socio-ecological studies of selected Small Water Bodies (dams and reservoirs) in order to establish their Carrying capacity for fisheries production. To the best of our knowledge all the information contained in this report represents the accurate and truthful representation of the survey and findings as related to the report.

ACKNOWLEDGEMENT

We wish to thank the International Fund for Agricultural Development (IFAD) and The Government of Kenya through the Aquaculture Business Development Programme (ABDP) for funding the expedition. We also wish to thank all the KMFRI, Kisumu, Kenya Fisheries Service - KeFS (Ms. Christine Etiegni, Mr. Stanley Tonui and Alice Hamisi), County Programme Coordinators (CPCs) and Fisheries Directors (from Nyeri, Kirinyaga, Meru, Tharaka Nithi, Embu, Kiambu, Kajiado, Machakos, Homa Bay, Migori, Kisii, Kisumu, Busia, Siaya and Kakamega), County administrative officers and dam management units for their valuable contributions.

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Executive summary

Small water bodies (SWBs), including dams, are the most numerous freshwater environments globally, are critical for freshwater biodiversity and are increasingly recognized for their role in ecosystem service delivery. SWBs often represent the best remaining examples of intact freshwater habitats and are the most likely to remain unpolluted, often being a refuge for species which have disappeared from larger, more degraded, water bodies. In Kenya, SWBs remain among the least investigated part of the water environment and are largely excluded from fisheries management planning. The situation has now changed with the government and private sector focusing on fisheries and aquaculture as key drivers of the blue economy and food and nutrition security. SWBs offer a new frontier to increase fish production in Kenya. It is however imperative to promote sustainable fisheries development that does not degrade the environment and takes into account all sectors (resource users) involved. It is against this backdrop that the Aquaculture Business Development Programme (ABDP) supported a survey of SWBs covering 15 counties in Western and Central regions of Kenya. The aim of the activity was to establish biological, ecological and socio-economics carrying capacities for fisheries development in SWBs. Socio-economics, land characteristics, water chemistry, plankton, macroinvertebrates, fisheries data were used to estimate the social and trophic state indices for each of the surveyed SWBs. The two indices together with the physical attributes (area and depth) were then used to estimate the Carrying capacity (metric tonnes, mt) of fish for each dam. Results indicate that the surveyed dams have a Carrying capacity of about 72,894 mt of fish. Masinga dam has the highest Carrying capacity followed by Kamburu, Kindaruma, and Gitaru with 51,217, 15,135, 2,409, and 2,351 mt respectively. All the four dams are in Embu County were within the River Tana system. Other dams with substantial carrying capacity are Kiserian (522.95 mt) and Chinga (396.90 mt) in Kajiado and Nyeri Counties respectively. In the Western Kenya region, Yao Kosiga Dam in Homa Bay County exhibited the highest potential (47 mt). This was followed by Olasi (41.98 mt) and Karamu (39.46) both located in Migori County. Overall, the central region had a potential of 72,447 mt while that of western region was only 447 mt. The comparatively high potential in the central region is attributable to the huge hydro-electric dams. Given the shallow depths of all the dams in the western region, restocking with limited or no supplementary feeding is recommended. The same is true for the Central region except for Kiserian Dam in Kajiado and the hydro-electric dams in Embu that are deep enough to accommodate cage fish farming. Despite their huge potential for fish production, the hydro-dams are not accessible to local communities since they are owned by KenGen. Most of the surveyed dams had multiple purposes, a recipe for conflict among resource users. To avoid conflict and improve performance, development of SWBs strategy is recommended. The strategy will among other things detail: investment under the blue economy precipice; optimize operation by re-defining the dam objectives; economic analysis, rehabilitation, rebranding and upgrade; dam safety; sedimentation; and research.

1 Introduction

Kenya is richly endowed with Fresh Water Systems (FWS) comprising lakes, rivers and dammed reservoirs which provide several livelihood opportunities to riparian fishing communities and beyond. These FWS account for about 73% of national fisheries production and 0.37% of GDP, with the remaining proportions of landings (27%) and value (0.13) jointly supplied by marine sources and aquaculture (MoALF, 2016). Fish is a low-fat high quality protein providing omega-3 fatty acids and vitamins such as D and B2 (riboflavin) that can play an important role in reducing the high prevalence of under nutrition in Kenya where 26% of under-5 population are suffering from chronic malnutrition (KNBS et al., 2015; USAID, 2017). However, in spite of the economic significance of FWS and their potential to contribute towards food and nutritional security the riverine, dams and small lakes fisheries which are estimated to contribute only 2% of Kenya's annual landings are not well recognized at national level, thus they are not properly reflected in the national economic statistics. For instance, while there are at least one thousand (1000) dams in the country, many of which are stocked with fish, national statistics only capture four main dams, namely: Jipe, Tana and Turkwel.

Kenyan dams provide a critical source of water for domestic, livestock, fisheries, irrigation and other commercial purposes. Therefore, the Government of Kenya (GoK) through the National Water Master Plan (NWMP) 2030 anticipates the development of a total of 17,860 dams and water pans towards the realization of Kenya Vision 2030. Since there are already several dams and small reservoirs in Kenya, with others still earmarked for construction, there is potential for the application innovations to increase their fisheries production in order to bridge the national per capita fish consumption deficit of 4.0 kg against the African average of 10 kg (FAO, 2019). Besides, owing to their relatively small size and the fact that most dams are either state-owned or communal property, their fisheries can be easily managed by local governments or dependent communities, thereby increasing the possibilities of enhancing their productivity. With the witnessed reduction in fisheries contribution to Kenya's GDP from 0.7% in 2014 to 0.4% in 2017 due to decline in capture fisheries, the utilization of Small Water Bodies (dams, pans and reservoirs) for fisheries production can significantly increase landed quantities while at the same time reduce malnutrition.

Given two most common fisheries innovations for Small Water Bodies (SWBs) i,e. stocking and cage culture, fish stocking is probably the oldest and most successful intervention from a fishery development perspective when used in the right manner and in the right location. Cage culture is less preferable as an alternative innovative technology due to the relative shallowness of water depths in SWBs which can lead to enhanced eutrophication and floatation challenges for cages during lean seasons. On the other hand, stocking of juveniles can maintain fish populations or supplement those produced naturally, thereby increasing fish abundance and fisheries yields. However, in some instances introductions have been found to be counter-productive, exhibiting undesirable impacts such as disruption of fish communities, loss of wild strains and reduced genetic diversity (Li and Moyle, 1993; Schramm and Piper, 1995). Nonetheless, before undertaking the stocking of SWBs there are several precautionary approaches that need to be carefully considered in order to mitigate adverse impacts on the environment, biota and livelihoods of riparian communities. Within an ecosystem based management approach, Carrying capacity (metric tonnes, mt) has been identified as the key consideration which helps to set the upper limits of production given the environmental limits and

social acceptability (Cross, 2013). According to GESAMP (1986), Carrying capacity refers to the ability of the environment to accommodate a particular activity or rate of activity without unacceptable impact".

Based on this premise, the Kenya Marine and Fisheries Research Institute (KMFRI) undertook research in selected SWBs in Kenya with the aim of establishing their biological, ecological and socio-economics carrying capacities for species introductions. This activity was collaboratively conducted with the Aquaculture Business Development Programme (ABDP), the Kenya Fisheries Service (KeFS) and fifteen (15) County Governments implementing the ABDP. The ABDP is a partnership project between the Government of Kenya, and the International Fund for Agricultural Development (IFAD), being implemented by the Ministry of Agriculture, Livestock, and Fisheries under the State Department for Fisheries, Aquaculture and the Blue Economy.

1.1 Objectives

The overall goal of the programme is to increase the incomes, food security and nutritional status of the wider communities of poor rural households involved in aquaculture in the targeted Counties.

The specific objectives of the SWBs assessment included:

i) To assess the history and prevailing status of fisheries development, ecological integrity and socio-economics dynamics;
ii) To determine the carrying capacity within an ecosystem based approach (fisheries, environment and socio-economics); and
iii) To provide management options for sustainable fisheries development.

Within the Ecosystem Approach to Fisheries Management (EAFM), the assessment encompassed aspects of fisheries and aquaculture, water quality, land characteristics, macro invertebrates, plankton, and socio-economics.

2 Materials and Methods

2.1 Study area

The study area covered SWBs in all the programme counties within Western and Central regions, such as, Homa Bay, Migori, Kakamega, Kisii, Kisumu, Siaya, Busia, Kirinyaga, Nyeri, Meru Tharaka Nithi, Embu, Kiambu, Machakos and Kajiado (**Fig. 1 and 2**). Whereas ABDP is national in scope, its implementation took into account poverty targeting criteria in selecting the operational Counties. The target Counties were those with high concentrations of aquaculture activity, high production, existing sectoral infrastructure (processing, marketing and research), adequate water resources and marketing potential. A detailed description of the study sites can be found on Appendix 1.

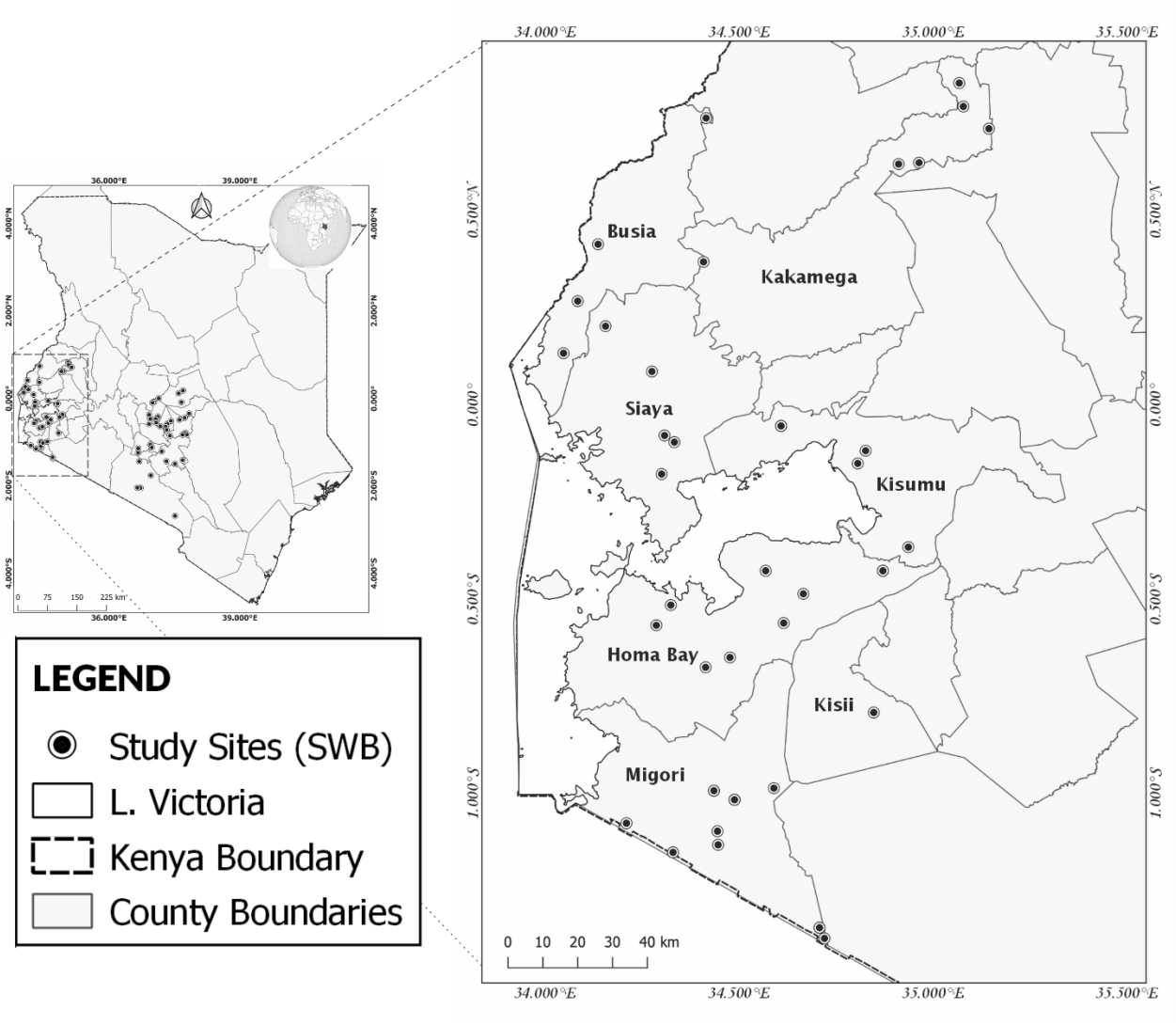


Figure 1. Study sites in Western Region of Kenya.

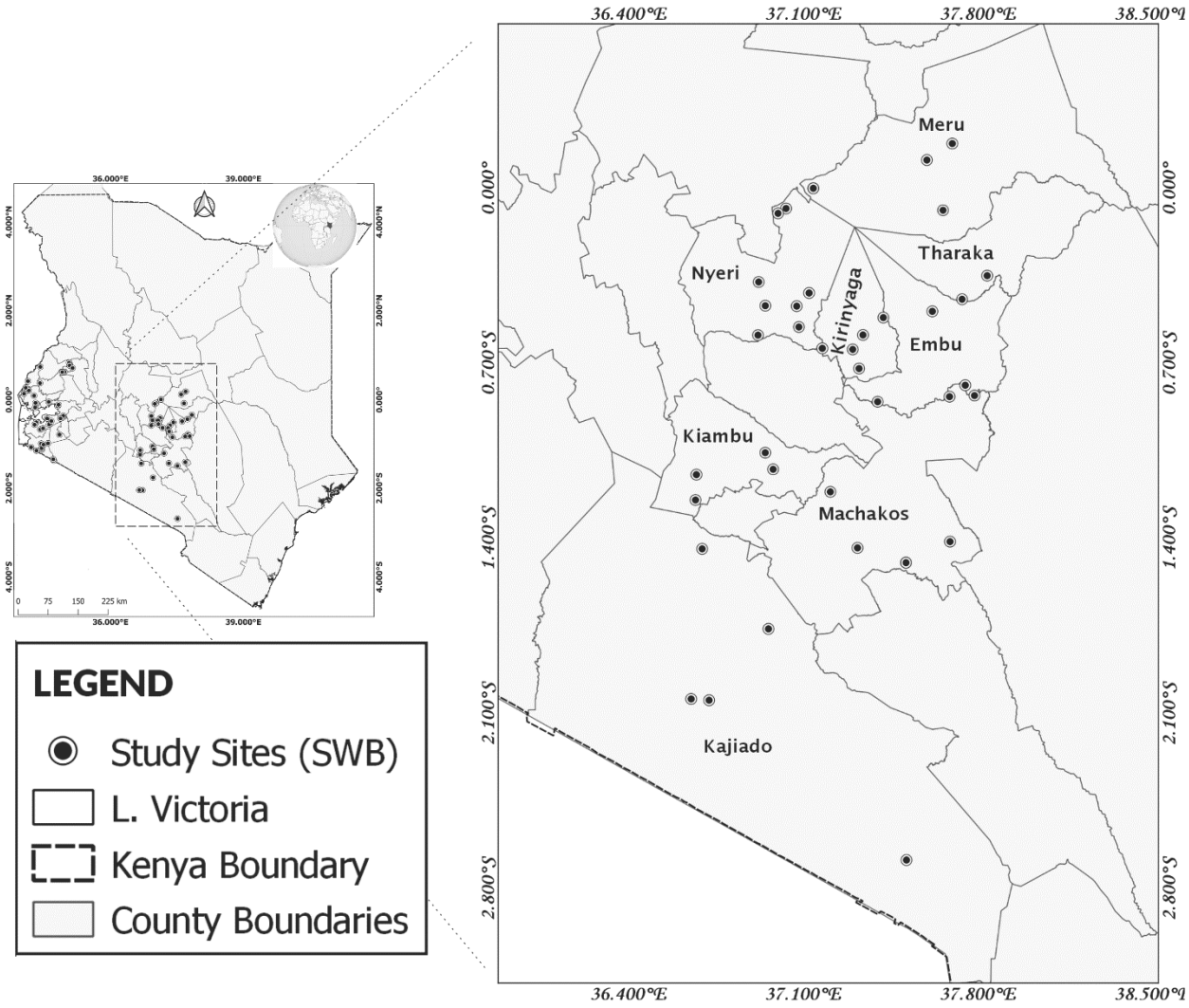


Figure 2. Study sites in Central Region of Kenya.

The landscape of the surveyed regions ranged from undulating, gently sloping to plains. Some areas in the Central region are very close to Mount Kenya which influenced there climatic conditions depending on whether they are on the windward or the leeward side of the mountain. The climatic condition of any given area would influence the recharge, water circulation and the water temperature of a given reservoir. Nyeri County, for example, which is close to Mount Kenya and with an undulating landscape receives high rainfall and has several perennial dams recharged through springs. Figures 3 and 4 show annual weather patterns for various counties. The water temperatures of most dams during the survey (July-August) were cold for optimal growth performance of tilapia. Considering that the dry seasons are much colder than during the rainy season, it is postulated that the measured water temperatures were the coldest. The average annual temperature in Nyeri is 17.1 ^{0}C while the annual precipitation is about 1004 mm. Kirinyaga has three different types of climate; Tropical Savanna (95%), Oceanic (2.5%) and Warm-summer Mediterranean (2.5%). The ambient temperatures are higher during rainy season than in dry season. The average annual temperature is 20.6 °C while the annual rainfall is 1138

mm. The climate in Meru is warm and temperate. There is more rainfall in the months of October to December than in March to May months in Meru. The average annual temperature in Meru is 18.4 °C. Precipitation here is about 1602 mm per year. Tharaka Nithi has two types of climate; Tropical Savanna (56%) and Warm-summer Mediterranean (44%). In months of October to December, there is much less rainfall than in March to May. The average annual temperature in Tharaka Nithi is 20.6 °C. Precipitation here is about 1288 mm per year.

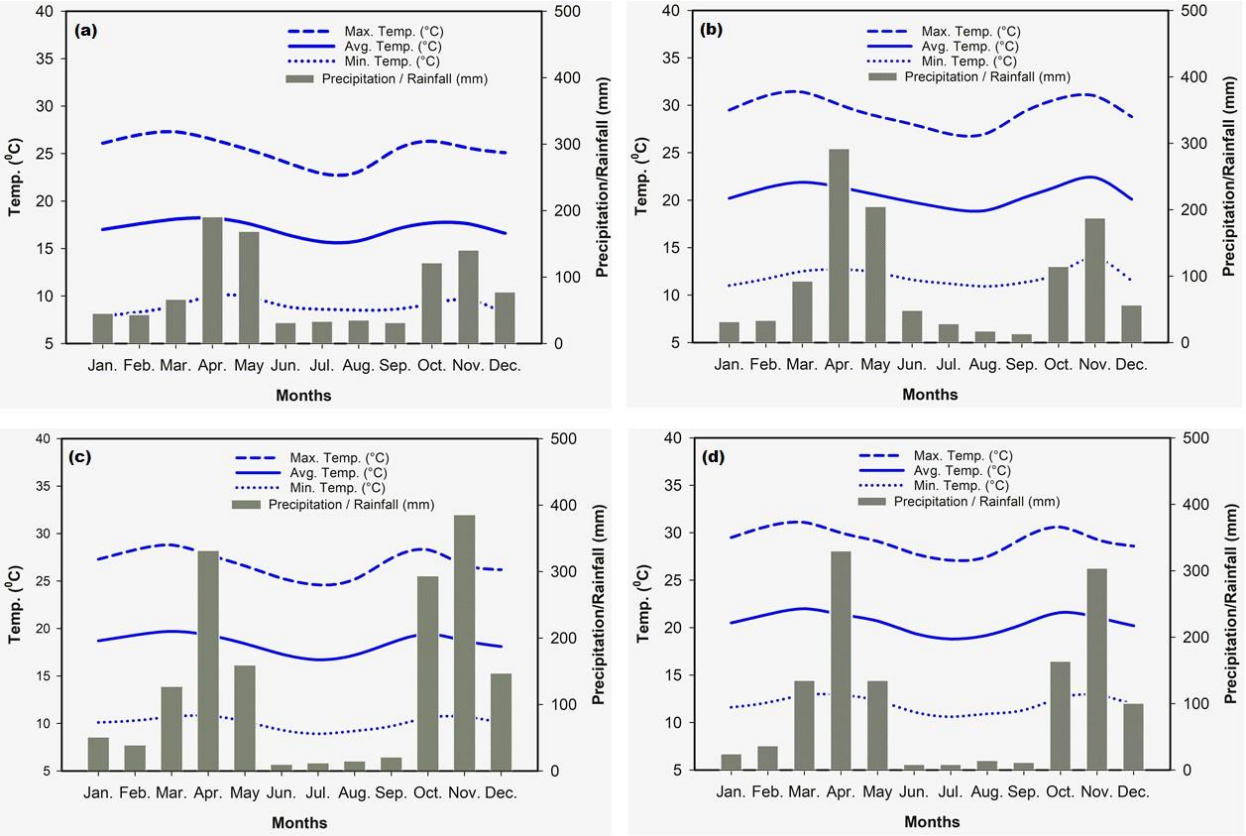


Figure 3. The average annual weather patterns of (a) Nyeri; (b) Kirinyaga; (c) Meru; and (d) Tharaka-Nithi Counties.

The Embu climate is tropical. In winter (Oct. – Dec.), there is much less rainfall than in summer (Mar. – May). The average annual temperature is 20.2 °C. The rainfall here is around 1120 mm per year. The Kiambu climate is warm and temperate. There is a great deal of rainfall even in the driest month. The temperature here averages 18.8 °C. In a year, the rainfall is 962 mm. There are two major climatic conditions in Kajiado; hot semi-arid climate (38%) and tropical savanna climate (33%). The temperatures are colder during dry periods of the year than during wet periods. The average annual temperature is 20.1 ^{0}C while the annual precipitation is 509 mm. The Machakos climate is mild, and generally warm and temperate. The summers here have a good deal of rainfall, while the winters have very little. The temperature here averages 19.0 °C with an annual mean rainfall of 830 mm.

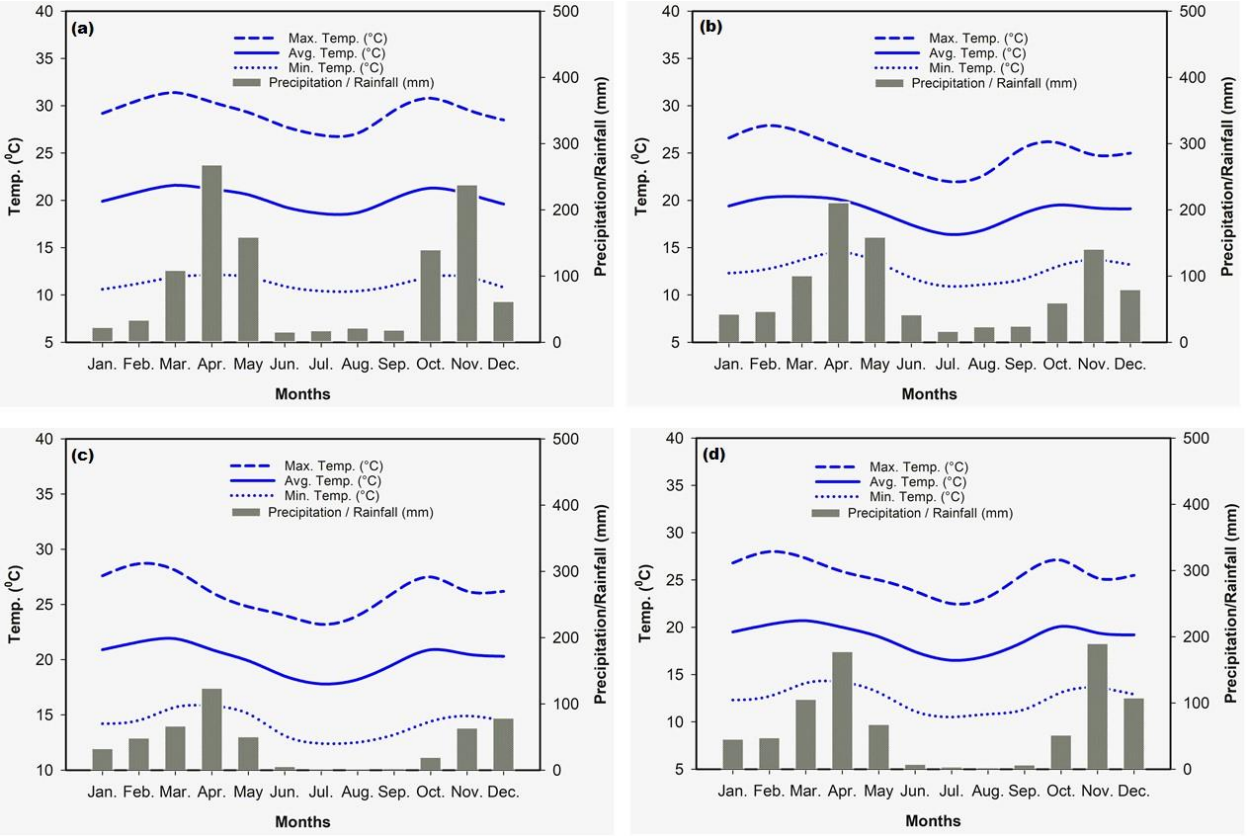


Figure 4. The average annual weather patterns of (a) Embu; (b) Kiambu; (c) Kajiado; and (d) Machakos Counties.

2.2 Data collection and analysis

2.2.1 Socio-economic

The socio-economics research team undertook a questionnaire survey which mainly collected 5-Likert point perceptions on water usage, resource use conflicts, gender and group dynamics, climate risks, ancillary services, social acceptability and investment scale. Coding of the data was done to allow for thematic analyses; this involved identification of patterned meaning in the dataset.

Observations on the general environmental conditions of the basin/ catchment including the land use patterns, substrate types, basin vegetation cover and the climatic elements, were recorded immediately on arrival at the site.

2.2.2 Water quality

Assessment of water characteristics followed published standard methods for aquatic environmental studies (APHA, 2012). Portable water physico-chemical electronic sensor-based probes were used to take measurements at every sampling site/ dam. Data were 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; column depth (m), temperature (^{o}C), dissolved oxygen (mgL^{-1}), conductivity (µS cm^{-1}), pH, turbidity (Formazin Turbidity Units -FTU), Salinity (ppt), Oxidation-Reduction Potential (ORP) and Total Dissolved Solids (TDS) (mgL^{-1}). Water transparency measured as Secchi depth (photic depth) was measured using a standard Secchi disk of 20 cm diameter.

Optimal level of nutrients (nitrogen and phosphorus) are important for autotroph productivity that forms the primary source of energy for the heterotroph predators. Elevated or reduced nutrient levels would lead to a shift in habitat characteristics with consequential impact on biotic health, structure, abundance and overall change to ecological processes. The shifts from optimal levels will ultimately result in reduced fish productivity in the water body. This study therefore investigated the 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) and silicate species concentrations on all the study sites. Chlorophyll-a, a measure of levels of primary production which acts as the primary energy source for the heterotrophs was also measured.

Dams are either closed or open systems with rivers or streams discharging into the water bodies. Three sites were identified and sampled where possible, two at the littoral areas and one at the center. The samples were then composited to make one sample. Water samples were collected using a Van Dorn water sampler at the surface. The water samples for soluble nutrient fractions were then 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 aluminum foil before refrigeration at about 4 ^{0}C. The samples were later on transported to the laboratory and analyzed according to methods adopted from APHA (2012).

2.2.3 Microbiology

Water samples were collected in the field and analyzed in situ by using a portable incubator test kit Wagtech Potalab +(M). Membrane Filtration method was used to determine the Total Coliforms and Fecal Coliforms at 37^{0}C and 44^{0}C, respectively. Total coliforms and fecal coliforms were detected and quantified using selective and differential culture media, Lauryl Sulphate Broth was used for cultivation of the organisms, where three composite samples were analyzed per each dam. Sample volumes depended on the water turbidity of the sampled dam.

Plate 1. Portable Field Incubator for field water microbiology test.

2.2.4 Plankton

Samples were taken using a horizontal 2.2-litre Van Dorn sampler from subsurface 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 microscopic analysis. Phytoplankton cells were identified to species level where 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).

Zooplankton samples were collected using 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, 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 (1992). Estimates of abundance of zooplankton were made from counts of sub samples under a Leica dissecting microscope (x25) taking into account the sample, subsample and water volume filtered.

2.2.5 Macroinvertebrates

At each sampling station triplicate samples were taken from the shoreline and the bottom, washed with sieve having a mess of 500 µmm, sorted live in a white tray then preserved in (70%) ethanol. 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 failed, the feeding guild was assigned according to Gerber and Gabriel (2002) and Chesire et al. (2005). Macroinvertebrate community structure and functional composition was described in terms of number of genera per station, relative abundance, numerical abundance, evenness, dominance, diversity, species richness, and functional feeding guilds of all taxa. The ratios of the various FFGs were calculated based on numerical abundance.

2.2.6 Fish/Fisheries/Aquaculture

Fish samples were collected using a beach seine 50 m long with a depth of 3 m and a stretched mesh size of 1". The data collected was supplemented with commercial catches from fishermen where possible. Fish measurements (morphometrics) were taken and fish identified to species level. The health status of fish was assessed by using the standard fish health diagnostic protocols (Aloo, 2012). Additionally, feedback from the aquaculture structured questionnaires on diseases was used to complement the field study. Aquaculture sampling used a semi-structured questionnaire which was administered to community leaderships, surrounding communities, aquaculture systems farmers, hatchery owners and feed processing owners.

2.2.7 Calculation of carrying capacity

i) Socioeconomics Index

A composite Socioeconomics Index (SI) was calculated as a measure of the general socio-economics carrying capacity acceptable for any fisheries development interventions in the SWBs. This percentage score was derived from weighted averages of the specific ordinal scores subject to the Likert scale ratings of various socio-economics perception indicators. The overall socio-metric scale was segmented as follows: $0 \leq$ Unsuitable < 0.2; $0.2 \leq$ Subsistence < 0.4; $0.4 \leq$ Low-scale commercial < 0.6; $0.6 \leq$ Medium-scale commercial < 0.8; and $0.8 \leq$ Large-scale commercial < 1.0.

ii) Trophic status index

Biological productivity of any given water body can be limited by either light or nutrient availability. Light irradiance in the water column would therefore be influenced by algal or suspended sediment turbidity. The calculation of trophic state index (TSI) therefore took into consideration

the Secchi Depth (SD) measurement and concentration levels of Total Nitrogen (TN), Total Phosphorus (TP) and Chlorophyll-a (Chlor.). The TSI was first calculated for individual parameters before calculating the average value of all the parameters.

$$\text{TSI (SD)} = 10*(6 - (\frac{In(SD)}{In\ 2}))$$

$$\text{TSI (Chlor.)} = 10*(6 - (\frac{2.04 - 0.68\ In\ (Chlor.)}{In\ 2}))$$

$$\text{TSI (TP)} = 10*(6 - \frac{\frac{In\ 48}{TP}}{In\ 2})$$

$$\text{TSI (TN)} = 54.45 + 14.43\ \ln(TN)$$

$$\text{TSI} = (\text{TSI (SD)} + \text{TSI (Chlor.)} + \text{TSI (TP)} + \text{TSI (TN)})/4$$

iii) Carrying capacity

The Carrying capacity (mt) takes into account the socio-economics index, trophic state index and physical size (area and euphotic depth) of the dam. The estimated carrying capacity (mt) is scaled down by 30% to mitigate against overestimation given that dams' physical-chemical attributes exhibit huge seasonal variability.

$$C = ((A*D\_e*SD)*SI*TSI)\times 30\%$$

Where C = Carrying capacity (mt), A = area of dam, D_e = Euphotic depth, SD = Stocking density of fish in kg m^{-1} SI = Socioeconomics Index, and TSI = Trophic State Index.

3 Results, Discussion and Conclusion

The findings of the socio-ecological survey of the 89 dams and reservoirs, found in the 15 Western and Central Kenya ABDP Implementation counties have been summarized in this section. The dams/ reservoirs have been systematically clustered in their respective counties, beginning with the Western Kenya counties and ending with the Central Kenya Counties. For each dam/ reservoir, a pictorial illustration of the land characteristics is presented with a detailed caption describing the observed physical nature of the surrounding/ basin landscape. The findings of the main parameters used in the socio-ecological assessment to derive the carrying capacity, are subsequently tabulated.

Observations on key social and ecological indicators are then stated in summary thematic statements on physicochemical characteristics, indicator microbial counts, plankton assemblage, resident fish fauna and social acceptability of the proposed aquaculture business investments. Further, data on existing fish fauna have been visualized graphically to compare the species diversity and abundance in each dam/ reservoir.

Finally, conclusive statements and recommendations on the best strategic opportunity for aquaculture investment have been made. This takes into account the determined carrying capacity, the social acceptability and the implied viable aquaculture business option

3.1 Western region

3.1.1 Kisii County

i. ***Ibeno dam***

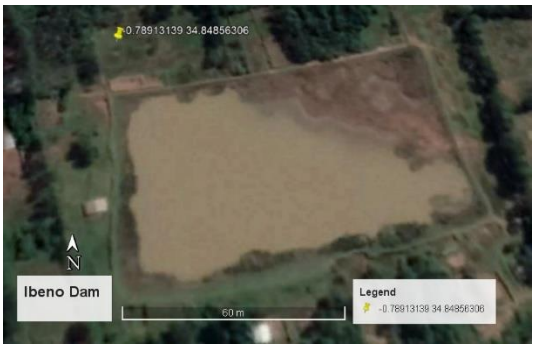


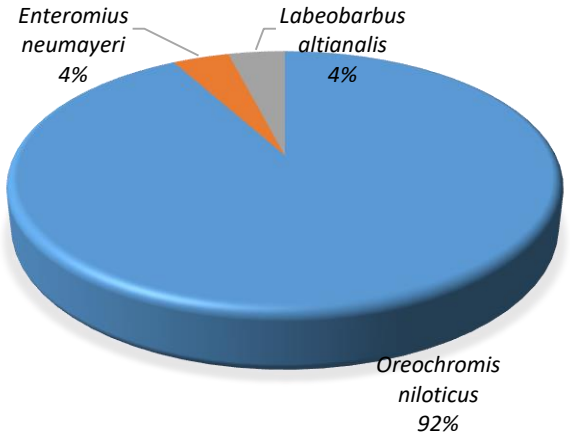
Plate 2. Located around GPS point, -0.7891, 34.8486, the dam lies within a forested landscape with exotic trees (mainly Eucalyptus) dominating the tall shady groves. Almost derelict surrounding land highly impacted by excavations for brick making. Muddy substrate.

Table 1. Socio-ecological findings of Ibeno dam

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.47	0.4 ≤ Low-scale commercial < 0.6	Suitable for low scale commercial fishing.	2.06
Trophic State Index (TSI)	72.6	> 70 (Hypereutrophic)		
Ammonium (µg/l)	16.56	2000 ug/l	Best condition for fish growth	
Dissolved Oxygen (DO) (mg/l)	5.8	5mg/L and above	Best condition for fish growth	
Temperature (^{0}C)	28	20-31 for warm adaptive fish <20 for cold adaptive fish	The observed value is favorable to fish farming for warm temperature adaptive fish.	
pH	7.67	6-9	The observed value is within the range for fish growth	
TN:TP	3.7	10 - 30	Nitrogen limited. This can promote the growth of	

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
			undesirable algae like cyanophytes	
Secchi Depth (m)				
Fish condition factor	1.67 (*E.p*) and 2.3 (*O. n*)	2.9 - 4.8	Poor growth performance. Supplementary feeding required for restocking with *O. n. E.p* is a fish of low economic value	
Microbial contamination indicators (Fecal Coliforms) cfu	0	$10^3 – 10^4$	No microbial contamination. Highly Suitable for fish farming.	
Phytoplankton Shannon index H	1.456	Species that were found indicated that the water is suitable for fishing although they were not well represented in terms of productivity.	Suitable indicator favoring fish farming in terms of productivity	
Phytoplankton Indiv per litre	1090	Suitable for fish farming	Suitable indicator favoring fish farming in terms of productivity	
Zooplankton abundance (ind.L-1)	29.2	Secondary production was low	Low suitability for fish farming unless its productivity is enhanced through sound management	
Zooplankton Shannon index H	1.49			

Given that this SWB reported nil fecal coliforms, an indication of non- pollution activities within and around the dam, the embankment is still in good shape to help stop storm drains into the dam. The phytoplankton species show that the water is suitable for fishing although not very well presented in terms of productivity. On the other hand, physicochemical parameters suggest sound environmental conditions for fish farming. However, the poor growth performance of the resident fish shows that there is not enough food in the natural environment and therefore restocking the dam will require supplementary feeding. Socially, the dam had very low indications of community based group formation and a much lower social acceptability score, thus generally compromising the potential scale of investment achievable. As such, capacity building initiatives meant to promote group cohesion and skills coupled with a proper community engagement and involvement framework is required for this dam in order to improve fisheries development prospects. In the event of restocking, which has been recommended as a fisheries development option for this county's SWB, supplementary feeding will be required in light of the poor growth performance.



3.1.2 Migori County

i) Silanga dam

Plate 3. The reservoir is situated around GPS point -1.0136, 34.4896 at basin with a mix of cultivated crops (mostly sugarcane, plantains, and planted trees, mostly eucalyptus. Water comes mainly from groundwater/ natural spring seepage. The entire shore is covered by predominantly hippo grass. Reservoir sits in a deep basin and is evidently silted from heavy shoreline substrate and deep gullies along feeder roads. Reservoir is fed by runoff and drains into River Kajami. Water used for washing clothes and bathing on site. The dominant macrophyte is hippo grass. The others are the submerged *Egeria densa* and the free floating water lilies.

Table 2. Socio-ecological findings of Silanga dam

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.49	0.4 ≤ Low-scale commercial < 0.6	The dam is suitable for low scale commercial fisheries	8.9964
Trophic State Index (TSI)	60.9	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium-ions (µg/l)	46.34	2000 ug/l	Within recommended limit	
Dissolved Oxygen (DO) (mg/l)	2.62	5mg/L and above	Growth will be slow if exposure to low dissolved oxygen is continuous.	
Temperature (^{0}C)	24.3	20-31 for warm adaptive fish <20 for cold adaptive fish	The observed value is favorable to fish farming for warm adaptive fish.	
pH	6.34	6-9	The observed value is favorable to fish farming for warm adaptive fish.	
TN:TP	2.9	10 - 30	Nitrogen limited. This can promote the growth of undesirable algae like cyanophytes	
Secchi Depth (m)	0.6	0.35 – 0.5	Phytoplankton becoming scarce	
Fish condition factor	1.85 (*O. l*)	2.9 - 4.8	The fish were performing poorly. An alternative to *O. leucostictus* should be considered for introduction.	
Microbial contamination indicators (Fecal Coliforms) cfu	2300	$10^3 – 10^4$	Good water quality for growing fish	
Phytoplankton Shannon index H	0.7054	Families like diatoms were more abundant showing that the water is good for fish growth	Preferred species for fish growth, availability of food for aquatic animals	
Phytoplankton abundance (ind.L^{-1})	5.5226	Suitable for fish growth	Good for aquaculture practices	

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Zooplankton abundance (ind.L^{-1})	114.3	100-500	Suitable for fish farming availability of good prey (crustaceans)	
Zooplankton Shannon index H	2.586			

The microbial load of the dam reported is low, a clear indication that the dam is less loaded with pathogens that can cause infections. The fairly high counts of fecal coliforms could be emanating from domesticated animals within the catchment. There is need for an embankment to help stop storm drains into the dam. The phytoplankton abundance was relatively low that renders the dam unsuitable for aquaculture. However, the water quality parameters indicated that the dam registered low dissolved oxygen and nitrogen limited conditions that may promote the growth of undesirable algae like cyanophytes. The physicochemical parameters indicated sound environmental conditions for fish farming. The poor growth performance of resident fish may be as a result of prolonged exposure to low DO and relatively low primary and secondary productivity. This dam had relatively high social acceptability and there was an indication of very high potential for investment to realize socioeconomic benefits.

The cause and extent of low DO levels and the causative factors for low growth performance of fish needs to be re-examined before any tangible remark and mitigation measures can be made. Presently, the dam is a suitable candidate for catfish culture that may feed on detritus.

ii) Konyona

Plate 3. Located in Uriri sub-county around GPS -0.9904, 34.4364, and altitude of 1392 m a.s.l., the reservoir is the emergence point of abundant natural springs within the area. The dam is marked by short grass dominating the water land interface. Scanty shrubs surround the exterior boundaries while sugarcane and maize plantations occur within the basin.

Table 3. Socio-ecological findings of Konyona dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.43	0.4 ≤ Low-scale commercial < 0.6	Low scale subsistence farming	0.43
Trophic State Index (TSI)	66.3	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium (µg/l)	211	2000 ug/l	Within recommendable range.	
Dissolved Oxygen (DO) (mg/l).	7.21	5mg/L and above	Favorable to fish growth	
Temperature (^{0}C)	24.2	20-31 for warm adaptive fish <20 for those in cold places	Preferred temperature for fish growth	
pH	7.4	6-9	Best growth	

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
TN:TP	20.8	10 - 30	No limiting nutrients. Can support diverse population of algae	
Secchi Depth (m)	0.2	0.35 – 0.5	Turbidity becoming excessive.	
Fish condition factor	2.01 (O.l) and 2.03 (O. n)	2.9 - 4.8	Both species were performing below the threshold.	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	1400	103 – 104	Recommended for fish farming	
Phytoplankton abundance (ind.L-1)	415.013	Most species find like chlorophytes are good for Zooplankton and other aquatic animals	Preferred species for fish growth	
PhytoplanktonShannon index H	1.699	Suitable for fish growth	Good for aquaculture practices	
Zooplankton abundance (ind.L-1)	559.6	100-500		
Zooplankton Shannon index H	1.496			

The fecal coliform counts fell within range of acceptance, though high agricultural activities contribute to the high levels of turbidity due to surface run-offs. High dissolved oxygen was observed, an indication of suitability for fish growth. Overall, the physicochemical parameters indicated sound environmental conditions for fish farming. This dam was dominated by a catch of *Oreochromis leucostictus* in totality (100% abundance) whose performance was fair as indicated by the condition factor (2.03). Relatively fair social acceptability was registered and there was an indication of moderately low potential for investment to realize socioeconomic benefits. The ecological conditions are good for fish culture except for the turbidity which may inhibit primary productivity. The dams within Lake Victoria basin have been used as refugia for endangered tilapiine species. K'onyona dam should therefore be conserved for its pure species of *Oreochromis leucostictus*.

iii) Mahena

Plate 4. Mahena dam is a small water mass around GPS point -0.9838, 34.5910. The reservoir is charged mainly by ground water but is also the convergence point of all land surface-based runoff within the basin. Water flows out slowly into the receiving valley downstream. The entire basin is characterized by cultivated cropland with sugarcane dominating. Dense mix of macrophytes consisting of water ferns, typha, and other grasses surrounding the dam.

Table 4. Socio-ecological findings of Mahena dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt
Socio-economics	0.47	0.4 ≤ Low-scale commercial < 0.6	Averagely recommended for low scale commercial fishing.	1.833
Trophic State Index (TSI)	64.6	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium (µg/l)	217	2000 ug/l	Within recommendable range	
Dissolved Oxygen (DO) (mg/l)	4.47	5mg/L and above	Growth will be slow if exposure to low dissolved oxygen is continuous.	
Temperature (^{0}C)	25.2	20-31 for warm adaptive fish <20 for those in cold places	Preferred temperature for fish growth	
pH	7.03	6-9	Best growth	Best growth
TN:TP	26.4	10 - 30	No limiting nutrient. Can support diverse population of algae	
Secchi Depth (m)	0.3	0.35 – 0.5	If turbidity is from phytoplankton, the dam is in good condition.	
Fish condition factor	1.81 (*O.l*)	2.9 - 4.8	The fish was performing poorly. Need to introduce a suitable aquaculture candidate.	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	100	$10^3 – 10^4$	Recommended below minimum threshold, good for fish farming.	
Phytoplankton abundance ind.L^{-1})	59	Low abundance needs enhancement	Recommended for small scale Aquaculture	
Phytoplankton Shannon index H	2.189	Low diversity of species	High diversity thus providing diverse food for the secondary predators.	
(Zooplankton abundance ind.L^{-1})	516	100-500	Recommended for small scale fish farming due to abundance diversity	
Zooplankton Shannon index H	1.187			

The microbial and physico-chemical variables showed recommendable levels that would support optimal growth of fish. TN:TP ratio also supported diverse phytoplankton population as observed (2.189). The phytoplankton abundance was low and this could be attributed to grazing by the secondary or tertiary producers. The poor performance of fish could be attributed to competition for available food. Generally, the habitat is in good state to support good fish farming. *Oreochromis niloticus* is a better candidate for culture but the choice would depend on whether the dam should be retained as a refugia for *Orechromis leucostictus* (O. l) or converted for commercial venture.

iv) Olasi

Plate 5. The reservoir sits around GPS point, -1.0741, 34.2108 and is fed by surface runoff with no visible outlet. Basin characterized by scanty trees of majorly the Euphorbias. Open grassland characterizing the background while the foreground comprise bare shoreline and banks from construction.

Table 5. Socio-ecological findings of Olasi dam

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.53	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fishing	41.98
Trophic State Index (TSI)	66.2	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium (µg/l)	2.1875	2000 ug/l	Within the recommended limit.	
Dissolved Oxygen (DO) (mg/l)	5.5	5 mg/L and above	Favorable to fish growth	
Temperature (^{0}C)	24.6	20-31 for warm adaptive fish <20 for those in cold places	Preferred temperature for fish growth	
pH	7.58	6-9	Best growth	
TN:TP	1.7	10 - 30	Nitrogen limited. This can promote the growth of undesirable algae like cyanophytes	
Secchi Depth (m)	0.1	0.35 – 0.5	Dam is too turbid. This may lead to low dissolved oxygen or productivity if turbidity is due to suspended soil particles.	
Fish condition factor	2.15 (*O.l*), 1.48 (*E.p*)	2.9 - 4.8	The performance by *O.l* is fair.I can be considered for semi intensive production. *E.p* performed poorly and is equally a species of low economic value.	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	300	$10^3 – 10^4$	Recommended for fish farming	
Phytoplankton abundance (ind.L-1)	253.6	There is diversity of different families showing a good indication of plenty of food for aquatic organisms	Recommended for fish farming since there is diversity for planktivorous fish.	
Phytoplankton Shannon index H	1.4	Good diversity	Good diversity since there is a lot food for other aquatic organisms	
Zooplankton abundance (ind.L-1)	88.8	100-500		

Zooplankton Shannon index H	2.104	Good diversity		

The dam reported low fecal coliforms which is an indication of non-pollution activities within and around the dam. Embankment is still in good shape to help stop storm drains into the dam. The phytoplankton species found showed a wide diversity and with clearly good abundance which is suitable for fisheries. The physicochemical parameters indicated sound environmental conditions for fish farming except limited nitrogen levels that can promote the growth of undesirable algae like the cyanophytes. The high growth performance shows that there is enough food in the natural habitat and therefore restocking the dam is highly recommended. There was high receptivity with relatively high levels of auxiliary services a clear indication of very high potential for investment to realize socioeconomic benefits beyond what was observed. The socio-ecological attributes were good for fish culture and *Oreochromis leucostictus* showed good performance but *Oreochromis niloticus* can perform much better given the environmental conditions. Since the dams around Lake Victoria have been used as a refugia for endangered fish species, there should therefore be a choice between conservation and commercial venture.

v) Siabai

Plate 6. Siabai dam lies at GPS -1.3432, 34.7091 and altitude of 1727 m a.s.l within a natural spring area. The outer terrestrial basin area is characterized grassland with prominent eucalyptus forests and cultivated crop land. The shoreline has patchy low grass with intervening sedges cover. Sandy substrate.

Table 6. Socio-ecological findings of Siabai dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.49	0.4 ≤ Low-scale commercial < 0.6	Averagely recommended for low scale commercial fish farming	2.73
Trophic State Index (TSI)	62.4	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium (µg/L)	105.31	2000 ug/l	Within recommended limit	
Dissolved Oxygen (DO) (mg/l0	5.3	5mg/L and above	favorable to fish growth	
Temperature (^{0}C)	20.6	20-31 for warm adaptive fish <20 for those in cold places	Within recommended level but require monitoring	
pH	7.63	6-9	Best growth	
TN:TP	19.7	10 - 30	No limiting nutrient. Can support diverse population of algae	
Secchi Depth (m)	0.0	0.35 – 0.5		

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Fish condition factor	2.16 (*O. n*)	2.9 - 4.8	The fish performance was moderate. Better growth can be achieved with interventions.	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	0	$10^3 – 10^4$	Quality water for fish growing.	
Phytoplankton abundance ind.L-1)	253.6	Diatoms and chlorophytes indicate productivity when they are more than 300 cells per litre.	The fish especially planktivo and other aquatic animals can thrive since the dam is productive	
Phytoplankton Shannon index H	0.2647	There is good diversity of aquatic plants	The fish especially planktivo and other aquatic animals can thrive since the dam is productive	
Zooplankton abundance (ind.L-1)	256.3	100-500		
Zooplankton Shannon index H	1.255			

A zero microbial load indicated no fecal contamination. The abundance and diversity of both phytoplankton and zooplankton were good and contusive for fish culture. TN:TP conditions was conducive for good phytoplankton diversity. Other measured physico-chemical variables were also within recommendable levels. Growth performance of the fish caught was above the threshold. The existing *Oreochromis niloticus* is a good candidate for this dam and showed moderate growth performance. However, there is need to establish the standing stock to evaluate whether there is need for restocking. There is very high community receptivity and a very good potential for investment. A low scale commercial fish farming is recommended.
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vi) Gwitembe

Plate 7. An ellipse shaped reservoir lies about GPS point -1.3429, 34.7086 at an altitude of 1759 m a.s.l., within a woody plain and gains water from groundwater sources. It is characterized by bare dyke and shores on one side and a healthy papyrus bush on the other. The substrate is predominantly muddy.

Table 7. Socio-ecological findings of Gwitembe dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.49	0.4 ≤ Low-scale commercial < 0.6	Highly recommended for low scale commercial fish farming	1.26

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Trophic State Index (TSI)	57.2	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium (µg/l)	119.06	2000 ug/l	Within recommended limit	
Dissolved Oxygen (DO) (mg/l)	7.21	5 mg/L and above	Favorable to fish growth	
Temperature (^{0}C)	24.2	20-31 for warm adaptive fish <20 for those in cold places	Preferred value for fish growth	
pH	7.49	6-9	Best growth	
TN:TP	5.0	10 - 30	Nitrogen limited. This can promote the growth of undesirable algae like cyanophytes	
Secchi Depth (m)	0.0	0.35 – 0.5		
Fish condition factor	No fish caught			
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	300	$10^3 – 10^4$	Good water below threshold values, good for fish farming	
Phytoplankton abundance (ind.L-1)	618	300		
Phytoplankton Shannon index H	1.469		Not suitable for fish farming since species like Microcystis and anabaena which are known to produce algal toxic were identified unless if the dams is cleaned	
Zooplankton aabundance (ind.L-1)	571	100-500		
Zooplankton Shannon index H	1.356			

Microbial contamination was low in this dam, indicating minimal pollution from humans. During the period of sampling *Microcystis sp*. and *Anabaena sp.* which produces algal toxins, were found to be predominant. Ammonium, temperature and pH were within the recommended levels except for nitrogen which was limiting and as such can promote growth of undesirable algae like the cyanophytes, microsystis and anabaena. Additionally, the dam was extremely turbid. This dam can be considered for stocking with catfish due to its high turbidity and muddy substrate. There is very high community receptivity and a very good potential for investment.

vii) Nyamome

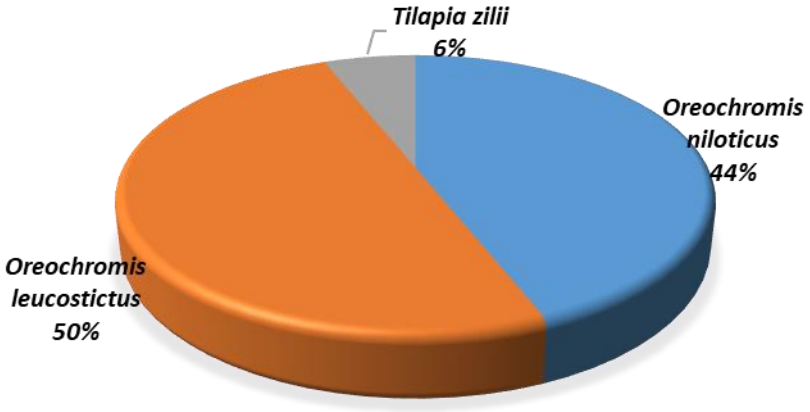
Plate 8: Lying about GPS point, -1.0955, 34.4453 at an altitude of 1356 m.a.sl., the relatively large reservoir drains from groundwater sources, majorly but is also the confluence point of the surface runoff ridges within the area. Surrounding vegetation comprise mainly shrubs. Human settlement occurs all-round the dam. Fringe papyrus, domestic water collection. Several open beaches around the water mass. Sandy substrate.

Table 8. Socio-ecological findings of Nyamome dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.51	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	25.70
Trophic State Index (TSI)	59.7	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium (µg/L)	69.69	2000 ug/l	Within recommended limit	
Dissolved Oxygen (DO) (mg/l)	5.77	5 mg/L and above	Favorable to fish growth	
Temperature (^{0}C)	22.5	20-31 for warm adaptive fish <20 for cold adaptive fish	Preferred value for fish growth	
pH	8.05	6-9	Best growth	
TN:TP	9.6	10 - 30	Nitrogen limited. This can promote the growth of undesirable algae like cyanophytes	
Secchi Depth (m)	0.3	0.35 – 0.5	Turbidity becoming excessive.	
Fish condition factor	1.95 (O. n), 1.89 (O.l)	2.9 - 4.8	Both species were below the reference value. Supplemental feeding recommended. Can be reared at semi intensive level.	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	0	103 – 104	Good water for growing fish	
Phytoplankton abundance ind.L-1)	770.6	Species that were found acy as food for the prey	Suitable for fish farming	
Phytoplankton Shannon index H	1.687			
Zooplankton abundance (ind.L-1)	153.8	100-500		
Zooplankton Shannon index H	1.838			

The dam showed no microbial contamination indicating zero fecal influx. Socio-ecological parameters measured were optimal for good growth and reproduction of fish. The plankton abundance and diversity were good and could support good biomass of fish. TN:TP ratio indicate nitrogen limitation but this may shift with time. The fish condition factor was below recommendable range and this may be because of overexploitation. The dam has high potential considering the

carrying capacity and further research needs to be conducted to establish the cause for low growth performance. Considering the size and ecological parameters, the dam can support good tilapia culture and possibly pen culture practice.



viii) Silanga Mubachi

Plate 9. At about GPS point -1.1502, 34.3312 and at an altitude of 1335 m a.s.l., within Suna West subcounty, the receding reservoir is mainly fed by surface runoff. Dense shrubs cover the immediate surroundings of the receding dam, while human settlement is confined to a trading center on one side of the basin. Dense sedges surrounding the entire dam. Sandy substrate.

Table 9. Socio-ecological findings of Silanga Mubachi.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.49	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fishing	19.73
Trophic State Index (TSI)	60.9	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium (µg/l)	46.34	2000 ug/l	Within recommended limit	
Dissolved Oxygen (DO) (mg/l)	2.62	5 and above mg/L	Growth will be slow if exposure to low dissolved oxygen is continuous.	
Temperature (^{0}C)	24.3	20--31 for warm temperature adaptive fish <20 for cold adaptive fis	Favorable to fish growth	
pH	6.34	6--9	Best growth	

TN:TP	2.9	10 - 30	Nitrogen limited. This can promote the growth of undesirable algae like cyanophytes	
Secchi Depth (m)	0.6	0.35 – 0.5	Phytoplankton are becoming scarce.	
Fish condition factor	1.83 (*O.l*)	2.9 - 4.8	*O.l had* poor performance. Can be reared at semi intensive level	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	2300	$10^3 – 10^4$	Good for fish farming though relatively high counts, with good management practices, the levels can come down significantly.	
Phytoplankton abundance (ind.L-1)	389	300	There is enough species of phytoplankton which can sustain a fishery and have better growth	
Phytoplankton Shannon index H	0.7054			
Zooplankton abundance (ind.L-1)	209.9	100-500	Zooplankton was enough to achieve a suitable growth and better quality of fish	
Zooplankton Shannon index H	2.065			

Fecal coliform counts were within permissible range but relatively high compared to other dams oin Migori. This could be attributed to human settlement and animal wastes within the basin. The waters trophic status was eutrophic, but with low phytoplankton productivity attributable to water purification by the abundant fringing macrophytes. However the diversity of both phytoplankton and zooplankton were fairly good. The DO levels were very low, that prolonged exposure of fish to such condition would affect growth as evidenced in the condition factor of *Oreochromis leucostictus*. The low levels could be due to decomposition of high organic biomass from encrusting macrophytes. The dam in its present status can therefore only effectively sustain catfish culture. In order to improve the ecological status, there is need to rehabilitate the dam through macrophyte removal. Socioeconomically, the dam is recommended for low scale commercial fish farming.

ix) Karamu dam

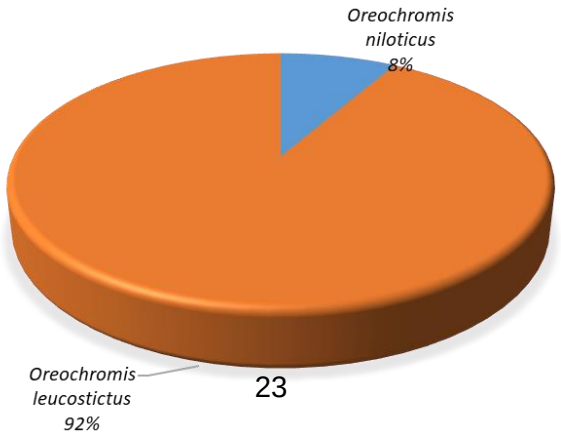
Plate 10. The large reservoir falls around the GPS point, -1.1301, 34.4466 and an altitude of 1406 m a.s.l., being fed mainly by groundwater. Human settlement alternating with open cultivated farm lands surround the dam. Sporadic eucalyptus forests occur around the dam while the shoreline has dense overgrowth of emergent macrophytes like typha and papyrus.

Table 10. Socio-ecological findings of Karamu dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.63	0.6 ≤ Medium-scale commercial < 0.8	Recommended for medium scale commercial fish farming.	39.46
Trophic State Index (TSI)	58.1	50 - 70 (Eutrophic)	Can support fairly high productivity	

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Ammonium (µg/l)	9.06	2000 ug/l	Within recommended limit for warm temperature adaptive fish	
Dissolved Oxygen (DO) (mg/l)	6.32	5 and above mg/L	Favorable to fish growth	
Temperature (^{0}C)	24.2	20--31 for warm temperature adaptive fish <20 for cold adaptive fish	Preferred temperature for fish growth	
pH	7.31	6--9	Best growth	
TN:TP	12.9	10 - 30	No limiting nutrients. Can support diverse population of algae	
Secchi Depth (m)	0.5	0.35 – 0.5	Phytoplankton are becoming scarce.	
Fish condition factor	1.89 (*O.l*), 2.05 (*O. n*)	2.9 - 4.8	Both species performed poorly. *O. n* recommended for culture at semi intensive level	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	100	$10^3 – 10^4$	Recommended suitable for fish farming.	
Phytoplankton abundance (ind.L-1)	1111	Somehow lethal since species like merismopedia were noted but with time fish farming can be done	Suitable for fish farming although small scale	
Phytoplankton Shannon index H	1.764			
Zooplankton abundance (ind.L-1)	42.2	100-500		
Zooplankton Shannon index H	1.91			

The dam exhibited low levels of microbial contamination thus supporting low chance of pathogenic infections. Other ecological parameters like DO, temperature, TN:TP ratio, pH, and plankton biodiversity fell within recommendable levels and were therefore contusive for fish culture especially for the tilapiines. The good plankton diversity is an indication of contusive water quality. Growth performance may be affected by other extraneous conditional factors like lake morphology, climatic, biological and environmental conditions. The exhibited poor growth performance that cut across many dams may be attributed to stress from varying extraneous factors. *Oreochromis leucostictus* dominated the catches at this dam with abundance at 91.7% while *Oreochromis niloticus* had an abundance of 8.3%. Socioeconomically, it was observed that the community acceptability was high. The dam size was considerably big and with good water quality parameters to support tilapiine culture. The fish stock and trophic interactions needs to be studied into details.



Gogo

Picture: Gogo dam was visited by the survey team but was not sampled since it had receded back to the flowing river channel due to siltation.

Conclusion and recommendations

A total of nine (9) water bodies in Migori County were sampled and analysed for fecal indicator microorganisms. A mean of 622 cfu/100ml was recorded with a range of 2300 cfu/100ml, minimum counts of 0 (Nil) and maximum of 2300 cfu/100ml, the results are far much below the minimum threshold value of $10^3 – 10^4$ cfu/100ml. This is indicative of good water quality which is within acceptable levels for fish farming. Surface runoff contributes to high indicator levels, these comprises both human activities and open access to animals. Specific abstraction water points need to be designated and all dams/ponds either to have manageable embankments or fenced.

3.1.3 Homa Bay County

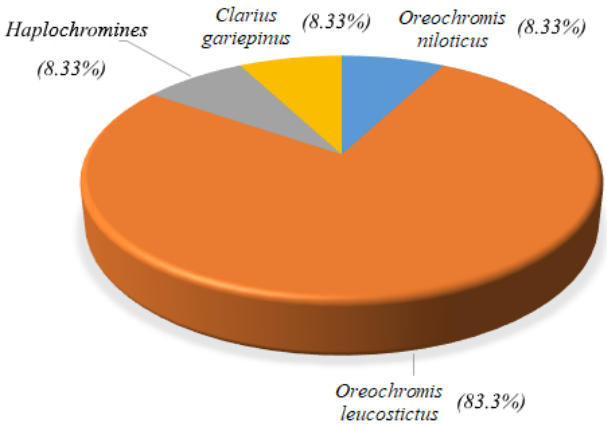
i) Kobodo dam

Plate 11. The reservoir lies around GPS point -0.6724, 34.4153 at an altitude of 1344 m a.s.l., being fed by Spring / groundwater and no visible outflow. Vegetation type: generally, a grassland with a busy highway passing close by. Human settlement dominating. A well-established car wash business on the side. Adjacent to a busy reading center. Shoreline macrophytes dominated by water hyacinth, planted eucalyptus forest, sugarcane plantation on one side. Muddy substrate of black cotton soil origin.

Table 11. Socio-ecological findings of Kobodo dam

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.41	0.4 ≤ Low-scale commercial < 0.6	Recommended for very low scale commercial fish farming	3.32
Trophic State Index (TSI)	53.6	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium	1.56	2000 ug/l	Within recommended limit for warm temperature adaptive fish	
Dissolved Oxygen (DO)	2.86	5 and above mg/L	Growth will be slow if exposure to low dissolved oxygen is continuous.	
Temperature	24.3	20--31 for warm temperature adaptive fish <20 for cold adaptive fish	preferred temperature for fish growth	
pH	7.93	6--9	Best growth	
TN:TP	4.3	10 - 30	Nitrogen limited. This can promote the growth of undesirable algae like cyanophytes	
Secchi Depth (m)≷	0.6		Phytoplankton becoming scarce.	
Fish condition factor	2.13(O.l) 0.74 (C.g)	2.9 - 4.8	(*O. l*) fair performance, needs food supplement (*C. g*) very poor performance	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	300	$10^3 – 10^4$	Suitable for fish farming	
Phytoplankton abundance ind.L-1)	415.013	Groups of species like diatoms, chlorophytes, Euglenophytes shows plenty of food for aquatic organisms	Suitable for fish farming	
Phytoplankton Shannon index H	1.699	Diversity is good presine environment for fish culture		
Zooplankton abundance (ind.l-1)	203.8	100-500	Highly recommended for fish farming	
Zooplankton Shannon index H	1.61			

Analysis done indicated a carrying capacity of 3.32 mt. The presence of fecal coliform bacteria (300) in the aquatic environment indicated that the water was contaminated with the fecal material of man or other animals. Results also showed a Shannon diversity index of 1.699 which indicated a good diversity and evenness of phytoplankton in the dam suitable for fish farming. Most of the water chemistry parameters were within the required limits suitable for fish growth. Nitrogen was however limited, and if not checked could promote the growth of undesirable algae. The shift in the trend was seen in DO and Nitrogen which had variable results. This dam was dominated by *O. leucostictus* with an abundance of 83.33% while *Oreochromis niloticus,* Haplochromines and *Clarias gariepinus* all had a relative abundance of 8.33%. Socioeconomically, the dam was recommended for very low scale commercial fish farming.



ii) Konyango Dam

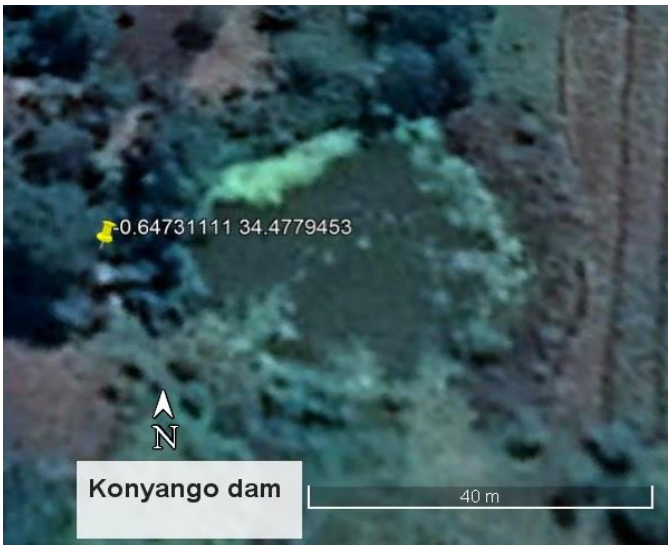


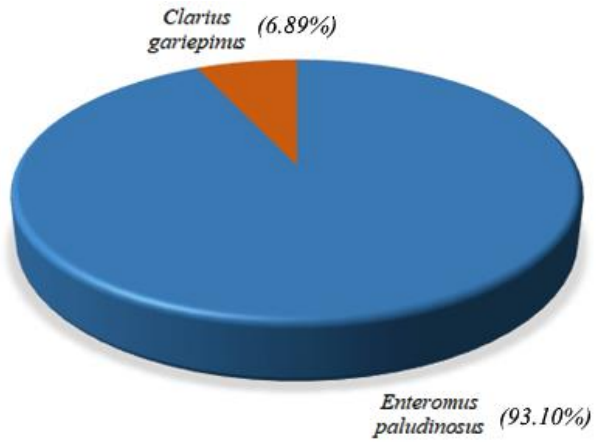
Plate 12. The reservoir is found in Homa Bay subcounty about GPS Point -0.6473, 34.4780 and at an altitude of 1354 m a.s.l. Dominant macrophytes are the leafy types while there are some rooted types. Cultivated crops including sugarcane, planted trees (eucalyptus), plantains, Napier grass, human settlement, etc. are prominent around the dam. Muddy substrate.

Table 12. Socio-ecological findings of Konyango dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.55	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	1.09
Trophic State Index (TSI)	64.5	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium (µg/l)	51.56	2000 ug/l	Within recommended limit	
Dissolved Oxygen (DO) (mg/l)	1.45	5 and above mg/L	Lethal if exposure lasts more than a few hours	
Temperature (^{0}C)	23.1	20--31 for warm temperature adaptive fish <20 for cold adaptive fish	Good but has to be under close monitoring	
pH	7.15	6--9	Best growth	

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
TN:TP	2.7	10 - 30	Nitrogen limited. This can promote the growth of undesirable algae like cyanophytes	
Secchi Depth (m)≷	0.2		Turbidity becoming excessive.	
Fish condition factor	1.7(E.p,)	2.9 - 4.8	poor performance, a fish of low economic value	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	0	$10^3 – 10^4$	Highly suitable for fish growing	
Phytoplankton Shannon index H	1.6	Highly	Highly suitable for growing fish	
Phytoplankton abundance (ind.L-1)	248.78	Suitable for fish farming	Suitable for aquaculture practices	
Zooplankton abundance (ind.L-1)	17.0	100-500	Good for small scale fish farming	
Zooplankton Shannon index H	1.957			

The lack of fecal coliform bacteria (0%) in the aquatic environment indicated that the water had not been contaminated with the fecal material of man or other animals. Results also showed a Shannon diversity index of 1.6 which indicated a good diversity and evenness of phytoplankton, which is highly suitable for fish culture. Analysis showed that most of the water physico-chemical parameters were not ideal and were unsuitable for fish growth. Nitrogen was limited, and if not checked could promote the growth of undesirable algae. DO was significantly low suitable while the water transparency was low as reflected in the high turbidity. This dam was highly dominated by *Enteromus paludinosus*, a low value species whose relative abundance was 93.10%. *Clarias gariepinus* was also found in the dam at an abundance of 6.89%. Socioeconomically, the dam was recommended for low scale commercial fish farming. The carrying capacity of Konyango Dam was determined to be approximately 11.09 mt.



Yao Kosiga Dam

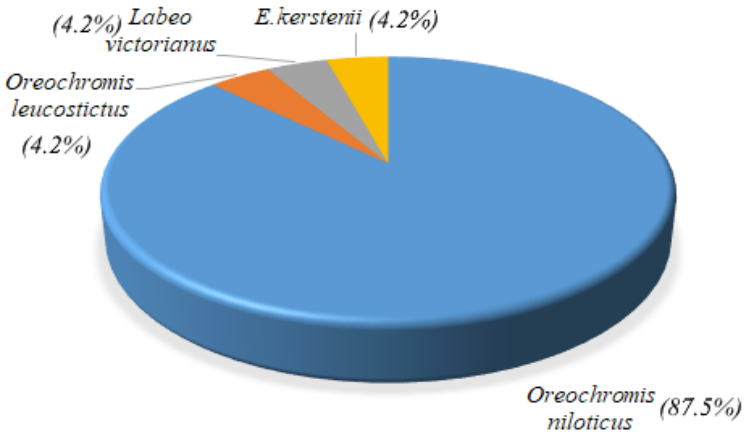
Plate 13. Located in Homabay County, Rangwe sub-county at about GPS point -0.5597, 34.6161and altitude of 1362 m a.s.l. Planted trees dominated the higher green vegetation on the adjacent lands with cropland and human settlement being the main features. Macrophyte types include Typha and Phragmites. A potable water intake point lies outside the main dam and separated by a causeway. Dam outlet continuously flows to River Awach Tende. Sandy substrate.

Table 13. Socio-ecological findings of Yao Kosiga dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.48	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	47.00
Trophic State Index (TSI)	68.0	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium (µg/l)	142.81	2000 ug/l	Within the recommended limit	
Dissolved Oxygen (DO) (mg/l)	6.21	5 and above mg/L	Favorable to fish growth	
Temperature (^{0}C)	27.8	20--31 for warm temperature adaptive fsh <20 for cold adaptive fish	Preferred temperature for fish growth	
pH	7.75	6--9	Best growth	
TN:TP	4.7	10 - 30	Nitrogen limited. This can promote the growth of undesirable algae like cyanophytes	
Secchi Depth (m)	0.22		Turbidity becoming excessive.	
Fish condition factor	3.74 (O. n)	2.9 - 4.8	Very good performance, recommended for culture at both intensive and semi intensive level.	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	0	$10^3 – 10^4$	Highly suitable for fish growing	
Phytoplankton abundance ind.L-1)	429		Suitable for fish farming since most diatoms were present like Synedra sp, Stephanodiscus sp	
Phytoplankton Shannon index H	2.758			
Zooplankton abundance (ind.L-1)	195.4	100-500	Zooplankton enough to achieve a suitable growth and better quality of fish	
Zooplankton Shannon index H	1.293			

The lack of fecal coliform bacteria (0%) in the aquatic environment indicated that the water had not been contaminated with the fecal material of man or other animals. Results also showed a Shannon diversity index of 2.758 which indicated a good diversity and evenness of phytoplankton in the dam. Results also showed that most of the water chemistry parameters were ideal and

were within the required limits suitable for fish growth. Nitrogen was however limited, and if not checked could promote the growth of undesirable algae. Socioeconomically, the dam was recommended for low scale commercial fish farming. *Oreochromis niloticus* dominated in this dam, with an abundance of 87.5% while *Oreochromis leucostictus*, *Labeo victorianus* and *E.kerstenii* all had a 4.2% abundance. Analysis done indicated a Carrying capacity of 47 mt. Generally, Yao Kosiga had parameter ranges that were condusive for fish farming especially the warm tropical fishes. The temperature can support rapid growth and reproduction of *Oreochromis niloticus* as evidenced by good fish condition factor. The high average depth, good water circulation and allowable carrying capacity of the dam can also support cage practices especially of *Oreochromis niloticus*. Yao Kosiga therefore provides a much better candidate for cage fish farming.



iii) K'ouma dam

Plate 14. Located in Rachuonyo North subcounty at about GPS -0.4244, 34.5697 and an altitude of 1192 m a.s.l. Characterized by dense shrubs surrounding the water body and prominent human settlement at the far foreground. Intermittently perturbed shores due to livestock grazing. Muddy substrate.

Table 14. Socio-ecological findings of K'ouma dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.38	0.2 ≤ Subsistence < 0.4	Recommended for subsistence fish farming	47.00

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Trophic State Index (TSI)	65.4	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium	148.43	2000 ug/l		
Dissolved Oxygen (DO)	4.94			
Temperature	29.3			
pH	7.82			
TN:TP	20.6	10 - 30	No limiting nutrient. Can support diverse population of algae	
Secchi Depth (m)≥				
Fish condition factor	N/A		No fishing was done for this dam.	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	3000	$10^3 – 10^4$	Suitable for growing fish though fairly high values.	
Phytoplankton Shannon index H	63		Lo diversity unless the dams can be enhanced with productivity	
Phytoplankon abundance (ind.L-1)	2.287			
Zooplankton abundance (ind.L-1)	1076.7	100-500	Highly productive and suitable for fish farming	Cladocerans are desirable fish prey since they have high energetic caloric value
Zooplankton Shannon index H	1.874			

Analysis through membrane filtration showed that there was fecal contamination in the water (3000 cfu/100 ml) though this was still suitable for fish growth. The high numeric structure determined by the good diversity of zooplankton abundance characterized a highly productive dam that is suitable for fish culture. Shannon diversity index showed a low diversity in phytoplankton which necessitated the need for the dam to be enhanced with productivity. Most physicochemical parameters fell within the tolerable ranges and thus were favorable for the growth of phytoplankton and fish. The carrying capacity of the dam was determined to be 47.0 mt. The socioeconomic analysis described a low-ranking reference value though the dam is still recommended for subsistence fish culture.

iv) Oseno/Tinga dam

Plate 15. The triangularly shaped reservoir located in Suba North sub-county at GPS point -0.5123, 34.3242 at an altitude of 1154 m a.s.l. Cultivated land under maize crops all-round the dam. Common shrubs covering the dam dykes. Scanty human settlement within the basin. Dam protected by a barbed wire fence and secured by a gate. Outlet drains out into domestic water supply structures and a spillway. Muddy substrate.

Table 15. Socio-ecological findings of Oseno/Tinga dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.52	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	37.58
Trophic State Index (TSI)	57.6	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium (µg/l)	3.44	2000 ug/l	Within the recommended limit for warm temperature adaptive fish	
Dissolved Oxygen (DO) (mg/l)	5.97	5 and above mg/L	favorable to fish growth	
Temperature (^{0}C)	25.7	20--31 for warm temperature adaptive fish <20 for cold adaptive fish	Preferred warm temperature fish growth	
pH	8.46	6--9	best growth	
TN:TP	9.0	10 - 30	Nitrogen limited. This can promote the growth of undesirable algae like cyanophytes	
Secchi Depth (m)	0.2	0.35 – 0.5	Highly elevated suspended matter (High turbidity).	
Fish condition factor	N/A		No fish sampled	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	0	10^3 – 10^4	Highly suitable for fish growing	
Phytoplankton Shannon index H	0.6977			
Phytoplankon abundance (ind.L-1)	100	300- and above	Favorable for fish but needs enhancement of productivity	
Zooplankton abundance (ind.L-1)	133.3	100-500	Favorable for fish farming but needs enhancement of productivity	
Zooplankton Shannon index H	1.754			

The lack of fecal coliform bacteria (0%) in the aquatic environment indicated that the water had not been contaminated and did not contain excess organic matter. The Shannon index showed a relatively high diversity of phytoplankton and zooplankton although for efficient fish culture there would still be a need for enhancement of productivity. The physicochemical parameters were within the range, favorable for fish growth. The only shift in this trend was in the limited Nitrogen. No fish were caught in this dam. *Endopthalmia* sp. was also recorded in this dam. Additionally, the low dissolved oxygen recorded can be concerning and aggravate bacterial infections. The dam was recommended for low scale commercial fish farming with a carrying capacity of 37.58 mt.

v) Pap Orage

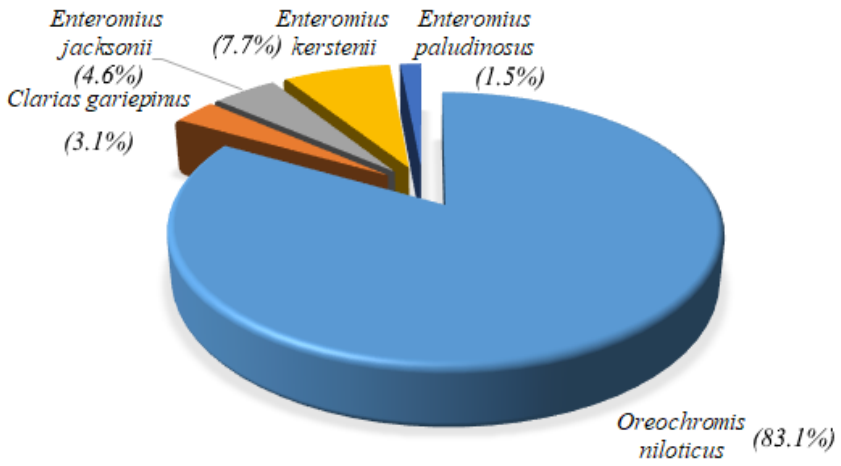
Plate 16. The dam occurs within Rachuonyo South subcounty at GPS -0.4834, 34.6668 and altitude of 1260 m a.s.l. Vast mixed bare ground and grass cover around the dam with some sedges on the western shores. Rocky outcrops on the northern shores with planted eucalyptus further out. Land outside the dam is open for grazing. Muddy substrate.

Table 16. Socio-ecological findings of Pap Orage dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.54	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	1.54
Trophic State Index (TSI)	65.8	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium (µg/l)	95.94	2000 ug/l	Within recommended limit	
Dissolved Oxygen (DO) (mg/l)	2.2	5 and above mg/L	Growth will be slow if exposure to low dissolved oxygen is continuous	
Temperature (^{0}C)	22.4	20--31 for warm temperature adaptive fish <20 for cold adaptive fish	Favorable to fish growth with close monitoring	
pH	7.46	6--9	Best growth	
TN:TP	17.5	10 - 30	No limiting nutrients. Can support diverse population of algae	
Secchi Depth (m)	0.1	0.35 – 0.5	Dam too turbid. This may lead to low dissolved oxygen or productivity if turbidity is from suspended soil particles.	
Fish condition factor	2.36 (O. n)	2.9 - 4.8	fair performance, can be cultured semi-intensively	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	700	10^3 – 10^4	Suitable for growing fish	
Phytoplankton Shannon index H	1.326			

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Phytoplankton abundance (ind.L-1)	178.57		Suitable for fish farming but they need enhancement of productivity	
Zooplankton abundance (ind.L-1)	284.3	100-500	Suitable for fish farming	
Zooplankton Shannon index H	0.9074			

Presence of fecal coliform (700) indicated that the water was contaminated and contained organic matter. There was a relatively high diversity and evenness in the community of phytoplankton and zooplankton. This however still needs enhancement for productivity. The physicochemical parameters fall below the threshold. There was a shift in trend when it came to dissolved oxygen and Turbidity which showed variable results. This dam was dominated by *Oreochromis niloticus* with an abundance of 83.1%. Other species that were obtained with varying abundances were; *Clarias gariepinus* (3.1%), *Enteromius jacksonii* (4.6%), *Enteromius kerstenii* (7.7%) and *Enteromius paludinosus* (1.5%). With a productivity level of 1.54 mt. The dam was recommended for low scale commercial *O. niloticus* farming.



vi) Ramula dam

Plate 17. The dam lies within Rachuonyo East sub-county at GPS -0.4234, 34.8713 and altitude 1448 m a.s.l. The vegetation around the dam mainly comprise shrubs. Prominent settlement and maize cultivation, planted trees mainly eucalyptus, closed shoreline with sedges. Sandy sediments.

Table 17. Socio-ecological findings of Ramula dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.56	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	4.54
Trophic State Index (TSI)	60.5	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium (µg/l)	29.06	2000 ug/l	Within recommended limit	
Dissolved Oxygen (DO) (mg/l)	3.1	5 and above mg/L	Growth will be slow if exposure to low dissolved oxygen is continuous	
Temperature (^{0}C)	24.4	20--31 for warm temperature adaptive fish <20 for cold adaptive fish	Favorable to warm temperature fish growth	
pH	7.29	6--9	Best growth	
TN:TP	3.5	10 - 30	Nitrogen limited. This can promote the growth of undesirable algae like cyanophytes	
Secchi Depth (m)≷	0.1		Dam is too turbid. This may lead to low dissolved oxygen or productivity if turbidity is from suspended soil particles.	
Fish condition factor	1.89 (O.l)	2.9 - 4.8	poor performance, *O. n.* can be introduced in the dam and reared semi intensively	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	500	$10^3 – 10^4$	Suitable for growing fish	
Phytoplankton Shannon index H	1.919			
Phytoplankon abundance (ind.L-1)	869.24	There is no growth for proliferation of other algal species which needs light for their growth	Suitable for fish farming in terms of productivity	
Zooplankton abundance (ind.L-1)	14.3	100-500	Probable high predation pressure in the dam. Fish farming will be enhanced by supplementing with feeds	
Zooplankton Shannon index H	1.286			

The fecal coliform level was under the threshold level. The phytoplankton and zooplankton abundance was low and could probably lead to high predation pressure in the dam. Fish culture in the pond should probably be enhanced by feeding. The physicochemical parameters were unfavorable for fish culture. The dam was too turbid, which would lead to low DO. The measured temperatures and pH were within the recommended level suitable for fish culture. The dam was recommended for low commercial fish farming. On the resident fish fauna, the dam yielded only *Oreochromis niloticus* whose condition factor was 2.69, indicative of a fair performance considering the conditions. Ramula dam registered a carrying capacity of 4.54 mt.

vii) Yongo dam

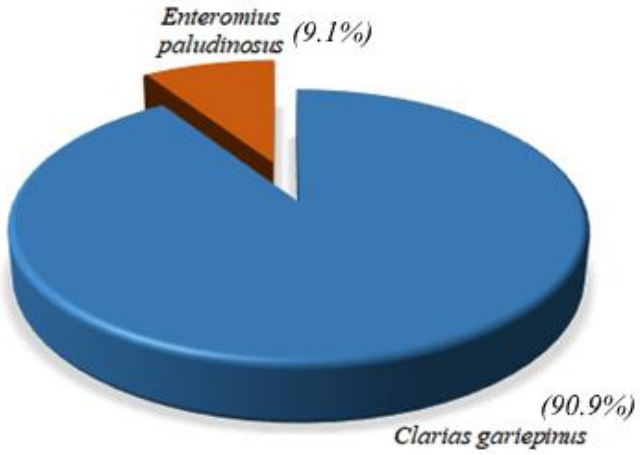
Plate 18. The reservoir is located within Suba South sub-county at about GPS -0.5642, 34.2882 at an altitude of 1159 m a.s.l. The surrounding land is vegetated with shrubs, acacia tree, euphoria and leafy macrophytes. Muddy substrate of black cotton origins.

Table 18. Socio-ecological findings of Yongo dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.50	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	10.44
Trophic State Index (TSI)	58.5	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium	175.31	2000 ug/l	Above recommended limit for cold adaptive fish	
Dissolved Oxygen (DO)	2.66	5 and above mg/L	Growth will be slow if exposure to low dissolved oxygen is continuous	
Temperature	25.50	20--31 for warm temperature adaptive fish <20 for cold adaptive fish	Favorable to warm temperature fish	
pH	7.19	6--9	Best growth	
TN:TP	92.0	10 - 30	Phosphorus limited. This would impede the growth of algal growth.	
Secchi Depth (m)≷	0.2		Turbidity is becoming excessive.	
Fish condition factor	0.77(*C.g*), 1.84 (*O.l*)		Both species performed poorly. *O. n* can perform better with supplemental feed.	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	0	$10^3 – 10^4$	Suitable for growing fish.	
Phytoplankton Shannon index H	0.8507		Very productive and suitable for fish farming although lethal species were noted; *Microcystis* spp	
Phytoplankton abundance (ind.L-1)	7802.1			
Zooplankton abundance (ind.L-1)	1277.8	Very productive and pristine environment with a lot of diatoms	Very productive and suitable for fish farming. High crustacean density (copepod & cladocerans)	

			but needs controlled human/cattle use	
Zooplankton Shannon index H	2.221			

The lack of fecal coliform bacteria in the dam indicated that the water was suitable for growing fish. There was a low presence and abundance of phytoplankton and zooplankton that proves very productive and suitable for fish farming. However, *Microcystis* sp. was noted in the water sample which may be harmful to the fish. The chemistry of the water was not favourable for fish farming with low DO, limited phosphorus and excessive turbidity. The pH and Temperature were however favourable. The resident fish fauna included C*larias gariepinus* (90.9% abundance) and *Enteromius paludinosus* (9.1%). The dam was recommended for low scale fish (C*larias gariepinus*) farming at a carrying capacity of 10.44 mt.



Conclusion and recommendations

A total of eight (8) water bodies in Homa Bay County were sampled and analyzed for fecal indicator microorganisms. A mean of 563 cfu/100ml was recorded with a range of 3000 cfu/100ml, minimum counts of 0 (Nil) and maximum of 3000 cfu/100ml, the results are far much below the minimum threshold value of 10^3 – 10^4 cfu/100ml. This is indicative of good water quality which is within acceptable levels for fish farming. Surface runoff contributes to high indicator levels, these comprises both human activities and open access to animals. Specific abstraction water points need to be designated and all dams/ponds either to have manageable embankments or fenced.

3.1.4 Kisumu County

i) Buoye Luanda

Plate 19. This dam is located in Kisumu East sub-county at an altitude of 1134 m around the GPS points -0.14802, 34.8072. The dam has clear water and a scanty shoreline macrophytes. Floating vegetation include water lilies and *Solanum spp*. Whistling thorn tree and eucalyptus are prominent around the banks. Muddy substrate.

Table 19. Socio-ecological findings of Buoye dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.44	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	0.93
Trophic State Index (TSI)	58.6	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium (µg/l)	2.1875	2000 ug/l	Within recommended limit for warm temperature fish growth	
Dissolved Oxygen (DO) (mg/l)	5.52	5 and above mg/L	Favorable for fish growth	
Temperature (^{0}C)	24.7	20--31 for warm temperature adaptive fish <20 for cold adaptive fish	Preferred warm temperature fish growth	
pH	7.02	6--9	Best growth	
TN:TP	2.4	10 - 30	Nitrogen limited. This can promote the growth of undesirable algae like cyanophytes	
Secchi Depth (m)	0.2	0.35 – 0.5	Turbidity becoming excessive.	
Fish condition factor	N/A		No fish were sampled at this lake.	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	400	10^3 – 10^4	Suitable for fish though high turbidity, surrounding to have grass to prevent soil erosion inflow.	
Phytoplankton Shannon index H	0.783			
Phytoplankton abundance (ind.L-1)	197.57		Not suitable for fish farming unless they remove the aquatic plants to enable proliferation of other groups	
Zooplankton abundance (ind.L-1)	356.0	100-500	Zooplankton abundance was within recommendable range though with Rotifers dominating (*Keratella* spp).an indication of either eutrophication or increased predation by higher predators.	
Zooplankton Shannon index H	1.388			

The level of microbial contamination was low in this dam, suggesting minimal interference/pollution from human activity. Though the waters were eutrophic, the phytoplankton abundance were low a probable indication of light limitation due to high mineral turbidity. The secondary producers were dominated by rotifers that confirmed the possible high eutrophication or predation levels. Water quality characteristics like ammonium, dissolved oxygen and pH were within the ranges recommended for warm water fish aquaculture. However, this 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. No fish species were captured during the survey. The Carrying capacity (mt) for the dam is 0.93 mt. According to the socio-economic index, this dam can be considered for small scale aquaculture activities. Though small and seasonal, the socio-ecological indicators are conducive for fish culture except for turbidity, phytoplankton abundance and rotifer species which could be as a result of high predation. The dam is thus a suitable candidate for catfish culture.

ii) Hejope dam

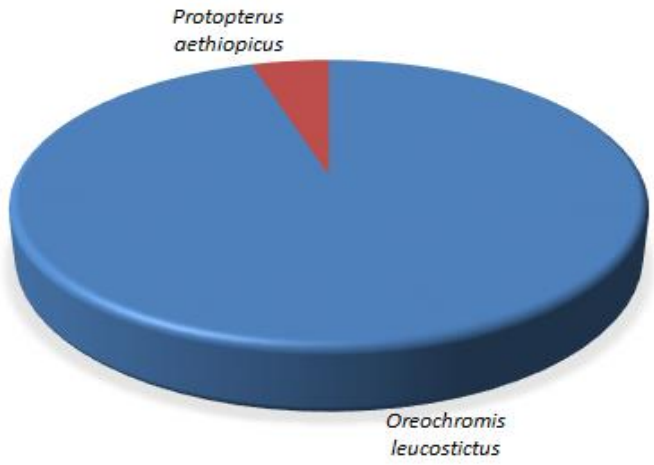
Plate 20. Hejope dam is located in Kisumu east sub-county at an altitude of 1131m around the GPS points, -0.1153, 34.8277. It is a relatively small reservoir with clear water. It is fed by a natural stream and has no visible outlet. A large proportion of the water is colonized by grass and water lilies.

Table 20. Socio-ecological findings of Hejope dam

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.60	0.4 ≤ Low-scale commercial < 0.6	Strongly recommended for low scale commercial fish farming	1.19
Trophic State Index (TSI)	66.2	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium (µg/l0	87.1875	2000 ug/l	Within recommended limit for warm temperature fish growth	
Dissolved Oxygen (DO) (mg/l)	1.17	5 and above mg/L	Lethal if exposure lasts more than a few hours.	
Temperature (^{0}C)	25.8	20--31 for warm temperature adaptive fish <20 for cold adaptive fish	Favorable to warm temperature fish growth	
pH	6.59	6--9	Best growth	
TN:TP	16.6	10 - 30	No limiting nutrient. Can support diverse population of algae	
Secchi Depth (m)	0.2	0.35 – 0.5	Turbidity becoming excessive.	
Fish condition factor	1.84 (*O.l*))	2.9 - 4.8	*O.l* poor, not recommended for culture	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	1300	10^3 – 10^4	Good for fish farming	

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Phytoplankton Shannon index H	139.6		Suitable for fish farming	
Phytoplankton abundance (ind.L-1)	0.4789			
Zooplankton abundance (ind.L-1)	132.8	100-500	Suitable for fish farming	
Zooplankton Shannon index H	1.836			

Microbial contamination indicators were low in this dam, indicating minimal pollution from humans. Both primary and secondary productivity from the dam was good, indicating adequate natural food availability. Ammonium, temperature and PH were within the recommended levels of warm water fish. This dam had no limiting nutrient, implying that a diverse population of algae can thrive here. However, the low dissolved oxygen levels observed (1.17 mg^{-1}) can be lethal to fish if exposure persists for a long time. Additionally, the dam was quite turbid. This dam was dominated by *Oreochromis leucostictus* which had an abundance of 95.2% while *Protopterus aethiopicus* had an abundance of 4.8%. Growth performance of these fish was below the threshold. According to the socio-economic index, there is a strong recommendation to use the dam for small scale aquaculture activities. The potential carrying capacity of the dam is 1.19 mt hence it can be considered for restocking with endemic species due to its structure and depth that make it unsuitable for aquaculture.



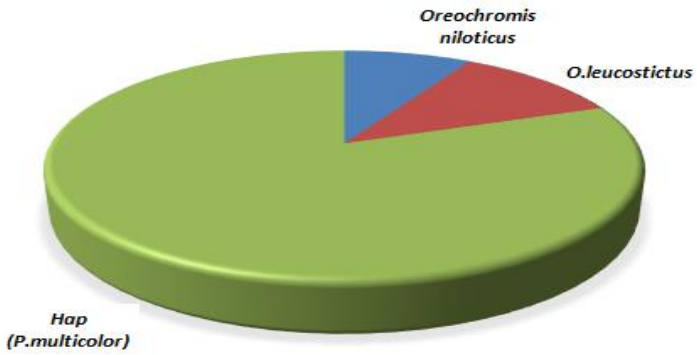
iii) Huma self-help group

Plate 21. Huma self-help group dam is located 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 21. Socio-ecological findings of Huma Self Help Group dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.48	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	0.76
Trophic State Index (TSI)	53.1	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium (µg/l)	6.5625	2000 ug/l	Within recommended limit for warm temperature fish growth	
Dissolved Oxygen (DO) (mg/l)	6.98	5 and above mg/L	Favorable for fish growth	
Temperature (^{0}C)	30.2	20--31 for warm temperature adaptive fish <20 for cold adaptive fish	Preferred warm temperature fish growth	
pH	5.98	6--9	The level tends towards acidity hence not preferred for fish growth	
TN:TP	4.7	10 - 30	Nitrogen limited. This can promote the growth of undesirable algae like cyanophytes	
Secchi Depth (m)	0.38	0.35 – 0.5	If turbidity is from phytoplankton, the dam is in good condition.	
Fish condition factor	2.11 (*O. n*)	2.9 - 4.8	fair can be cultured at semi-intensive level	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	200	10^3 – 10^4	Good water for fish farming	
Phytoplankton Shannon index H	2.333			
Phytoplankton abundance (ind.L-1)	119		Chlorophytes and diatoms indicative of productivity suitable for small scale fish farming	
Zooplankton abundance (ind.L-1)	203.1	100-500	96% rotifers, indicative of either eutrophication or high predation pressure on the bigger crustacean group.	
Zooplankton Shannon index H	1.477		Rotifers (97%).	

Microbial contamination indicators were below alarm levels, showing suitability of this water and minimal interference by humans through pollution. Primary productivity had an abundance of Chlorophytes and diatoms, supportive of small-scale fish farming. Secondary producers were dominated by rotifers suggestive of either eutrophication or high predation pressure on the bigger crustacean groups. Ammonium, temperature and DO were within the recommended levels of warm water fish but pH was tending towards acidity, which isn't suitable for fish growth. Turbidity of the dam was also high, indicating low sunlight penetration. The dam is nitrogen limited which can promote the growth of undesirable algae. Huma dam was dominated by Haplochromines with an abundance of 81%, followed by *Oreochromis leucostictus* (11.1%) then *Oreochromis niloticus* (8.3%). This dam seems to have the ideal conditions for thriving of Haplochromines. Hence consideration could be made on investing in semi intensive aquaculture of this species. The growth performance of *O. niloticus* in this dam was fair. The socio-economic index places the dam as having a potential for small scale commercial fish farming. However, it is proposed that interventions geared towards conservation of the Haplochromines.



iv) Kere

Plate 22. Kere dam is located 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 22. Socio-ecological findings of Kere dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.48	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	0.34
Trophic State Index (TSI)	60.8	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium (µg/l)	9.0625	2000 ug/l	Within recommended limit for warm temperature adaptive fish growth	
Dissolved Oxygen (DO) (mg/l)	7.64	5 and above mg/L	favorable to fish growth	
Temperature (^{0}C)	24.1	20--31 for warm temperature adaptive fish <20 for cold adaptive fish	preferred temperature for warm adaptive fish growth	
pH	7.79	6--9	Best growth	
TN:TP	2.9	10 - 30	Nitrogen limited. This would enhance the growth of undesired algal population like the cyanophytes.	
Secchi Depth (m)	0.15	0,35 – 0.5	Pond too turbid. This may lead to either low dissolved oxygen or low productivity if turbidity is from suspended soil particles.	
Fish condition factor	N/A		No fish were obtained. Recommended for stocking of *O. n*	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	200	10^3 – 10^4	Recommended for fish farming	
Phytoplankton Shannon index H	0.8983		Recommended for fish farming Diversity of algae like Cosmarium, Ampora spp indicates plenty of food for the prey.	
Phytoplankton abundance (ind.L-1)	217.79			
Zooplankton abundance (ind.L-1)	386.8	100-500	Abundant food available therefore suitable for fish farming	
Zooplankton Shannon index H	1.513			

Microbial contamination indicators were low in this dam, indicative of the little levels of pollution by humans. Primary and secondary productivity indices showed an abundance of food. Ammonium, temperature, DO and pH were within the recommended levels for optimal performance of warm water fish. However, the turbidity of the dam was too high and additionally nitrogen limited which can promote the growth of undesirable algae. No fish species were obtained for analysis. According to the socio-economic index, the dam can be considered for small scale fish farming. The dam can be utilized for semi intensive aquaculture of catfish.

Conclusion and recommendations

A total of four (4) water bodies in Kisumu County were sampled and analyzed for fecal indicator microorganisms. A mean of 525 cfu/100ml was recorded with a range of 1100 cfu/100ml, minimum & maximum counts of 200 ≤ 1300 cfu/100ml between the sites, the results are far much

below the minimum threshold value of 10^3 – 10^4 cfu/100ml. This is indicative of good water quality which is within acceptable levels for fish farming. Based on the study, Buoye and Kere dams are good candidates for semi intensive aquaculture of catfish. Hejope dam can be considered for restocking due to its unsuitable design for application in aquaculture while Huma dam hand can be used as a conservation site for Haplochromines.

3.1.5 Kakamega County

i) Mumunyonzo

Plate 23. Mumunyonzo dam is located in Likuyani Sub County at an altitude of 1807 m around the GPS points 0.8288, 35.0677. It is a turbid dam which is heavily silted by its breaking banks.

Table 23. Socio-ecological findings of Mumunyonzo dam

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.50	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	1.51
Trophic State Index (TSI)	67.0	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium	47.1875	2000 ug/l	Within the recommended limit for fish growth at observed temperature and pH	
Dissolved Oxygen (DO)	5.91	5 and above mg/L	favorable for fish growth	
Temperature	20.8	20--31 for warm temperature adaptive fish <20 for cold adaptive fish	Preferred temperature for warm adaptive fish growth	
pH	7.59	6--9	Best growth	
TN:TP	11.3	10 - 30	No limiting nutrient. Can support diverse population of algae	
Secchi Depth (m)≷	0.2		Turbidity becoming excessive.	
Fish condition factor	N/A		Fish not obtained. Restocking of well perfoming aquaculture species recommended.	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	600	10^3 – 10^4	Recommended for fish farming, has macrophytes to help filter run-offs.	
Phytoplankton Shannon index H	0.8746		There is productivity and suitable for fish farming	

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Phytoplankton abundance (ind.L-1)	355		There is productivity and suitable for fish farming	
Zooplankton abundance (ind.L-1)	39.4	100-500	Low abundance mostly due to predation by fish or and macroinvertebrates although fish farming can be done with enhancement	
Zooplankton Shannon index H	1.135			

The dam has low levels of microbial contamination arising from human pollution. Presence of macrophytes plays a function of filtering off run offs before it gets into the dam. The primary productivity indices point to availability of phytoplankton, which is suitable for fish growth. However, secondary productivity is low and this has been attributed to predation by fish. Levels of ammonium, Dissolved oxygen, temperature and pH were all within the recommended levels for aquaculture and there was no limiting nutrient. Of concern though was the high levels of turbidity in the dam. No fish were caught during the survey. The dam has a potential carrying capacity of 1.51 mt but with the current depth of 1 m, applying aquaculture is not feasible. The socio-economic index for this dam is 0.5, indicating a potential for low scale commercial fish farming. Dredging can be considered prior to investing in low scale commercial fish farming using endemic species.

ii) X- Rasa

Plate 25. X Rasa dam is located in Lugari sub-county at an altitude of 1698 m around the GPS points, 0.6259, 34.9639. This dam is fed by natural springs but has no visible outlet. It has comparatively clear water. However, siltation has resulted in the shrinking of the dam. Palm trees are found around the dam.

Table 24. Socio-ecological findings of X-Rasa dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.49	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	2.65
Trophic State Index (TSI)	59.7	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium (µg/l)	29.6875	2000 ug/l	Within recommended limit at observed temperature and pH	
Dissolved Oxygen (DO) (mg/l)	6.62	5 and above mg/L	Favorable for fish growth	

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Temperature (^{0}C)	27.6	20--31 for warm temperature adaptive fish <20 for cold adaptive fish	Preferred temperature for warm adaptive fish growth	
pH	7.38	6--9	Best growth	
TN:TP	13.2	10 - 30	No limiting nutrient. Can support diverse population of algae	
Secchi Depth (m)	0.3	0.35 – 0.5	If turbidity is from phytoplankton, dam is in good condition.	
Fish condition factor	N/A		Recommended for restocking. No fish were available.	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	0	$10^3 – 10^4$	Recommended for fish farming	
Phytoplankton Shannon index H	2.203		Suitable for fish farming although it needs enhancement for productivity.	
Phytoplankton abundance (ind.L-1)	161			
Zooplankton abundance (ind.L-1)	41.4	100-500	Low abundance.	
Zooplankton Shannon index H	1.68			

X-rasa dam is eutrophic, indicating that fairly high productivity can occur in this system. This dam had nil fecal coliforms indicating no pollution from human wastes. Primary and secondary productivity was low, suggesting a need for enhancement to ensure productivity. Water quality parameters (ammonium, DO, PH, and temperature) were all within the recommended levels for warm water aquaculture. The dam has no limiting nutrient hence can support a diverse range of algae. No fish were caught in this dam for analysis. The socio-economic index for this dam was within the range required for low scale commercial fish farming. The carrying capacity for this dam is 2.65 mt, indicating a huge potential. However, no fish were caught during the sampling. The dam can be considered for low scale aquaculture of key commercial warm water species.

iii) Lugulu

Plate 25. Lugulu dam is located in Likuyani sub-county at an altitude of 1776 m around the GPS points, 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 25. Socio-ecological findings of Lugulu dam

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.45	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	3.52
Trophic State Index (TSI)	61.9	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium (µg/l)	24.6875	2000 ug/l	Within recommended limit for fish growth	
Dissolved Oxygen (DO) (mg/l)	7.26	5 and above mg/L		
Temperature (^{0}C)	22.7	20--31 for warm temperature adaptive fish <20 for cold adaptive fish	Preferred temperature for warm adaptive fish growth under close monitoring	
pH	7.4	6--9	Best growth	
TN:TP	12.2	10 - 30	No limiting nutrient. Can support diverse population of algae	
Secchi Depth (m)	0.2	0.35 – 0.5	Turbidity becoming excessive.	
Fish condition factor	N/A		Recommended for restocking. No fish were available	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	300	10^3 – 10^4	Recommended for fish farming shoreline covered with grass	
Phytoplankton abundance ind.L-1)	536		Recommended for restocking since there is primary productivity since it needs enhancement	
Phytoplankton Shannon index H	1.453			
Zooplankton abundance (ind.L-1)	59.5	100-500	Fish farming may require supplementary feeding	
Zooplankton Shannon index H	0.8293			

Lugulu dam is eutrophic, showing that fairly high productivity can occur in this system. This dam had low fecal coliform load, indicating minimal pollution from human wastes. However this dam has low primary and secondary productivity, which implies that it needs enhancement. Water quality parameters (ammonium, DO, PH, and temperature) were all within the recommended levels for warm water aquaculture. The dam has no limiting nutrient hence can support a diverse range of algae. No fish were caught in this dam for analysis. The socio-economic index for this dam indicated that low scale commercial fish farming can be done in this dam. The Carrying capacity for this dam is 3.52, suggesting a huge potential. The dam has a considerable depth and size, which can be utilized for aquaculture of warm water aquaculture species.

iv) Lumino

Plate 26. Lumino dam is located in Likuyani sub-county at an altitude of 1919 m around the GPS points, 0.7138, 35.1457. This dam is relatively large, with moderate turbidity. It has low water levels due to the dilapidated spillway. The dam receives water from a permanent natural stream. Out flow through a spillway into the continuing stream

Table 26. Socio-ecological findings of Lumino dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.48	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	6.25
Trophic State Index (TSI)	62.1	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium (µg/l)	37.8125	2000 ug/l	Within recommended limit	
Dissolved Oxygen (DO) (mg/l)	7.79	5 and above mg/L	Favorable for fish growth	
Temperature (^{0}C)	27.3	20--31 for warm temperature adaptive fish <20 for cold adaptive fish	Preferred temperature for warm fish growth	
pH	6	6--9	Best growth	
TN:TP	6.9	10 - 30	Nitrogen limited. This can promote the growth of undesirable algae like cyanophytes	
Secchi Depth (m)	0.1	0.35 – 0.5	Dam too turbid. This may lead to low dissolved oxygen or productivity if turbidity is from suspended soil particles.	
Fish condition factor	N/A		Recommended for restocking. No fish were obtained for analysis.	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	100	10^3 – 10^4	Recommended for fish farming Muddy, shoreline surrounded with grass	
Phytoplankton Shannon index H	162		Recommended for fish farming	
Phytoplankton abundance (ind.L-1)	2.143			
Zooplankton abundance (ind.L-1)	41.4	100-500		

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Zooplankton Shannon index H	2.381			

Lumino dam is eutrophic, suggestive of the fact that fairly high productivity can be supported in this system. This dam has relatively low fecal coliform load, indicating minimal pollution from human wastes. However this dam was low in primary and secondary productivity, which implies that it needs enhancement when considered for aquaculture. The water quality parameters identified in this dam (ammonium, DO, PH, and temperature) were all within the recommended levels for warm water aquaculture. However, the dam is nitrogen limited and can promote growth of undesirable algae. No fish were caught in this dam for analysis. The socio-economic index for this dam indicated that low scale commercial fish farming can be a viable option for the dam. This dam is not recommended for aquaculture but can be restocked with endemic species for conservation purposes.

v) Musembe

Plate 27. Chekalini/Musembe dam is located in Lugari subcounty at an altitude of 1673 m around the GPS points, 0.6228, 34.9131. It is triangular shaped, fed by a permanent stream and drains out through a protected/channelized spillway. The deeper end has high banks with steep dykes separating the dam with a modern water supply installation. The dam has turbid water.

Table 27. Socio-ecological findings of Musembe dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt) (mt)
Socio-economics	0.53	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	16.89
Trophic State Index (TSI)	59.0	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium (µg/l)	120.9375	2000 ug/l	The level exhibits acidic condition as observed in temperature and pH levels respectively	
Dissolved Oxygen (DO) (mg/l)	7.8	5 and above mg/L	Favorable for fish growth	
Temperature (^{0}C)	21.3	20--31 for warm temperature adaptive fish	Preferred temperature for fish growth under close monitoring	

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt) (mt)
		<20 for cold adaptive fish		
pH	5.64	6--9	The observed value if moving towards acidic condition	
TN:TP	80.6	10 - 30	Phosphorus limited. This would impede the growth of algal growth.	
Secchi Depth (m)	0.3	0.35 – 0.5	If turbidity is from phytoplankton, pond is in good condition.	
Fish condition factor	N/A		No fish were available. Recommended for restocking.	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	300	$10^3 – 10^4$	Recommended for fish farming, muddy shoreline covered with grass	
Phytoplankton Shannon index H	1.097		Recommended for subsistence farming but needs enhancement for it to be productive.	
Phytoplankton abundance (ind.L-1)	57			
Zooplankton abundance (ind.L-1)	9.38		very low abundance likely dues to predation pressure from fish and invertebrates	
Zooplankton Shannon index H	1.798			

Chekalini/ Musembe dam is eutrophic, indicating potential for high productivity. This dam had low fecal coliform load, indicating minimal pollution from human wastes. However, this dam has low primary and secondary productivity, which implies that it needs enhancement for efficient productivity. Ammonium levels in this dam call for close monitoring of both pH and temperature with respect to fish farming. However, dissolved oxygen and temperature are within the required levels for warm water fish while the recorded PH was low. The dam was phosphorous limited suggesting that the growth of algae would be impeded. No fish were caught in this dam for analysis. The socio economic index for this dam indicated that low scale commercial fish farming is a viable option. The Carrying capacity (mt) was 16.89 indicating a high potential for the dam. No fish were caught during the survey. The dam can be considered for restocking and conservation of endemic species considering that it also hosts a modern water supply installation.

Conclusion and recommendations

A total of five (5) water bodies in Kakamega County were sampled and analyzed for fecal indicator microorganisms. A mean of 260 cfu/100ml was recorded with a range of 600 cfu/100ml, minimum & maximum counts of 0 ≤ 600 cfu/100ml between the sites, the results are far much below the minimum threshold values of $10^3 – 10^4$ cfu/100ml. This is indicative of good water quality which is within acceptable levels for fish farming.

3.1.6 Siaya County

i) Mauna

Plate 28**.** The dam is located in Ugenya sub-county, around GPS point, -0. 0.2051, 34.1567, has a depth of 2 m. Vast water body whose source is a permanent stream and single outflow through a stream. Water is very clear with water lilies near the shores. A water intake and processing facility nearby. Sandy substrate. The water is mostly used for domestic purposes.

Table 28. Socio-ecological findings of Mauna dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.54	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	24.79
Trophic State Index (TSI)	51.2	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium (µg/l)	1.5625	2000 ug/l	Within recommended limit	
Dissolved Oxygen (DO) (mg/l)	7.63	5 and above mg/L	Favorable to fish growth	
Temperature (^{0}C)	25.9	20--31 for warm temperature adaptive fish <20 for cold adaptive fish	Preferred temperature for fish growth	
pH	7.82	6--9	Best growth	
TN:TP	5.6	10 - 30	Nitrogen limited. This can promote the growth of undesirable algae like cyanophytes	
Secchi Depth (m)	0.7	0.35 – 0.5	Water is too clear. Inadequate productivity.	
Fish condition factor	N/A		No fish were obtained. Restocking of the dam is recommended	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	400	10^3 – 10^4	Recommended for fish farming	

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Phytoplankton abundance ind.L-1)	236	300	Suitable for fish farming	
Phytoplankton Shannon index H	2.316			
Zooplankton abundance (ind.L-1)	113.0	100-500	Suitable for fish farming	
Zooplankton Shannon index H	1.380			

Given the low microbial load reported (400cfus), the dam is not polluted with fecal matter thus good for fish health. The Secchi depth and phytoplankton productivity suggest clear waters with low primary production. The clear waters may be as a result of low water residence time within the dam. This may affect food availability across the trophic chain. The zooplankton abundance and diversity were favorable and may support the dam fisheries. The water clarity and primary production status is good since the dam water is being abstracted for urban supply. Because of the usage, the dam cannot be recommended for stocking, but pond fish culture can be practiced downstream using the outflow as a water source. Socio-economics status index was low but the water quality parameters support growth of fish.

ii) Nyadong

Plate 29. Nyadong dam is located in Bondo sub-county, around GPS point, -0.0932, 34.3346, with a water depth of 2m and sandy substrate. Relatively smaller water pan with highly turbid water. No permanent water source. No visible outlet. The dam is fed with Surface runoff / Spring as its major water source**.**

Table 29. Socio-ecological findings of Nyadong dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.45	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	1.51
Trophic State Index (TSI)	55.9	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium (µg/l)	2.1875	2000 ug/l	Within recommended limit	
Dissolved Oxygen (DO) (mg/l)	4.56	5 and above mg/L	Growth will be slow if exposure to low dissolved oxygen is continuous	

Temperature (^{0}C)	23.4	20--31 for warm temperature adaptive fish <20 for cold adaptive fish	Favorable for fish growth	
pH	8.04	6--9	Best growth	
TN:TP	4.9	10 - 30	Nitrogen limited. This can promote the growth of undesirable algae like cyanophytes.	
Secchi Depth (m)	0.22	0.35 – 0,5	Turbidity is becoming excessive.	
Fish condition factor	N/A		Restocking of the dam with *O. n* and *C. g* recommended.	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	300	$10^3 – 10^4$	Recommended for fish farming	
Phytoplankton abundance ind.L-1)	3396		Anabaena were noted. There is need for proper management	
Phytoplankton Shannon index H	1.097			
Zooplankton abundance (ind.L-1)	96.7	100-500	Recommended for fish farming	
Zooplankton Shannon index H	1.408			

The dam reported 300 cfu's of fecal coliforms which is an indication of low-pollution of fecal matter within and around the dam. The dam is highly turbid with a secchi reading of 0.22 m. This has affected the productivity of the dam across the trophic chain. The zooplankton abundance was low but with good diversity. With the underlying habitat conditions, the dam cannot support tilapia culture but the study recommends *Clarias gariepinus* for farming. To mitigate the on the high turbidity, there is need for afforestation within the catchment in order to control surface runoff and arrest erosion.

iii) Nyagoko

Plate 30. The dam is located in Rarieda sub-county, around GPS point, -0.1755, 34.3012, with a water depth of 1.5 m and muddy substrate. Relatively smaller water pan with highly turbid water. No permanent water source. No visible outlet. The dam is fed with Surface runoff / Spring as its major water source.

Table 30. Socio-ecological findings of Nyagoko dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.46	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	12.11
Trophic State Index (TSI)	68.2	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium (µg/l)	192.8125	2000 ug/l	Above recommended limit hence not recommended for fish growth	
Dissolved Oxygen (DO) (mg/l)	2.51	5 and above mg/L	Growth will be slow if exposure to low dissolved oxygen is continuous	
Temperature (^{0C}C)	23.2	20--31 for warm temperature adaptive fish <20 for cold adaptive fish	Preferred for warm temperature adaptive fsh growth	
pH	8.04	6--9	Best growth	
TN:TP	8.7	10 - 30	Nitrogen limited. This can promote the growth of undesirable algae like cyanophytes	
Secchi Depth (m)	0.1	0.35 – 0.5	Dam too turbid. There will be problem with either dissolved oxygen or low productivity if turbidity is due to suspended soil particles.	
Fish condition factor	N/A		Good performing aquaculture candidates plus supplemental feeding recommended.	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	200	10^3 – 10^4	Recommended for fish farming	
Phytoplankton abundance ind.L-1)	339.6	300	Recommended for fish since the dam is productive	
Phytoplankton Shannon index H	1.097			
Zooplankton abundance (ind.L-1)	209.9	100-500	Quality food available., so the dam is highly recommended for fish farming	
Zooplankton Shannon index H	1.926			

The dam being eutrophic can fairly support high productivity, but it may not support fish growth given the reported high turbidity which would limit light irradiance and subsequently result in low biological productivity. The dissolved oxygen level was also extremely low and would be lethal to fish if exposed for extended period of time. There was no fish caught during the survey but from the habitat characteristics, the dam may be a good candidate for *Clarias gariepinus* culture. The dam can only support lung fish and not gill fish that may be chocked by the suspended sediments.
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iv) **Ochot**

Plate 31. The dam is located in Bondo sub-county, around GPS point, -0.0759, 34.3091, with a water depth of 2.5 m and sandy substrate. It is a large water body with sheltered bays. Clarity is very high. High salinity and alkalinity. An important water drinking point with large herds turning up in turns. Dam outflows into a water abstraction point outside the high bank.

Table 31. Socio-ecological findings of Ochot dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.48	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	19.01
Trophic State Index (TSI)	47.9	Mesotrophic	Fair amount of productivity	
Ammonium (µg/l)	2.1875	2000 ug/l	Within recommended limit for warm adaptive fish growth at the observed pH	
Dissolved Oxygen (DO) (mg/l)	6.77	5 and above mg/L	Favorable to fish growth	
Temperature (^{0}C)	25.4	20--31 for warm temperature adaptive fish <20 for cold adaptive fish	Preferred temperature for warm adaptive fish growth	
pH	7.68	6--9	Best growth	
TN:TP	4.8	10 - 30	Nitrogen limited. This can promote the growth of undesirable algae like cyanophytes	
Secchi Depth (m)	0.7		Water too clear. Inadequate productivity.	
Fish condition factor			Four fish species were identified (O. n.; Gambusia, Haplochrime sp.)	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	300	$10^3 – 10^4$	Recommended for fish farming	
Phytoplankton abundance ind.L-1)	442	300	Not recommended for fish farming since cyanobacteria like Microcystis sp, Spirulina sp is turning saline	
Phytoplankton Shannon index H	1.8			

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Zooplankton abundance (ind.L-1)	3.3	100-500	Not recommended because of lack or scarcity of live food.	
Zooplankton Shannon index H	0.9713			

Apart from extremely high levels of conductivity and salinity, the dam exhibited good levels of other physico-chemical parameters. The dam reported 300 fecal coliforms which is an indication of non-pollution activities within and around the dam, but low abundance of plankton community suggesting low productivity and low Shannon-Wiener index indicating low diversity. The poor growth factor for fish may be attributed to high conductivity and salinity that would affect biological composition. The fresh water fish may not accommodate the brackish biological species. Three prominent fish species were obtained from the catch in this dam and additionally, gill rot (a clinical sign of bacterial infections) was noted by respondents of the questionnaire. Such varying parameters require further studies to ascertain requisite management interventions. The high conductivity and salinity of the waters may not allow for optimal performance of the fresh water fishes. The dam is therefore not suitable for any commercial fish culture venture at its state. There is need to establish the source of the salt for any mitigation measures to be taken.

v) Uranga Dam

Plate 32. The dam is located 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 mainly used for local irrigation.

Table 32. Socio-ecological findings of Uranga dam

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.51	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	26.25
Trophic State Index (TSI)	52.1	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium (µg/l)	85.3125	2000 ug/l	Within recommended limit given the observed values of temperature and pH	
Dissolved Oxygen (DO) (mg/l)	2.59	5 and above mg/L	Growth will be slow if exposure to low dissolved oxygen is continuous	
Temperature (^{0}C)	24.5	20--31 for warm temperature adaptive fish	Preferred temperature for fish growth	

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
		<20 for cold adaptive fish		
pH	7.62	6--9	Best growth	
TN:TP	54.5	10 - 30	Phosphorus limited. This would impede the growth of algal growth.	
Secchi Depth (m)	0.6	0.35 – 0.5	Phytoplankton are becoming scarce.	
Fish condition factor	N/A		No fish available for analysis. Restocking recommended.	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	200	$10^3 – 10^4$	Muddy, shoreline surrounded with macrophytes, recommended for fish farming	
Phytoplankton Shannon index H	3.83		Good diversity	
Phytoplankton abundance (ind.L-1)	191.4	300	Not Suitable for fish farming because limited food resources	
Zooplankton abundance (ind.L-1)	56.7	100-500/		
Zooplankton Shannon index H	1.569			

The dam reported 200 cfu's of fecal coliforms which is an indication of low-pollution activities within and around the dam. Though the water's trophic status is eutrophic and able to support good biological productivity, the plankton abundances were low. This was supported by the moderate secchi depth. The dissolved oxygen level was also considerably low to support optimal growth of fish. No fish was caught during the study but this could be due to sampling time. The cause for low DO needs to be established before any mitigation measures can be recommended. This is because the dam could have a high potential for investment to realize socioeconomic benefits beyond what was observed.

Conclusion and recommendations

Siaya County has a high potential for aquaculture development but most dams are small with seasonal drainages that limit the sustainability of the growth of cultured fish. The uptake of aquaculture farming in the area is minimal at the moment as people value fish from Lake Victoria more than cultured ones and other water uses like domestic, livestock watering and subsistence irrigation. Land ownership and management also pose a serious blockage to aquaculture development in the county. Uranga dam had the highest potential while Nyandong dam had the lowest.

3.1.7 Busia County

i) Buhuyi dam

Plate 33. The dam is located in Butula sub-county, around GPS point, -0.3702, 34.4097, with a water depth of 2 m and muddy substrate. Clear still water occurs within a permanent stream basin. The water is mainly used for domestic activities.

Table 33. Socio-ecological findings of Buhuyi dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.47	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	8.12
Trophic State Index (TSI)	57.6	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium (µg/l)	202.1875	2000 ug/l	Above the recommended limit	
Dissolved Oxygen (DO) (mg/l)	6.57	5 and above mg/L	Best condition for good growth	
Temperature (^{0}C)	26.3	20--31 for warm temperature adaptive fish <20 for cold adaptive fish	Preferred temperature for warm adaptive fish growth	
pH	7.64	6--9	Best growth	
TN:TP	15.3	10 - 30	No limiting nutrient. Can support diverse population of algae	
Secchi Depth (m)	1.5	0.35 – 0.5	Water is too clear. Inadequate productivity.	
Fish condition factor	N/A		No fish caught for analysis. Aquaculture candidates can be introduced in the dam.	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	300	10^3 – 10^4	Muddy, shoreline surrounded with grass and macrophytes. Recommended for fish farming	
Phytoplankton abundance ind.L-1)	168	300	Suitable for subsistence farming	
Phytoplankton Shannon index H	2.2248			
Zooplankton abundance (ind.L-1)	N/A			
Zooplankton Shannon index H	N/A			

The dam reported low fecal coliform loads and would therefore sustain good health condition of fish in terms of pathogenic infections. From the secchi depth reading, the water was too clear meaning that primary productivity was too low to support other organisms up the trophic chain. This was confirmed by the low phytoplankton abundance counts. Other limnological parameters of TSI, ammonium, dissolved oxygen, temperature, pH and TN:TP ratio were within permissible limits and able to support better growth of warm tropical fishes. Because dam habitat characteristics are dynamic and would change seasonally, time series sampling would be recommended before any concrete recommendation can be made. No fish was caught during the survey. The dam is considerably small and given present condition, it would support small scale tilapia culture of *Oreochromis niloticus. Stocking of Oreochromis niloticus* is therefore recommended.

ii) Changara

Plate 34. The dam is located in Teso North sub-county, around GPS point, -0.7409, 34.4164, with a water depth of 4 m and muddy substrate. The dam is surrounded with grass on the shoreline. Clear water mass occurring along a permanent stream basin. Reservoir has outlets draining into downstream catchment with another bigger dam currently under construction. Domestic activity is the main water use in this dam

Table 34. Socio-ecological findings of Changara dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.51	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	3.34
Trophic State Index (TSI)	64.7	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium (µg/l)	251.5625	2000 ug/l	Above the recommended limit. Not good for fish growth	
Dissolved Oxygen (DO) (mg/l)	3.42	5 and above mg/L	Growth will be slow if exposure to low dissolved oxygen is continuous.	
Temperature (^{0}C)	22.8	20--31 for warm temperature adaptive fish <20 for cold adaptive fish	Preferred temperature for warm adaptive fish growth	
pH	7.93	6--9	Best growth	
TN:TP	31.3	10 - 30	Phosphorus limited. This would impede the growth of algal growth.	
Secchi Depth (m)	0.3	0.35 – 0.5	If turbidity is from phytoplankton, the dam is in good condition.	
Fish condition factor	N/A		No fish were obtained during the survey. Restocking recommended.	
Microbial contamination indicators (Fecal	200	10^3 – 10^4	Muddy, dam with grass on the shoreline, at the lower side construction of another dam in	

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Coliforms) cfu/100 ml)			progress. After completion, recommended for fish farming	
Phytoplankton abundance ind.L-1)	245	300 cells	Not good for fish farming unless it is enhanced with productivity	
Phytoplankton Shannon index H	2.274			
Zooplankton abundance (ind.L-1)	37.7	100-500	Not very good for fish farming unless the productivity is enhanced.	
Zooplankton Shannon index H	1.289			

Changara dam exhibited low fecal coliform counts that were within recommendable concentration levels. The concentration level may not pose danger to the fish health in terms of pathogen infections. The trophic state index, an index of nutrients, light irradiance indicated that the water was eutrophic and can support a good level of primary productivity which would subsequently support biological productivity of higher trophic organisms. Temperature, pH, TN:TP ratio and secchi depth readings were optimal and would support a healthy productive system. The dissolved oxygen was rather moderately low and the cause should be confirmed. The phytop[ankton and zooplankton abundances were below threshold ranges but this limitation may be temporal since there is enough nutrients to support a productive system. The sytem supported quite diverse plankton specie, an indication of a productive system. The dam is warm and can stimulate rapid growth of tilapiines especially *Oreochromis niloticus*. Mixed culture with *Clarius gariepinus* can provide maximum biomass yield. No fish was caught during the study and therefore (re)stocking would be recommended.

iii) Munana

Plate 35. The dam is located in Samia sub-county, around GPS point, -0.2697, 34.0851, with a water depth of 3 m and sandy substrate. The dam has very clear water surrounded with macrophytes, the main water source is River Sio. The water is used for domestic and aquaculture activities.

Table 35. Socio-ecological findings of Munana dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.51	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	24.79
Trophic State Index (TSI)	54.3	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium (µg/l)	68.4375	2000 ug/l	Within the recommended limit for warm temperature adaptive fish growth at the observed pH	

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Dissolved Oxygen (DO) (mg/l)	3.81	5 and above mg/L	Growth will be slow if exposure to low dissolved oxygen is continuous.	
Temperature (^{0}C)	24.6	20-31 for warm temperature adaptive fish <20 for cold adaptive fish	Preferred temperature for warm adaptive fish growth	
pH	7.49	6-9	Best growth	
TN:TP	11.0	10 - 30	No limiting nutrient. Can support diverse population of algae	
Secchi Depth (m)	0.8	0.35 – 0.5	Water is too clear. Inadequate productivity.	
Fish condition factor	N/A		Restocking of the dam is recommended. Survey did not obtain samples.	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	400	$10^3 – 10^4$	Recommended for fish farming, surrounded with macrophytes	
Phytoplankton Shannon index H	0.2231		Recommend for scale fish farming	
Phytoplankton abundance (ind.L-1)	362.8	300		
Zooplankton abundance (ind.L-1)	94.8	100-500	Recommended for fish farming but some interventions	
Zooplankton Shannon index H	1.332			

Munana's trophic index was eutrophic and able to support good level of primary productivity. However, the water was quite clear with low productivity. Aerial photo shows a dam that is dynamic and can get turbid, both from suspended sediments and/or phytoplankton biomass. Other limnological parameters of temperature, pH, TN:TP ratio and ammonia were within permissible levels. The microbial contamination levels measured from fecal coliform counts were favorable for fish culture. The dissolved oxygen was low and continual exposure by fish may turn lethal. Other factors like Biochemical Oxygen Demand (BOD) may be looked at to try and establish the cause for low DO. In the mean-time, with the low DO, *Clarias gariepinus* provides the best candidate for the dam.

iv) **Namalenga**

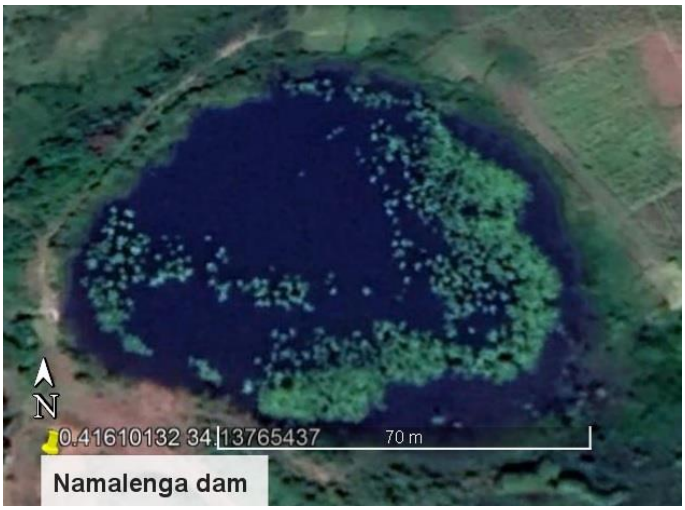


Plate 36. The dam is located in Matayos sub-county, around GPS point, 0.4161-, 34.1376, with a water depth of 2 m and sandy, shoreline with grass and macrophytes. The dam's main uses are domestic and aquaculture activities.

Table 36. Socio-ecological findings of Namalenga dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.56	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	21.42
Trophic State Index (TSI)	59.7	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium (µg/l)	50.3125	2000 ug/l	within the recommended limit for warm temperature adaptive fish growth at the observed pH	
Dissolved Oxygen (DO) (mg/l)	9.71	5 and above mg/L	Best condition for good growth	
Temperature (^{0}C)	25.5	20--31 for warm temperature adaptive fish <20 for cold adaptive fish	Preferred temperature for warm adaptive fish growth	
pH	7.79	6--9	Best growth	
TN:TP	14.3	10 - 30	No limiting nutrient. Can support diverse population of algae	
Secchi Depth (m)	0.4	0.35 – 0,5	If turbidity is from phytoplankton, the dam is in good condition.	
Fish condition factor	N/A		No fish were obtained for the sample analysis. Restocking recommended.	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	300	$10^3 – 10^4$	Muddy, shoreline with grass and macrophytes, recommended for fish farming	
Phytoplankton abundance ind.L-1)	121.29		Low diversity of algae but if enhanced can be suitable for fish farming.	
Phytoplankton Shannon index H	2.112			
Zooplankton abundance (ind.L-1)	53.1	100-500	Dominated by rotifers (64.7%). Not recommended for commercial fish farming	
Zooplankton Shannon index H	2.193			

Most parameters that were measured from Namalenga dam were within allowable concentration levels. The microbial contaminations were low and may not pose health risk to the resident biotic organisms. The dissolved oxygen, ammonium, temperature, and pH, TN: TP ratio and secchi depth readings fell within allowable levels that would promote better growth and reproduction and fish. The trophic state index also points to a productive system. Phytoplankton and zooplankton abundances, however, were moderately low and this could be impacted by the time of sampling since these organism migrate across the water column depending on the time of day. Diversity of both phytoplankton and zooplankton were good indicating that the water is of good integrity. No fish were caught during the sampling survey, but the dam is able to support *Oreochromis niloticus* species. *O. nilotics* should therefore be used to stock the dam.

v) Namonye

Plate 37. The dam is located in Bunyala sub-county, around GPS point, -0.1355, 34.0485, with a water depth of 2 m and muddy, shoreline with grass and macrophytes. Clear water from a permanent swamp along a stream. The outlet discharges back into the nearby swamp. Occurrence of water lilies at 40 percent. The dam's main uses are domestic and aquaculture activities.

Table 37. Socio-ecological findings of Namonye dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.41	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	6.64
Trophic State Index (TSI)	54.3	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium (µg/l)	151.24	2000 ug/l	Within the recommended limit for cold temperature adaptive fish growth	
Dissolved Oxygen (DO) (mg/l)	5.51	5 and above mg/L	Best condition for good growth	
Temperature (^{0}C)	25.1	20--31 for warm temperature adaptive fish <20 for cold adaptive fish	Preferred temperature for warm adaptive fish growth	
pH	7.72	6--9	Best growth	
TN:TP	8.8	10 - 30	Nitrogen limited. This can promote the growth of undesirable algae like cyanophytes	
Secchi Depth (m)	0.34	0.35 – 0.5	If turbidity is from phytoplankton, the dam is in good condition.	
Fish condition factor	N/A		Restocking recommended, the team did not obtain samples for analysis.	

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	1100	$10^3 – 10^4$	Recommended for fish farming, formed as a result of floods from River Nzoia (An Ox-bow lake)	
Phytoplankton Shannon index H	1.962		Restocking is recommended since productivity is good for aquaculture.	
Phytoplankton abundance (ind.L-1)	132			
Zooplankton abundance (ind.L-1)	38.2	100-500/L.-Minimum at fry stocking & within the post-stocking range	Not recommended. Productivity to be enhanced to allow the farming	
Zooplankton Shannon index H	1.896			

Namonye dam is relatively small and can support small scale fish farming. The water quality parameters are fairly good for optimal performance of fish growth and reproduction. However, the dam requires rehabilitation by removal of the macrophytes, both emergent and floating. The microbial contamination levels were low and could not pose any health risk. The water quality parameters of temperature, pH dissolved oxygen, ammonium and the trophic index were of permissible values. The eutrophic condition implies that the nutrient levels are good to support healthy biological productivity. With rehabilitation, the dam would promote optimal performance of tilapiine fishes. The water temperature would enhance growth performance. O. n. can be stocked.

vi) Busia ATC

Picture: The Busia ATC dam was visited by the survey team but was not sampled. The dam was overgrown by rooted macrophytes making it difficult to be sampled.

Conclusion and recommendations

Busia County lies within the warm tropical climate with ample rainfall to recharge the existing dams. Most of the dams have an open system with rivers or streams recharging the water masses. Though the sizes of most dams are relatively small and can only sustain small scale farming, the limnological conditions were fairly good to support high biological productivity. Some dams were encrusted with macrophytes and requires rehabilitation before any necessary investment is carried out. Some follow-up studies to some dams are also necessary to ascertain the habitat characteristic to enable proper identification of preferable candidate species.

3.2 Central region

3.2.1 Nyeri County

i) Chinga

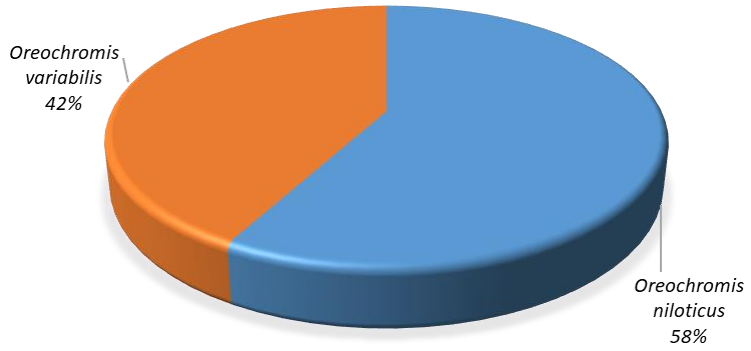
Plate 38. The dam is located in Nyeri South sub-county at around GPS point, -0.5831, 36.9204 and at an altitude the dam lies within Wet climatic condition, densely populated, forested with agricultural activities of tea and maize plantations, open basin with perennial recharge from spring and surface run-off, fringing vegetation, highly turbid from algal productivity, cage culture practiced.

Table 38. Socio-ecological findings of Chinga dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.54	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	396.9
Trophic State Index (TSI)	50.2	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium (µg/l)	95.2	2000 ug/l	Recommended limit	
Dissolved Oxygen (DO) (mg/l)	6.4	5 mg/L and above	preferred value	
Temperature (^{0}C)	18.9	20-31 warm adaptive fish <20 for cold adaptive fish	Within recommended value for cold adaptive fish	
pH	6.8	6-9	Best for growth	
TN:TP	15.9	10 - 30 (No limiting nutrient)	No limiting nutrients. Can support diverse population of algae	
Secchi Depth (m)	1.07	0.35 – 0.5	Water is too clear. Inadequate productivity.	
Fish condition factor (O.V)	2.15	2.9-4.8	Condition of the fish was fair. It is good for aquaculture but there will be a need for feed supplements. Restocking recommended with preferred aquaculture species.	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	90	10^3 – 10^4	Large dam with a wetland at the inlet end. Recommended for fish farming.	
Phytoplankton Shannon index H	5.50687		Pristine environment and can support a fishery since the dam is productive	
Phytoplankton abundance (ind.L-1)	899			

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Zooplankton abundance (ind.L-1)	207.2	100-500/L Minimum required at fry stocking and post-stocking range	Food for fish available., thus recommended for fish farming	
Zooplankton Shannon index H	1.108			

Cinga dam was comparatively large and located in a well maintained environment. It supports a considerable range of activities including fisheries, cage culture and eco-tourism. The limnological variables measured were considerably good for tilapia farming except the temperature. The dam had high primary productivity as measured from chlorophyll-a (36.4 µg/l). The high productivity of the dam was also exhibited in the phytoplankton and zooplankton abundance measurements. The Shannon indices also showed good diversity for the plankton, an indication of hogher integrity of the waters. Ammonium, dissolved oxygen, TN:TP ratio, and pH were optimal for good fish growth. The temperatures were considerably low for optimal performance of tilapia growth and reproduction. The levels may stress the fish and lead to stunting. The growth condition factor was slightly below the recommendable range. Considering that the sampling was done between the months of July and August, the coldest season of the year, follow-up studies needs to be undertaken to check whether there is any shift in temperature and condition factors of fish before identifying the best fish candidate. Because of increased flushing by the running stream and well maintained environment, the dam can continue supporting cage culture, fisheries, irrigation and eco-tourism.



ii) Gaikuyu Dam

Plate 39. Located around GPS point, -0.4144, 37.1251 Small and shallow dam, agricultural activities around the basin, water used for irrigation and domestic use, open basin with surface recharge and discharge, fringing wetland plants, inhabited by fish.

Table 39. Socio-ecological findings of Gaikuyu dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.54	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	0.9
Trophic State Index (TSI)	42.7	40 - 50 (Mesotrophic)	Can support a fair amount of productivity.	
Ammonium (µg/l)	55.7	2000 ug/l	Above recommended limit	
Dissolved Oxygen (DO) (mg/l)	7.0	5mg/L and above	Very good for fish farming	
Temperature (^{0}C)	18.5	20-31 for warm adaptive fish <20 for cold adaptive fish	preferred temperature for cold adaptive fish	
pH	7.1	6-9	Best for growth	
TN:TP	71.1	10 - 30	Phosphorus limiting. This would impede algal growth.	
Secchi Depth (m)	0.6	0.35 – 0.5	Water is too clear. Inadequate productivity.	
Fish condition factor	N/A		No fish were obtained. Restocking proposed.	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	80	10^3 – 10^4	1. Outlet and inlet present. 2.Typha plants at one end of the pond, recommended for fish farming	
Phytoplankton Shannon index H	3.12926			
Phytoplankton abundance (Ind.L-1)	160		The dam is fairly productive but needs enhancement	
Zooplankton abundance (ind.L-1)		100-500/L Minimum required at fry stocking and post-stocking range	Recommended for fish farming	
Zooplankton Shannon index H				

Gaikuyu dam was relatively small and with fair limnological conditions to support fish growth. Primary productivity was supported by nitrogen nutrient concentrations which were fairly high while the phosphorus concentrations were extremely low to necessitate rapid growth of phytoplankton. Chlorophyll-a was therefore low (2.2 µg/l) a fact that is replicated in secchi depth reading and phytoplankton abundance. The phytoplankton diversity was, however, high. The trophic state was fair, mesotrophic and could support fair amount of primary productivity. Ammonium, pH and dissolved oxygen were within permissible levels. Being in close proximity to Mount Kenya, the water temperature was low, but expected to be higher in the rest of the months. Temperature dynamics needs to be established but from the community knowledge, the stocked fishes are not doing well. Socially, the dam had a relatively high investment acceptance index but a very low gender inclusion index which moderated the socio-economics index for fisheries development at low-scale commercial production. Tilapia may not be the best candidate for this dam but the establishment of the best candidate may require time series data.

iii) Guara Dam

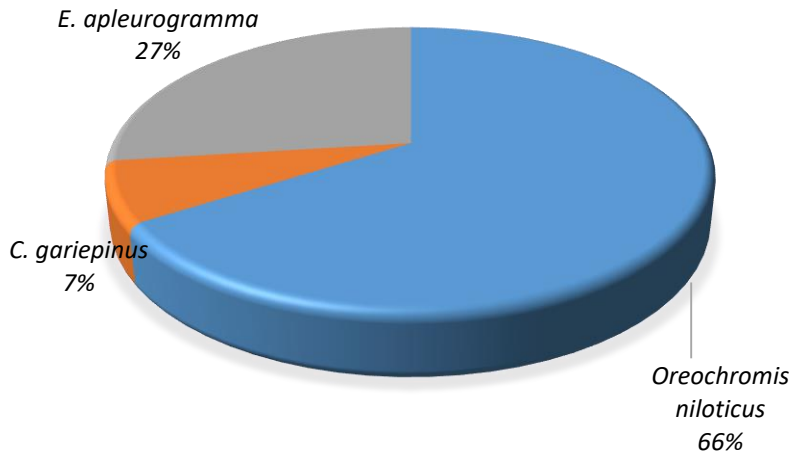
Plate 40. It is located in Nyeri County, Kieni West sub-county around GPS point, -0.0761, 37.0330 and at 1905.4 m a.s.l. The area is Semi-arid, with sparsely populated, intermediate agricultural activities, open basin with seasonal recharge from surface run-off, fringing vegetation, highly turbid from siltation, cage culture practiced.

Table 40.Socio-ecological findings of Guara dam

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.54	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	3.76
Trophic State Index (TSI)	57.7	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium	567.1	2000 ug/l	Extremely above the recommended limit. Exhibited presence of NH3 which is toxic. The dam needs thorough joint removal and good flow of inlet water as this may result in fish kills.	
Dissolved Oxygen (DO)	6.5	5mg/L and above	Very good level for fish growth	
Temperature	21.1	20-31 for warm adaptive fish <20 for cold adaptive fish	Preferred temperature for fish growth	

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
pH	7.7	6-9	Best growth	
TN:TP	105.4	10 - 30	Phosphorus limited. This would impede the growth of algal growth.	
Secchi Depth (m)≷	N/A			
Fish condition factor	1.77 (Haplochromines), 1.82 (*O. n*)	2.9 - 4.8	Both species have performed below the threshold. Supplemental feeding is recommended to enhance performance of *O. n*.	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	80	$10^3 – 10^4$	Single seasonal inlet. Cage farming active. Literal zone covered with emergent macrophytes. High potential for fish farming.	
Phytoplankton Shannon index H	2.6814			
Phytoplankton abundance (Ind.L-1)	297	300 and above	There is good productivity fish farming can thrive since there is a lot of algae for the prey	
Zooplankton abundance (ind.L-1)		100-500/	Productive and food available fry stocking and post-stocking stage	
Zooplankton Shannon index H				

The eutrophic waters of Guara is able to support a fairly good amount of primary productivity a fact that is exhibited in chlorophyll-a concentrations (23.6 µg/l) and in phytoplankton abundance. The dam is located in a semi-arid area and is highly turbid. Both nitrogen and phosphorus levels are high to promote phytoplankton productivity. Temperature, dissolved oxygen and pH measurements were within allowable levels that is conducive for fish growth. Ammonium levels, though within allowable limits, were relatively high. The sources of ammonium needs to be established whether it's generated from the cage culture practice or whether from exogenous sources. Microbial contamination counts showed low levels that poses no health risk. The resident fishes were not performing well and this be due to high turbidity of the water that limits light irradiance and the fishes are not able to properly see their prey. Of the two fish species recorded, *Pseudotropheus* sp was dominant. Significant variations in weather patterns and dominance of farm and livestock agriculture in the area were observed to form a cultural livelihood bias which resulted into low-scale commercial socioeconomics index with regards to prospects for the SWB's fishery development. It would be of utmost importance to build the capacity of the dam's stakeholders with regards to fisheries development as a step towards deconstructing salient and covert livelihood biases formed by pre-exposure to dominant economic activities and cultural practices. Because of the high turbidity, *Clarius gariepinus* would form a better candidate for culture in this dam.



iv) Hohwe Dam

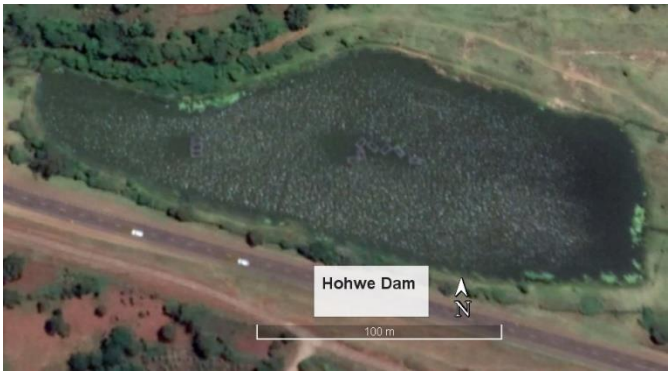


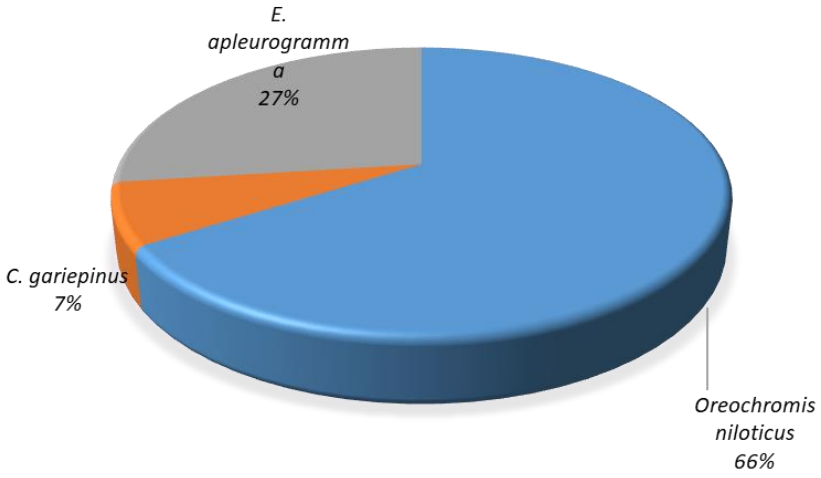
Plate 41. Located around GPS point -0.4671, 37.0756, Wet climatic region, dense human settlement, intense agricultural activities, open basin with perennial recharge from surface run-off and with a discharge, fringing wetland vegetation cover, cage culture practice, beside a major road.

Table 41.Socio-ecological findings of Hohwe dam

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.47	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	6.09
Trophic State Index (TSI)	41.7	40 - 50 (Mesotrophic)	Can support a fair amount of productivity.	
Ammonium (µg/l)	45.7	2000 ug/l	Within recommended limit	
Dissolved Oxygen (DO) (mg/l)	N/A	5 mg/L and above		
Temperature (^{0}C)	21.6	20-31 for warm adaptive fish <20 for cold adaptive fish	Preferred temperature for fish growth	
pH	6.8	6-9	Best growth	
TN:TP	22.7	10 - 30	No limiting nutrient. Can support diverse population of algae	
Secchi Depth (m)	N/A	0.35 – 0.5		
Fish condition factor	1.78 (*O. n*))	2.9 - 4.8	*O. n* here performed poorly. Need to enhance production by	

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
			supplementing food. Restocking recommended.	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	120	$10^3 – 10^4$	Dam adjacent to a major road. Access open for all uses, requires fencing. Recommended for fish farming	
Phytoplankton Shannon index H	2.563	300 and above	Preferred for fish farming and its productivity is good.	
Phytoplankton abundance (Ind.L-1)	324			
Zooplankton abundance (ind.L-1)		100-500/		
Zooplankton Shannon index H	1.735			

The moderate low microbial values reported (120 cfu's/100) is an indication of good water quality that can support the growth of safe fish for animal consumption. On the other hand, the high abundance of plankton in the dam is good for fish growth. Three fish species were recorded with *O. niloticus* dominating numerical abundance at 79 %, while *E. apleurogram and Clarias gariepinus* constituting 27% and 7%, respectively. The socio-economics perceptions on the dam recommend low-scale commercial fisheries development for either fish farming or restocking.



v) Ichamara

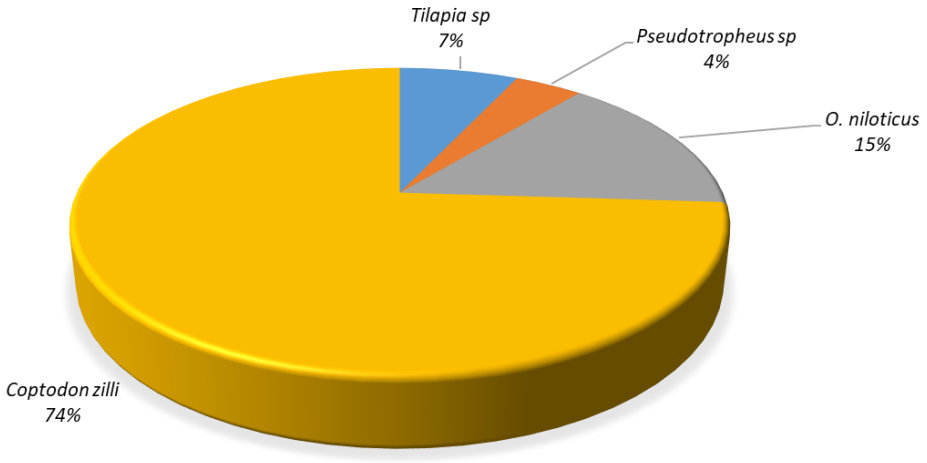
Plate 42. Located in Mukurweini Sub-county at GPS point, -0.5504, 37.0843 and an altitude of 1617.1 m a.s.l. It experiences semi-dry climatic conditions, sparsely populated, sparsely vegetated with agricultural activities, fringing wetland vegetation, open basin with surface recharge and discharge, highly turbid with algal productivity, low cage culture practice.

Table 42. Socio-ecological findings of Ichamara dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.57	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	2.12
Trophic State Index (TSI)	30.8	> 40 (Oligotrophic)	Low nutrients to support healthy algae and fish.	
Ammonium	181.4	2000 ug/l	Above the recommended limit	
Dissolved Oxygen (DO)	6.5	5mg/L and above	very good level	
Temperature	21.9	20-31 for warm adaptive fish <20 for cold adaptive fish	Preferred temperature for fish growth	
pH	5.72	6-9	Slow growth	
TN:TP	N/A			
Secchi Depth (m)≷	N/A			
Fish condition factor	1.81 (*O. n*), 2.31 (*C.z*)	2.99 - 4.8	Coptodon Zilli performed fairly while *O. n*'s performance was poor. Need to supplement food.	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	30	$10^3 – 10^4$	*Recommended for fish farming, Pond with cages,*	
Phytoplankton Shannon index H	1.93174			
Phytoplankton abundance (Ind.L-1)	2077			
Zooplankton abundance (ind.L-1)	281.2	100-500	The diversity and abundance is good and is bound to favor good environment for fish farming	
Zooplankton Shannon index H	0.8839			

The low fecal coliforms (30 cfu/100) reported in Ichamara dam is indicative of relatively good quality since the cfu/100 lies within the acceptable standard for fish farming. The low trophic index and the low nutrient levels reported justify the oligotrophic nature of the dam. The fair growth performance of *Coptodon Zilli* and poor growth performance for *O. niloticus*, illustrates the differential food requirements for different fish/aquatic species. The diverse nature of fish species (*Tilapia* sp, *Pseudotropheu*s sp and *O. niloticus*) in this dam is an indication of availability of good

food resources for various fish species. In spite of the perceived variability of weather patterns that have impacted this SWB, the socio-economics index indicates that a low-scale commercial fishery development is very sustainable for this dam. This would provide an adequate balance for other complementary livelihood activities possible within the water body.



vi) **Kiboya**

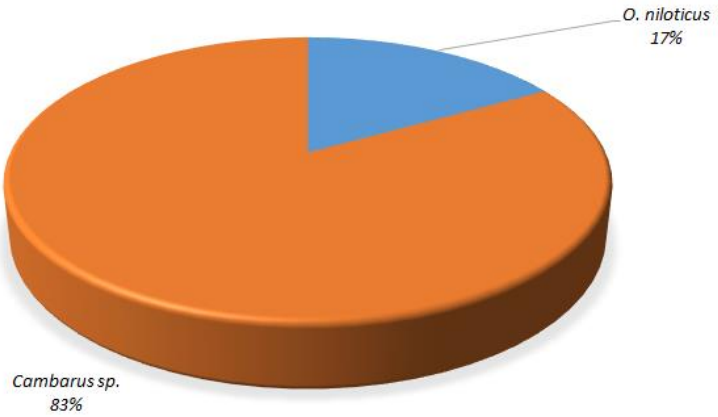
Plate 43. Located in Kieni Sub-county, GPS point,-0.2292, 35.8962 and at 1970.2 m a.s.l. Semi-arid climatic condition, shrub vegetation, limited agricultural activities, seasonal surface run-off recharge, open basin with seasonal discharges, sparse fringing macrophyte cover, highly turbid from siltation.

Table 43.Socio-ecological findings of Kiboya dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.42	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	0.71
Trophic State Index (TSI)	33.2	< 40 (Oligotrophic)	Low nutrients to support healthy algae and fish.	
Ammonium (µg/l)	257.1	2000 ug/l	Above recommended limit	

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Dissolved Oxygen (DO) (mg/l)	7.01	5mg/L and above	Very good level for fish growth	
Temperature (^{0}C)	20.8	20-31 for warm adaptive fish <20 for cold adaptive fish	Preferred temperature for fish farming but monitoring is key to successful harvest	
pH	8.0	6-9	Best for growth	
TN:TP	108.8	10 - 30		
Secchi Depth (m)	N/A	0.35 – 0.5		
Fish condition factor	0.56 (*Cambarus* spp.), 1.84 (*O. n*)	2.9 - 4.8	*Cambarus* spp. performed very poorly while *O. n* was poor. Supplemental feeding recommended to enhance performance of *O. n*.	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	20	$10^3 – 10^4$	Small seasonal inlet river. Cattle watering from the dam. Requires fencing to prevent potential contaminants. Recommended for fish farming	

The low fecal coliforms (20 cfu/100) reported in Kiboya dam, is indicative of relatively good quality since the cfu/100 lies within the acceptable standard for fish farming. The prevailing physico-chemical conditions, reflected in low nutrient availability. Poor growth performance of *Cambrus* sp. is likely to be due to low food supply in this system which is a consequence of low nutrients which affects the productivity up the food chain. The diverse nature of fish species (*Tilapia* sp, *Pseudotropheu*s sp and *O. niloticus*) in this dam is an indication of availability of good food resources for various fish species.



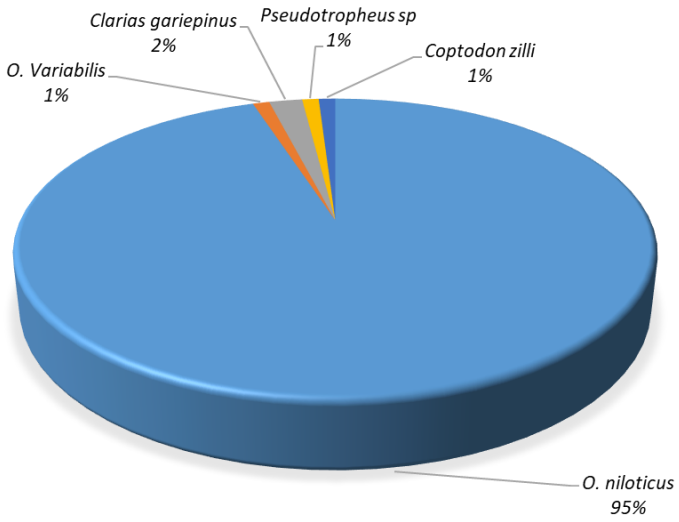
vii) Kiunyu

Plate 44. The dam is located in Nyeri Sub-county around GPS point, -0.4654, 36.9499 at an altitude of 1788.1 m a.s.l. Wet climatic condition, undulating landscape, densely populated, agricultural activities, spring source water with discharge, high algal productivity, fringing wetland of *Typha domingensis*.

Table 44. Socio-ecological findings of Kiunyu dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.52	0.4 ≤ Low-scale commercial < 0.6		0.72
Trophic State Index (TSI)	54.5	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium	80.0	2000 ug/l	Recommended for fish farming because the ammonium ions are within the limit.	
Dissolved Oxygen (DO)	7.7	5mg/L and above	Favorable for fish farming	
Temperature	22.7	20-31 for warm adaptive fish <20 fr cold adaptive fish	preferred temperature for fish farming	
pH	8.0	6-9	good for fish farming	
TN:TP	25.1	10 - 30	No limiting nutrient. Can support diverse population of algae	
Secchi Depth (m)≷	0.4		If turbidity is from phytoplankton, dam is in good condition.	
Fish condition factor	N/A		Fish not available for analysis. Restocking recommended.	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	40	$10^3 – 10^4$	Shores covered with typha, high water conductivity. Not very good for fish farming.	
Phytoplankton Shannon index H	2.542			
Phytoplankton abundance (Ind.L-1)	173	300 and above	Diversity and abundance is good and favourable for fish farming	
Zooplankton abundance (ind.L-1)	178.2	100-500		
Zooplankton Shannon index H	0.9723			

Kiunyu dam has good limnological characteristics that can support fairly good biological productivity but shallow across the entire span of the dam. The dam requires dredging to improve on its Carrying capacity (mt).



viii) Njengu

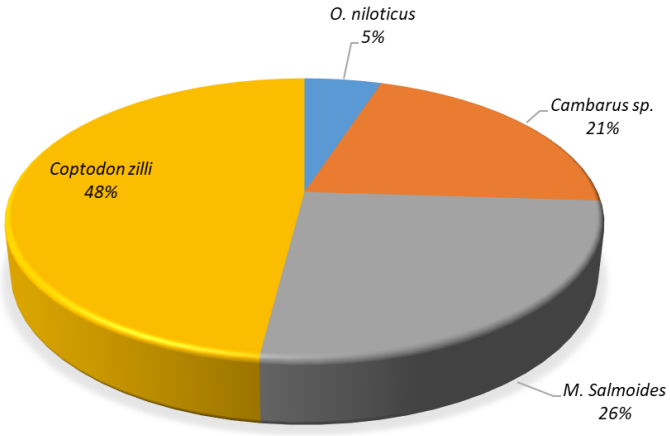
Plate 45. This dam is located in Kieni West Sub-county in the larger Nyeri County around GPS point, -0.3704, 36.9232 at 1838.5 m a.s.l. It has wet climatic condition, undulating landscape, sparsely populated, forested with agricultural activities in the catchment, initially encrusted by macrophytes and still under rehabilitation, fringing macrophytes, open basin with perennial recharge and discharge.

Table 45. Socio-ecological findings of Njengu dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.57	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	20.04
Trophic State Index (TSI)	42.4	40 - 50 (Mesotrophic)	Can support a fair amount of productivity.	
Ammonium	497.1	2000 ug/l	Extremely high. Not recommended for fish farming unless the water is treated or passed under purification to remove toxic ammonia.	

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Dissolved Oxygen (DO)	6.0	5mg/L and above	Preferred dissolved oxygen level for fish farming	
Temperature	21.1	20-31 for warm adaptive fish <20 for cold adaptive fish	Within the preferred range but needs monitoring when fish farming is in the process.	
pH	7.8	6-9	Best for fish farming	
TN:TP	265.8	10 - 30	Phosphorus limiting. This would impede the growth of algae.	
Secchi Depth (m)≷	N/A			
Fish condition factor	1.12 (*Macropterus* spp.), 2.1 (*Cambarus* spp.)	2.9 - 4.8	*M. s* performed poorly while *Cambarus* spp. was fair. *Cambarus* spp. can be cultured /restocked for humans and the animal feed industry	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	130	$10^3 – 10^4$	1. Outlet and inlet present. 2.Typha plants at one end of the pond, recommended for fish farming	
Phytoplankton Shannon index H	3.58406			
Phytoplankton abundance (Ind.L-1)	636	300 and above	Suitable for fish farming	
Zooplankton abundance (ind.L-1)	258.7	100-500	Recommended for fish farming	
Zooplankton Shannon index H	1.214			

The dam is under rehabilitation after it was completely encrusted with macrophytes. Organic matter decomposition led to elevated nitrogen species concentrations but with phosphorus limitation. Given time, the dam's integrity may be restored and with fairly high productivity. The low fecal coliforms (130 cfu/100) reported in Njengu dam is below the threshold, it is indicative of good quality acceptable sustainable fish farming. The prevailing physico-chemical conditions like the high Ammonia, relatively low trophic status which impedes primary production and consequently affect the organisms up the food chain which eventually have poor growth performance observed for *Micropterus salmoides*. The diverse composition of fish species in the dam is an indication of differential use of available food resources in the dam environment allowing the other species, *Cambarus sp* to have fair performance with a condition factor 2.1. The low socio-economic index report is within the threshold and can therefore support low scale commercial fish farming in the dam.



Conclusion and recommendations

A total of eight (8) water bodies in Nyeri County were sampled. A mean of 73.8 cfu/100ml with a range of 20-130 cfu/100ml was recorded for microbial contaminants using fecal indicator microorganisms). The results are much below the minimum threshold values of 103 – 104 cfu/100ml. This is indicative of good water quality which is within acceptable levels for fish farming. Physico-chemical variables and plankton varied between dams. Eight (8) fish species were recorded in the County. Chinga dam had the highest potential for aquaculture practice since in exhibited the highest carrying capacity (396.9 mt) while the least is Kiboya dam with a capacity of 0.71 mt.

3.2.2 Kirinyaga County

i) Ahiti Ndomba

Plate 46. Ahiti Ndomba dam Located around GPS 0.5824, 37.3417 is in Kirinyaga county, Mwea East sub-County. A region with low rainfall, sparsely populated, intense horticultural practices within the basin, a relatively young emerging dam (about 3 years old), closed basin with spring source water, water used for irrigation, water dark in color from decomposition of refractory organic matter, fringing wetland plants.

Table 46. Socio-ecological findings of Ahiti Ndomba dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.48	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	5.45
Trophic State Index (TSI)	43.4	40 - 50 (Mesotrophic)	Can support a fair amount of productivity.	
Ammonium	95.7	2000 ug/l	Within the recommended limit. Therefore, it is good for fish farming.	
Dissolved Oxygen (DO)	5.7	5mmg/L and above	Favorable for fish farming	
Temperature	25.4	20-31 for warm adaptive fish. <20 for cold adaptive fish	Preferred temperature for fish farming	
pH	7.5	6-9	Best for fish farming	
TN:TP	44.8	10 - 30	Phosphorus limiting. This would impede the growth of algae.	
Secchi Depth (m)≷	N/A			
Fish condition factor	N/A		Fish not obtained for analysis. Restocking recommended.	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	240	$10^3 – 10^4$	1. Typha plants. 2. Submerged terrestrial plants. 3. Small maize farms around the dam. 4.Homesteads around, with good drainage pattern, good for fish farming	
Phytoplankton Shannon index H	2.64655			
Phytoplankton abundance (Ind.L-1)	268	300 and above	Suitable for fish farming	

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Zooplankton abundance (ind.L-1)		100-500	Suitable for fish farming	
Zooplankton Shannon index H				

Microbial contaminants and fecal coliform counts were observed to be within the range and suitable for farming. Limnological parameters like Temperature, phosphorus and ammonia were within the range and there was good diversity of plankton and encourages the growth of fish preferred by fish. Plankton diversity and abundance shows that there is potential for fish farming hence productivity is good. Water quality affects the abundance, species composition and physiological condition of indigenous population of fish in Ahiti Ndomba is a fairly new emerging dam still undergoing limnological transformations. Presently, the dam exhibits a fair amount of productivity but with phosphorus limitation. The socioeconomic index shows low scale fish farming with a capacity of 5.45 mt and thus the dam is recommended for restocking.

ii) Kangai

Plate 47. Kangai dam is located in a small water body located in Mwea west with GPS point, -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 will also be used for irrigation.

Table 47. Socio-ecological findings of Kangai dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.55	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	1.09
Trophic State Index (TSI)	51.9	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium (µg/l)	87.1	2000 ug/l	Within the recommended limit. Therefore, good for fish farming	
Dissolved Oxygen (DO) (mg/l)	6.7	5mg/L and above	Good for fish farming	
Temperature (^{0}C)	20.9	20-31 for warm adaptive fish. <20 for cold adaptive fish	Tolerated by cold and warm adaptive fish	
pH	7.3	6-9	Best for fish farming	
TN:TP	1.9	10 - 30	Nitrogen limited. This can promote the growth of	

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
			undesirable algae like cyanophytes	
Secchi Depth (m)	N/A	0.35 – 0.5		
Fish condition factor	N/A		Fish not available for analysis.	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	70	$10^3 – 10^4$	The dam is still under construction.	
Phytoplankton Shannon index H	1.34076			
Phytoplankton abundance (Ind.L-1)	827		Good for fish farming diversity and abundance of phytoplankton for the prey	
Zooplankton abundance (ind.L-1)		100-500	A wide range of prey types available. Recommended for farming	
Zooplankton Shannon index H				

The dam recorded fecal coliform which was below the detection range. However, an indication of low activities was noted from the farm land and also within the farm. Phytoplankton and zooplankton showed a clear indicative that the water is suitable for fish farming although low productivity was noted. The physical chemical parameters is an indicative of a pristine environment for fish farming. The poor performance showed that there is food from the natural environment but there is a need for restocking and enhancement of the food. However, there is a high likelihood for high investment to realize socioeconomic benefits but for small scale. There is a need for integrated fish farming. The social economic index observed corresponds with other attributes indicative of a low fish scale farming.

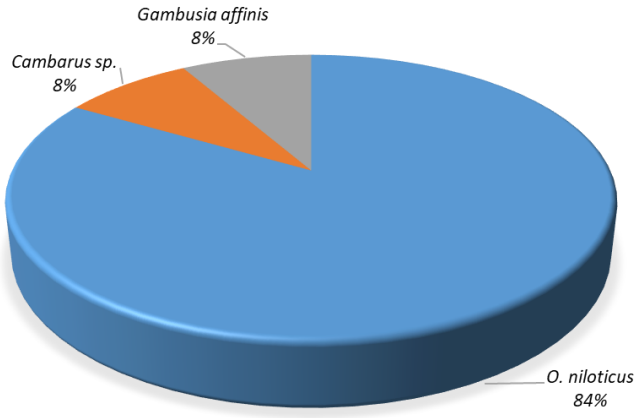
iii) Karura

Plate 48. Karura dam is situated Kirinyaga county, Kirinyaga west with a GPS of -06.3593 37.1781. 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 48. Socio-ecological findings of Karura dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.52	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	13.8
Trophic State Index (TSI)	52.0	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium (µg/l)	18.6	2000 ug/l	Within the recommended limit. Therefore, it is good for fish farming at semi- intensive level.	
Dissolved Oxygen (DO) (mg/l)	6.4	5 and above mg/L	Favorable for fish farming	
Temperature (^{0}C)	24.4	20-31 for warm adaptive fish <20 for cold adaptive fish	Good for fish farming	
pH	7.4	6-9	Best for fish farming	
TN:TP	7.4	10 - 30	Nitrogen limited. This can promote the growth of undesirable algae like cyanophytes	
Secchi Depth (m)	N/A	0.35 – 0.5		
Fish condition factor	1.84(*O. n*), 1.96(*O.v*)	2.9 - 4.8	Both species performed poorly. Restocking with *O. n* and *C.g* recommended in addition to supplemental feeding.	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	30	10^3 – 10^4	1.The dam partially covered with papyrus 2.Vegetable farm around the dam, good for fish farming	
Phytoplankton Shannon index H	1.86322			
Phytoplankton abundance (Ind.L-1)	152		favourable for fish farming if enhanced	
Zooplankton abundance (ind.L-1)		100-500	Favourable for fish farming	
Zooplankton Shannon index H				

The measurement of microbial contaminants and fecal coliform counts were observed to be within range and suitable for fish culture but unfortunately limnological parameters like phosphorus and silica tend to encourage the growth of nitrogen fixing limiting cyanophytes which are less preferred by fish and man and may be toxic. Plankton diversity and abundance shows that there is potential for fish farming hence primary and secondary productivity is good. Though a low socio economics index was observed and Carrying capacity (mt) was 13.75 mt which can support low level fish farming. According to the study *Oreochromis niloticus* being abundant with 53.1%, *Oreochromis variabili*s 38% and least *C. gariepinus* 4%, *O. leucosticus, Pseudotropheus* and *O. esculentus* had 2%, respectively. It depicts water values that can allow low fish scale fish farming hence fish farming is recommended.



iv) Njuki-ini

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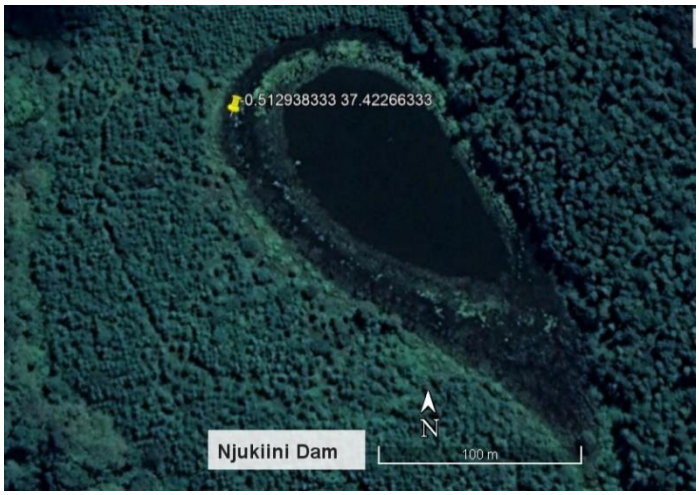


Plate 49. Njuki-ini dam is located in Kirinyaga County, Kirinyaga East sub-county with GPS 0.5824, 37.3254. Wet climatic region, closed basin dam in the middle of a forest, spring source water, fringing and floating macrophytes, dark colored from decomposition of refractory organic matter.

Table 49. Socio-ecological findings of Njuki-ini dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.52	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	6.84
Trophic State Index (TSI)	51.1	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium (µg/l)	74.3	2000 ug/l	Recommended for fish farming	
Dissolved Oxygen (DO) (mg/l)	6.3	5 and above mg/L	Good for fish farming	
Temperature (^{0}C)	25.3	20-31 for warm adaptive fish <20 for cold adaptive fish	Preferred temperature for fish farming	
pH	6.5	6-9	Best for fish farming	
TN:TP	14.6	10 - 30	No limiting nutrient. Can support diverse population of algae	

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Secchi Depth (m)	1.3	0.35 – 0.5	Water too clear. Inadequate productivity.	
Fish condition factor	N/A		No fish were obtained for analysis. Restocking recommended.	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	0	$10^3 – 10^4$	1. Dam inside a forest. 2. Water Lily covers the literal zone, highly recommended for fish farming.	
Phytoplankton Shannon index H	3.61132			
Phytoplankton abundance (Ind.L-1)	303			
Zooplankton abundance (ind.L-1)	233.8	100-500	Good for fish farming	
Zooplankton Shannon index H	1.151			

Njuki-ini is highly loaded with nutrients enough to support good productivity. It exhibits no limiting nutrients and thus can support good diversity of the algal population. It should be rehabilitated through removal of encroaching macrophytes. The dam is suitable for fish farming with food supplements and close management to deter growth of undesirable blue-green and green algae. The water is pristine. The dam is already stocked with *O. niloticus* but needs to be restocked again. The dam can be used in promoting ecotourism and benefits of environmental conservation. The community can be allowed to harvest fish on a quota system hence schools around can benefit through training on new technologies of breeding and other amenities. The social economic index indicates low scale fish farming at a capacity of 6.84 mt to support a fishery.

v) Thiba

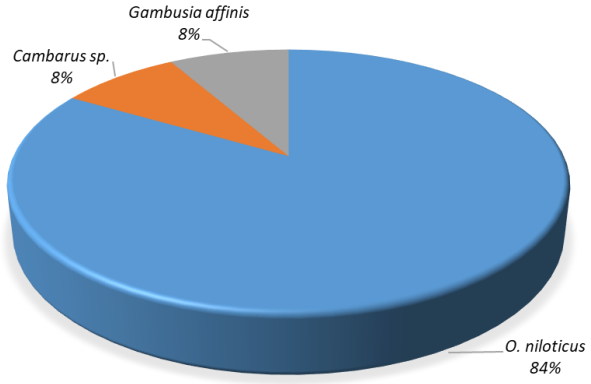
Plate 50. Thiba dam is found Kirinyaga County, Mwea West with a GPS of -0.7166, 37.3254. Thiba is a small dam by the roadside, intense agricultural activities in the basin (rice farming), clay soil, closed basin with underground recharge, high turbidity from algal biomass, fringing wetland plants.

Table 50. Socio-ecological findings of Thiba dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.61	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	1.33

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Trophic State Index (TSI)	65.0	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium (µg/l)	61.4	2000 ug/l	Recommended for fish farming	
Dissolved Oxygen (DO) (mg/l)	6.0	5 and above mg/L	Favorable for fish farming	
Temperature (^{0}C)	27.2	20-31 for warm adaptive fish <20 for cold adaptive fish	Preferred temperature for fish farming	
pH	8.3	6-9	Best for fish farming	
TN:TP	9.1	10 - 30	Nitrogen limited. This can promote the growth of undesirable algae like cyanophytes	
Secchi Depth (m)	N/A	0.35 – 0.5		
Fish condition factor	2.21(*O. n*)	2.9 - 4.8	The fish here had fair performance. Restocking and semi intensive culture recommended.	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	150	10^3 – 10^4	Along the road. Small vegetable farms around the dam require fencing and proper drainage channels to avoid pesticides contaminants. Recommended for fish farming	
Phytoplankton Shannon index H	2.724			
Phytoplankton abundance (Ind.L-1)	187		Suitable for fish farming, plenty of food for the prey since the dam is productive..	
Zooplankton abundance (ind.L-1)	304.2	100-500	Suitable for fish farming since there is indication of high plankton production	
Zooplankton Shannon index H	1.252			

The dam reported 150 Fecal Coliforms which is an indication of non-pollution activities within and around the dam. The phytoplankton species found showed a clear indication that the water is suitable for fishing. Though small, exhibits good limnological characteristics but with slight nitrogen limitation. It showed a good amount of primary productivity that can support general biological productivity. The physico-chemical parameters indicated sound environmental conditions for fish farming except for DO level that can be managed. No fish caught during sampling; this shows that the dam needs restocking of fish. This dam has a high potential for investment to realize socioeconomic benefits beyond what was observed. The dam was dominated by *O. niloticus* with an abundance of 83.3% while *Gambusia affinis* and *Cambarus sp* had 8.3%. Socio-economically, the dam is suitable for very low scale commercial fish farming.



Conclusion and recommendations

A total of five (5) water bodies in Kirinyaga County were sampled and analyzed for fecal indicator microorganisms. A mean of 98 cfu/100ml was recorded with a range of 240 cfu/100ml, minimum & maximum counts of 0 ≤ 240 cfu/100ml within the sites, the results are far much below the minimum threshold values of 10^3 – 10^4 cfu/100ml. This is indicative of good water quality which is within acceptable levels for fish farming. In terms of productivity most dams can sustain a fishery since most species like Aulacosoera, Nitzschia palea, *Aulacoseira ambigua*, *Diatoma* spp, and *Navicula exigulformis* are indicative of pristine environment.

3.2.3 Meru County

i) Kaguru

Plate 51. Kaguru dam is located around GPS point -0.08341, 37.6617 at an altitude of 1494.4M in a densely populated area. The dam came about as a result of filling of a quarry with water through underground seepage. Wet climatic condition, densely populated, agricultural activities, active quarry for excavation of building stones, closed basin with underground recharge, high turbidity from algal biomass.

Table 51. Socio-ecological findings of Kaguru dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.55	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	1.43
Trophic State Index (TSI)	46.2	40 - 50 (Mesotrophic)	Can support a fair amount of productivity.	
Ammonium (µg/l)	118.6	2000 ug/l	Recommended for fish farming	
Dissolved Oxygen (DO) (mg/l)	6.4	5 and above mg/L	Favorable for fish growth	
Temperature (^{0}C)	24.6	20--31 for warm adaptive fish <20 for cold adaptive fish	Preferred temperature for fish growth	
pH	7.7	6-9	Best for fish growth	
TN:TP	17.8	10 - 30	No limiting nutrient. Can support diverse population of algae	
Secchi Depth (m)	0.5	0.35 – 0.5	Phytoplankton becoming scarce. low productivity	
Fish condition factor	N/A		No fish samples obtained. Restocking recommended.	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	60	10^3 – 10^4	1. Dam located in a stone mining area. 2. Steep cliff around the dam, recommended for fish farming	
Phytoplankton Shannon index H	2.724			

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Phytoplankton abundance (Ind.L-1)	173	300 and above	Favourable for fish farming with diversity and abundance of phytoplankton which acts as food for the prey.	
Zooplankton abundance (ind.L-1)	89.1	100-500	Can support Fairly high production of fish	
Zooplankton Shannon index H	1.106			

Kaguru dam is used as a quarry for building stones. It is fairly large, deep and with fair amount of productivity. The water quality conditions were fairly good for fish culture. Ammonium, dissolved oxygen, temperature, pH and TN:TP ratio levels were optimum for sound fish farming. Chlorophyll-a levels of 7.6 µg/l supported the mesotrophic condition observed and can support fair amount of biological productivity. Microbial contamination was low and would therefore not endanger fish health. Zooplankton and phytoplankton abundance were moderate but with very good diversity. The dam is recharged through underground spring and has no outlet and is therefore not a good candidate for cage fish farming. Cage fish farming requires proper flushing, something that is lacking in Kaguru dam. Going by the prevailing limnological characteristics, the dam can fairly support *Oreochromis niloticus* culture.

ii) Nguthiru Laing'o

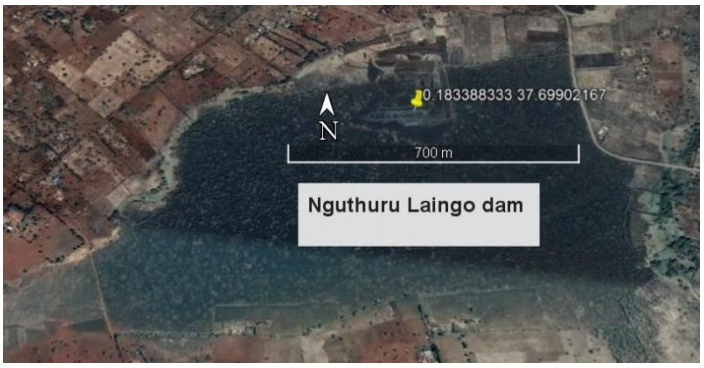


Plate 52. Nguthiru Laing'o is located around GPS point 0.1833, 37.6990 at an altitude of 1367.9 m in a semi-arid area. The climate is semi-arid, characterized by acacia trees, black clay soil, limited agricultural activities, plain landscape, open basin with river recharge and discharge, new dam (1 year old), stocked with about 50 *C. gariepinus* borrowed from a farmer.

Table 52. Socio-ecological findings of Nguthiru dam

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.53	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	8.37
Trophic State Index (TSI)	54.2	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium (µg/l)	33.6	2000 ug/l	Recommended for fish growth	
Dissolved Oxygen (DO) (mg/l)	7.2	5 and above mg/L	Favorable for fish growth	
Temperature (^{0}C)	22.3	20--31 for warm adaptive fish <20 for cold adaptive fish	Preferred temperature for fish growth	
pH	8.6	6--9	Best for fish growth	
TN:TP	43.6	10 - 30	Phosphorus limiting. This would impede the growth of algae.	
Secchi Depth (m)	N/A	0.35 – 0.5		
Fish condition factor	N/A		Sampling did not obtain any fish for analysis. Restocking recommended.	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	20	$10^3 – 10^4$	Dam located in an open area with semi-arid shrubs Recommended for fish farming	
Phytoplankton Shannon index H	2.344	300 and above	Recommended for fish farming. Primary production favorable.	
Phytoplankton Abundance (Ind.L-1)	198			
Zooplankton abundance (ind.L-1)	247.6	100-500	Abundant food type available to support fish farming	
Zooplankton Shannon index H	1.3			

Nguthiru Lai'ngo is a newly constructed dam that is hardly 2 years old, but with promising water quality parameters. It is located in a warm climatic area giving the water good temperature for tropical fishes. The dam is still stabilizing and the ecological conditions may shift over time with probably enhanced biological productivity. The dam showed good nutrient levels that is able to support a fairly good productivity. The chlorophyll-a observation was fairly good, 14.4 µg/l. The trophic index, ammonium, DO, temperature and zooplankton abundance were within optimal levels. pH was almost outside range and needs to be monitored. Nevertheless, the dam provides good habitat characteristics and can provide good environment for *Oreochromis niloticus* and *Clarius gariepinus* polyculture. Phosphorus is a limiting factor but this may change as the dam stabilizes. Management of the dam embankment by planting plant cover needs to be done to stop erosion back to the dam.

iii) Nkunga Sacred Lake

Plate 53. Nkunga Sacred Lake; is situated around GPS point 0.1173, 37.5972 at an altitude 1812.3 m a.s.l at the edge of Imenti National Reserve. The dam was sampled in the dry season. It is a closed basin with underground water recharge, has forest cover in the catchment, used as a water pan for livestock and wild animals like elephants, quarrying activities in the neighborhood. There are plans to rehabilitate the dam.

Table 53. Socio-ecological findings of Nkunga Sacred Lake.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.55	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	69.00
Trophic State Index (TSI)	41.4	40 - 50 (Mesotrophic)	Can support a fair amount of productivity.	
Ammonium (µg/l)	14.3	2000 ug/l	Recommended for fish growth under close monitoring	
Dissolved Oxygen (DO) (mg/l)	5.2	5 and above mg/L	Good for fish growth	
Temperature (^{0}C)	21.4	20--31 for warm adaptive fish <20 for cold adaptive fish	Within the range for fish growth	
pH	N/A			
TN:TP	4.7	10 - 30	Nitrogen limited. This can promote the growth of undesirable algae like cyanophytes	
Secchi Depth (m)	N/A	0.35 – 0.5		
Fish condition factor	1.95 (*O. n*)	2.9 - 4.8	Species performed poorly. Semi intensive culture of this species within the dam is recommended	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	0	10^3 – 10^4	1. Dam in the middle of the forest. 2. Underground seepage. 3. Dam largely covered with macrophytes. Recommended for fish farming	
Phytoplankton Shannon index H	1.72128			
Phytoplankton abundance (Ind.L-1)	389	300 and above	Good for fish farming although lethal species like anabaena and Microcystis sp were noted.Management need to be undertaken.	

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Zooplankton abundance (ind.L-1)	350.2	100-500	High diversity and abundance of palatable prey. Suitable for fish farming	
Zooplankton Shannon index H	1.597			

Nkunga sacred lake is the largest dam in Meru County but with a large portion covered by macrophytes. The dam is located in a warm tropical climate with enough rain to support its recharge. The dam lies within a basin and is recharged through underground springs. It is protected by KWS since the dam is used as a watering point for protected wild animals in the catchment forest. The ecological parameters of ammonium, dissolved oxygen and temperature were optimal for good fish farming. The trophic index showed that the water was mesotrophic and could support a fair amount of primary productivity. Phytoplankton and zooplankton abundances were above the lowest threshold mark and therefore provided conducive levels. Chlorophyll-a, a measurement indicative primary production levels, were moderate (7.5 µg/l). The resident fish showed poor performance and this could be attributed to poor management of the dam. The lake has strong cultural values that have kept the dam almost pristine. It is already stocked with *O. niloticus* but the thick floating macrophytes, mainly reeds and sedges need to be removed in order to improve its aesthetic quality. The dam would provide good potential for fish farming and eco-tourism but only after macrophyte removal and dredging has been conducted. It can also support educational tours.

iv) Ontulili Dam

Plate 54. Ontulili dam situated at around GPS reading 0.0043, 37.1421 at an altitude of 2074.6 m in the middle of a farming area with loose volcanic red soil. The area is characterized by dry climatic conditions, some agricultural activities in the basin, galley erosion in the catchment, open basin with surface run-off recharge and discharge, highly turbid waters as a result of siltation (mineral turbidity).

Table 54. Socio-ecological findings of Ontulili dam

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.53	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	8.37
Trophic State Index (TSI)	42.5	40 - 50 (Mesotrophic)	Can support a fair amount of productivity.	
Ammonium (µg/l)	117.1	2000 ug/l	Recommended for fish farming	
Dissolved Oxygen (DO) (mg/l)	6.5	5 and above mg/L	Favorable to fish growth	
Temperature (^{0}C)	23.2	20--31 for warm adaptive fish <20 for cold adaptive fish	Preferred temperature for fish growth	
pH	7.3	6--9	Best for fish growth	
TN:TP	5.9	10 - 30	Nitrogen limited. This can promote the growth of undesirable algae like cyanophytes	
Secchi Depth (m)	N/A	0.35 – 0.5		
Fish condition factor	N/A		No samples were available for analysis.	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	30	10^3 – 10^4	1. Dam located in highly eroded banks. 2. Rocky shores. 3. The dam is turbid, high turbidity can be ideal for certain fish species.	
Phytoplankton Shannon index H	4.5242			
Phytoplankton abundance (Ind.L-1)	830	300 and over	Can sustain a fishery since the dam looks pristine and productivity is good.	
Zooplankton abundance (ind.L-1)	267.9	100-500	Suitable for fish farming	
Zooplankton Shannon index H	1.329			

Ontulili dam is an open basin system with seasonal recharge and discharge. The dam lies within a warm tropical climate that gives the water its warm temperature that is highly conducive for tropical fish. However, the water is highly turbid from suspended sediment particle. This would

limit light irradiance that is necessary for photosynthesis. The primary production that forms the base of the food chain was therefore low and would therefore limit trophic production up the food chain. The low primary productivity of the dam was exhibited in the low chlorophyll-a measurement (1.2 µg/l) that was observed for the dam. However, the phytoplankton and the zooplankton abundances were within allowable limits. *Clarias gariepinus* is a good candidate for the dam.

Conclusion and recommendations

Meru County provides good prospects for fish farming given the suitable climatic conditions and socio-economics infrastructure. The socio-ecological status of most dams that we visited indicate that aquaculture should proceed with the necessary management measures highlighted for each dam. Of concern is the securing of all dam areas and catchments through fencing in order to avoid human encroachment and accidents such as drowning.

3.2.4 Tharaka Nithi County

i) Gatuntu

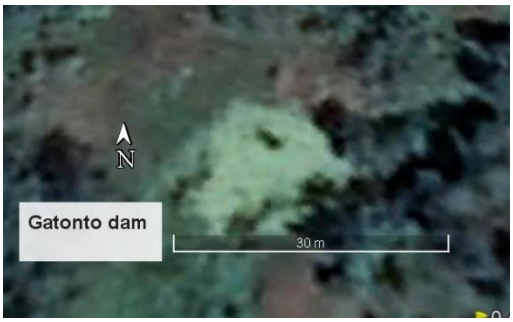


Plate 55. Gatuntu dam is located at GPS reading -0.4395, 377381 at an altitude of 1076.4 right at source of a tributary of Thuci River, itself a tributary of Tana River. The area is semi-arid surrounded by shrub bushes at the catchment. There are little agricultural activities. The dam is sustained by small perennial springs and is almost completely covered by water lilies (*Nymphaea sp.*), an indication of fresh shallow unpolluted waters.

Table 55. Socio-ecological findings of Gatuntu dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.47	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	0.30
Trophic State Index (TSI)	13.7	> 40 (Oligotrophic)	Scanty nutrients with limited productivity to support fish culture.	
Ammonium (µg/l)	31.4	2000 ug/l	Within the recommended limit	
Dissolved Oxygen (DO) (mg/l)	3.5	5 and above mg/L	Growth will be slow if exposure to low dissolved oxygen is continuous.	
Temperature (^{0}C)	24.5	20--31 for warm temperature adaptive fish <20 for cold adaptive fish	Preferred growth temperature	
pH	7.4	6--9	Best growth	
TN:TP	8.4	10 - 30	Nitrogen limited. This can promote the growth of undesirable algae like cyanophytes	
Secchi Depth (m)	N/A	0.35 – 0.5		
Fish condition factor	N/A		No fish were obtained for analysis.Restocking with aquaculture candidates recommended	

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	0	$10^3 – 10^4$	1. Dam covered with macrophytes around and water Lily. 2. Community fetching water from the dam. 3.Source of water from underground, highly recommended for fish farming	
Phytoplankton Shannon index H	2.54272			
Phytoplankton abundance (Ind.L-1)	356			
Zooplankton abundance (ind.L-1)	141.6	100-500		
Zooplankton Shannon index H	1.391			

The dam is small with the water source coming from an underground spring. It is fully covered by water lilies and is hence extremely low in DO and primary productivity measured through chlorophyll-a. The water is also nitrogen limited. These limiting conditions can improve if the residence time of the water in the dam can be increased through increasing the size of the dam.

ii) Ndetha

Plate 56. 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 56. Socio-ecological findings of Ndetha dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.47	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	1.25
Trophic State Index (TSI)	59.2	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium (µg/l)	40.0	2000 ug/l	Recommended for fish growth	
Dissolved Oxygen (DO) (mg/l)	5.2	5 and above mg/L	Good for fish growth	

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Temperature (^{0}C)	29.4	20--31 for warm temperature adaptive fish <20 for cold adaptive fish	Preferred temperature for fish growth	
pH	8.7	6-9	Best growth	
TN:TP	11.3	10 - 30	No limiting nutrient. Can support diverse population of algae	
Secchi Depth (m)	0.4	0.35 – 0.5	If turbidity is from phytoplankton, the dam is in good condition.	
Fish condition factor	2.87(*O. n*)	2.9 - 4.8	This is a relatively good performance from *O. n* implying a good potential for restocking or culture at semi intensive/intensive levels	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	140	$10^3 – 10^4$	1. Animals watering. 2.One inlet 3. Recommended for fish farming but water abstraction point to be made for animals not to wade into the water.	
Phytoplankton Shannon index H	4.07116			
Phytoplankton abundance (Ind.L-1)	467	300 and above	Favorable for fish farming	
Zooplankton abundance (ind.L-1)	81.1	100-500	Food supplement will be need at time of stocking the fry	
Zooplankton Shannon index H	1.495			

The dam, though small with seasonal drainage, exhibits good limnological parameters that can support good biological productivity. The parameters are also conducive for tilapia culture.

Conclusion and recommendations

Tharaka-Nithi County has a high potential for aquaculture development but the community will have to accept fish rearing as a viable occupation. Consumption of fish in the area is minimal at the moment as people value the other uses of water e.g. irrigation, as livestock watering point and other domestic uses. Ndetha dam had the highest potential, Gatuntu dam had the lowest.

3.2.5 Embu County

i) Gitaru

Plate 57. Gitaru dam is located at around -0.7834, 37.7510 at an altitude of 931 m. The water was turbid with muddy shores and forested. The surroundings were dotted with acacia shrubs.

Table 57. Socio-ecological findings of Gitaru dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.55	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	2351.35
Trophic State Index (TSI)	54.1	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium (µg/l)	29.1	2000 ug/l	Within the recommended limit. Therefore, it is good for fish farming.	
Dissolved Oxygen (DO) (mg/l)	8.2	5 and above mg/L	Favorable for fish farming	
Temperature (^{0}C)	24.0	20--31 for warm temperature adaptive fish <20 for cold adaptive fish	Preferred temperature for fish growth	
pH	8.9	6--9	best growth	
TN:TP	26.0	10 - 30	No limiting nutrient. Can support diverse population of algae	
Secchi Depth (m)	0.4	0.35 – 0.5	If turbidity is from phytoplankton, the dam is in good condition.	
Fish condition factor	2.06 (*T.rendalii*), 1.75(*T.mossambicus*)	2.9 - 4.8	*T.rendalii* had a fair perfomance while *T.mossambicus* was poor. Introduction of well performing aquaculture candidates recommended.	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	50	10^3 – 10	1.Few fishermen, 2.Irrigation activities, 3.Domestic water abstraction A hydro power water dam, suitable for cage fish farming.	
Phytoplankton Shannon index H	2.11353			
Phytoplankton abundance (Ind.L-1)	116		Suitable for fish farming if productivity is enhanced	
Zooplankton abundance (ind.L-1)	183.5	100-500	Suitable for fish farming	
Zooplankton Shannon index H	0.9315			

The species recorded here were *T. rendalii*, *T. mosambicus*, *Labeo victorianus*, *Cyprinus carpio* and *C. gariepinus*. *T. rendalii* and *T. mosambicus* dominated the catch in almost equal proportions. A management plan targeting the two species needs to be drawn. Restocking of T. rendalii is recommended as it seems to be doing well in the dam, while stocking of the dam with *C. gariepinus* and *C. carpio* can increase the economic value of the dam. *O. niloticus* should only be introduced if the existing tilapia proves to be of low economic value.

ii) **Ithatha**

Plate 58. Ithatha dam is located around -0.4881, 37.6190 at an altitude of 1236.9 m. The shores of the dam are surrounded by macrophytes, mostly *Typha spp.* with agricultural farms surrounding the dam. There's the risk of erosion and contamination through use of pesticides and herbicides.

Table 58. Socio-ecological findings of Ithatha dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.47	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	4.02019
Trophic State Index (TSI)	53.5	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium (µg/l)	30.9	2000 ug/l	Within the recommended limit, therefore good for fish farming	
Dissolved Oxygen (DO) (mg/l)	4.81	5 and above mg/L	Growth will be slow if exposure to low dissolved oxygen is continuous.	
Temperature (^{0}C)	23.7	20--31 for warm temperature adaptive fish <20 for cold adaptive fish	Preferred temperature for tilapia growth	
pH	7.6	6--9	Best growth	
TN:TP	239.6	10 - 30	Phosphorus limiting. This would impede the growth of algae.	
Secchi Depth (m)	0.3	0.35 – 0.5	If turbidity is from phytoplankton, the dam is in good condition.	
Fish condition factor	2.7 (*O. n*)	2.9 - 4.8	*O. n* performance was fair.Species shows good potential for restocking	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	40	10^3 – 10^4	A large water surrounded with typha plants. Had been stocked with fish, but not doing well.	
Phytoplankton Shannon index H	4.6085			
Phytoplankton abundance (Ind.L-1)	301	300 and above	Diversity and abundance are high thus an indicative of high productivity. Recommended for fish farming	
Zooplankton abundance (ind.L-1)	294.3	100-500	Relatively fair plankton abundance.	
Zooplankton Shannon index H	1.150			

The species caught here was the Nile tilapia (*O. niloticus*) whose performance needs to be improved through semi-intensive farming and restocking of the dam as need arises. The dam is fairly good for *O. niloticus* farming at semi-intensive level i.e. will need food supplements. A sound

management plan to address issues of threats from farming activities and the low phosphorus needs to be put in place

iii) Kamburu

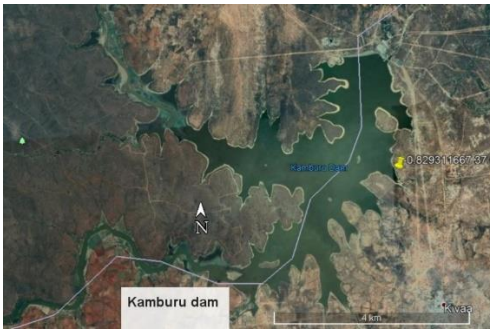
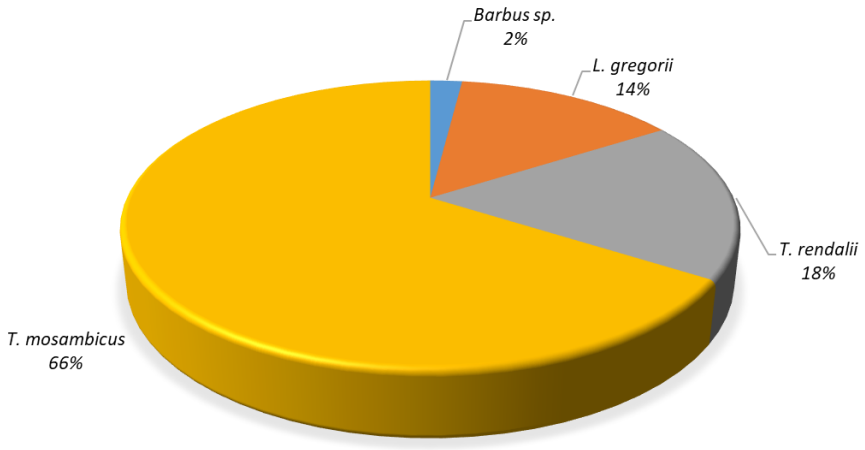


Plate 59. Kamburu dam is located at around -0.8293, 37.6878 at an altitude of 1025.3 M. The climate is semi-arid, with the area covered by sparse vegetation. Water was clear. The dam is situated around farm lands with rocks in the farmed area.

Table 59. Socio-ecological findings of Ithatha dam

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.54	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	4.02
Trophic State Index (TSI)	54.5	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium (µg/l)	37.8	2000 ug/l	Within the recommended limit for fish growth	
Dissolved Oxygen (DO) (mg/l)	8.2	5 and above mg/L	Favorable for fish growth	
Temperature (^{0}C)	23.5	20--31 for warm temperature adaptive fish <20 for cold adaptive fish	Preferred temperature for fish growth	
pH	7.1	6--9	Best for fish growth	
TN:TP	23.8	10 - 30	No limiting nutrient. Can support diverse population of algae	
Secchi Depth (m)	0.4	0.35 – 0.5	If turbidity is from phytoplankton, the dam is in good condition.	
Fish condition factor	1.84(*T.m*), 2.55 (*T.r*)	2.9 - 4.8	*T.m* had poor performance while *T.r* had fair performance. *O. n* and *C.g* recommended for restocking at semi intensive levels.	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	160	10^3 – 10^4	1. Fishing beach site with settlement. 2. Surrounding forest trees Highly suitable for fish cage farming.	
Phytoplankton Shannon index H	2.98315			
Phytoplankton abundance (Ind.L-1)	159	300 and above	Conducive for fish farming if enhanced	
Zooplankton abundance (ind.L-1)	141.6	100-500	Good availability of plankton. Cage fish farming involving food supplements	
Zooplankton Shannon index H	0.965			

The species recorded in this dam were *Tilapia mosambicus*, *Tilapia rendalii*, *L. gregorii* and *Barbus sp. T. mosambicus* dominated the catch, with *T. rendalii* coming a distant second.
A management plan targeting the two tilapias (*T. rendalii and T. mosambicus*) is recommended while *C. gariepinus* can be introduced to increase the economic value of the dam. Restocking of the dam *T. rendalii* is preferred while cage culture of *O. niloticus* should be considered if the current species proves uneconomic



iv) Kindaruma

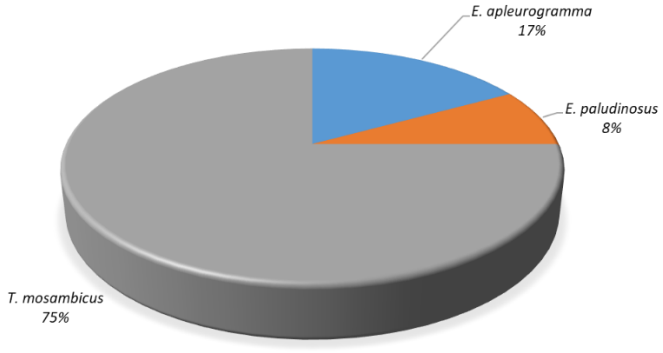
Plate 60. Kindaruma dam is located at -0.8248, 37.7880 at an altitude of 788.6 m. The general climate is semi-arid with poor vegetation cover. Forest cover was concentrated around the shores of the dam. The soil is sandy and the dam was turbid.

Table 60. Socio-ecological findings of Kindaruma dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.51	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	2409

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Trophic State Index (TSI)	45.1	40 - 50 (Mesotrophic)	Can support a fair amount of productivity.	
Ammonium (µg/l)	61.6	2000 ug/l	Within the recommended limit for fish growth	
Dissolved Oxygen (DO) (mg/l)	7.6	5 and above mg/L	Favorable for fish growth	
Temperature (^{0}C)	26.4	20--31 for warm temperature adaptive fish <20 for cold adaptive fish	Preferred temperature for fish growth	
pH	8.1	6-9	Best growth	
TN:TP	82.0	10 - 30	Phosphorus limiting. This would impede the growth of algae.	
Secchi Depth (m)	0.4	0.35 – 0.5	If the turbidity is from phytoplankton, the dam is in good condition.	
Fish condition factor	2.01 (*T. m*)	2.9 - 4.8	*T. m* had fair performance. *O. n* recommended for restocking.	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	150	$10^3 – 10^4$	1.Sandy beach with forest background, 2.Animals grazing Highly suitable for Fish Cage Farming.	
Phytoplankton Shannon index H	5.116			
Phytoplankton abundance (Ind.L-1)	500	300 and above	Suitable for fish farming since primary productivity is good	
Zooplankton abundance (ind.L-1)	86.0	100-500	Below the limit but fish production can achieved through enhancement	
Zooplankton Shannon index H	1.450			

This is one of the oldest among the Seven Fork dams. The species caught here were *T. mosambicus* and the minnows *Enteromius apleurogramma* and *E. paludinosus. T. mosambicus* was the dominant species and the only fish of economic value. This fish's performance was good compared to the other Seven Fork dams. A management plan targeting this species needs to be drawn and implemented. Restocking of the dam and introduction of new species into the dam should be done if need arises. Cage farming of *O. niloticus* could be introduced to enhance productivity.



v) **Masinga**

Plate 61. Masinga dam located around at -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 61. Socio-ecological findings of Masinga dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.52	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	51,218
Trophic State Index (TSI)	48.5	40 - 50 (Mesotrophic)	Can support a fair amount of productivity.	
Ammonium (µg/l)	38.4	2000 ug/l	Within the recommended limit for fish growth	
Dissolved Oxygen (DO) (mg/l)	5.7	5 and above mg/L	Favorable for fish growth	
Temperature (^{0}C)	25.8	20--31 for warm temperature adaptive fish <29 for cold adaptive fish	Preferred temperature for fish growth	
pH	8.5	6--9	Best growth	
TN:TP	57.7	10 - 30	Phosphorus limiting. This would impede the growth of algae.	
Secchi Depth (m)	0.7	0.35 – 0.7	Water is too clear. Inadequate productivity.	
Fish condition factor	3.16 (*O. n*)	2.9 - 4.8	Good performance. High potential for restocking/ culture at intensive/ semi intensive levels	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	80	10^3 – 10^4	Fishing site beach with fishermen. An established fishery, highly recommended for fish farming.	
Phytoplankton Shannon index H	4.3965			
Phytoplankton abundance (Ind.L-1)	214	300 and above	Suitable for fish farming	
Zooplankton abundance (ind.L-1)	186.3	100-500	Suitable for fish farming	
Zooplankton Shannon index H	0.9982			

This is a multi-purpose dam, the biggest and with the highest carrying cappcity amongst the Seven-Fork dams and the entire central region. Fishing activities have been going on for a long time. The dam is the home of some dangerous wildlife like the hippopotamus and the crocodiles. This is a source of concern as it raises issues of human-wildlife conflicts frequently. The fish species caught here were *O. niloticus* and *Labeo gregorii*. *O. niloticus* (98%) literally dominated the catch, with *L. gregorii* (2%) occurring very rarely in the catch. A management plan rotating around the Nile tilapia fishery needs to be drafted for implementation. On the other hand, a protected area needs to be identified and gazetted as a Marine National Park to reduce the human-wildlife conflict in the dam. Restocking of the dam with the same species is highly recommended.

Conclusion and recommendations

Embu County is the home of the Seven Fork dams which produces the bulk of the nations' hydro-electric power. The dams were constructed primarily for provision of hydro-electric power to the national grid. The Seven-Fork dams consist of; Masinga, Kamburu, Gitaru, Kiambere and Kindaruma dams. The dams are expansive thus aquaculture development is not the best way to utilize these aquatic environments instead stock assessment needs to be done and a good management plan put in place. Stocking of the dams needs to borrow heavily from the Lake Naivasha model. These dams have good potential in fisheries production if well managed. Research should be undertaken to come up with the most appropriate legal gears for use in harvesting the target species sustainably.

3.2.6 Kiambu County

i) Kimunyu water pan

Plate 62. Map of Kimunyu water pan, located at latitude (- 1.0534) and longitude (36.9496) sitting at an altitude of 1602.8 m a.s.l. The catchment is covered with shrubs, grassland, and bare soil and with highly turbid waters.

Table 62. Socio-ecological findings of Kimunyu dam

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.51	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	0.64
Trophic State Index (TSI)	51.6	50 - 70 (Eutrophic)	Can support fairly high productivity	

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Ammonium (µg/l)	32.2	2000 ug/l	Within the recommended limit for fish growth	
Dissolved Oxygen (DO) (mg/l)	6.2	5 and above mg/L	Favorable for fish growth	
Temperature (^{0}C)	23.6	20--31 for warm temperature adaptive fish	Preferred temperature for fish growth	
pH	8.3	6--9	Best growth	
TN:TP	51.7	10 - 30	Phosphorus limiting. This would impede the growth of algae.	
Secchi Depth (m)	0.4	0.35 – 0.5	If turbidity is from phytoplankton, the dam is in good condition.	
Fish condition factor	N/A		No fish samples were available for analysis.	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	70	10^3 – 10^4	Fenced fish pond for Self Help group community. Had been stocked.	
Phytoplankton Shannon index H	1.671			
Phytoplankton abundance (Ind.L-1)	396	300 and above	Good diversity and abundance for aquatic animals, thus recommended for fish farming	
Zooplankton abundance (ind.L-1)	320..0	100-500	Diverse and abundant prey for juvenile fish. Recommended for fish stocking with favourable fish species	
Zooplankton Shannon index H	1.533			

Measurement of microbial contaminants through fecal coliform counts were observed to be within range and suitable for fish culture. Plankton diversity and abundance can be used as a measure of water suitability and productivity. The abundance and diversity of both phytoplankton and zooplankton were found to be within recommendable range and hence able to provide sufficient food for fish. The trophic state index (TSI), DO, temperature, pH and ammonium concentrations were observed to be within range and highly conducive for fish growth and reproduction. However, phosphorus was found limiting which may have a negative impact on algal growth but this may not have a significant impact on biological productivity. There were no fish caught, a fact that was corroborated by the indigenous knowledge. According to limnological observations, the dam can be stocked for great success.

ii) Rungiri

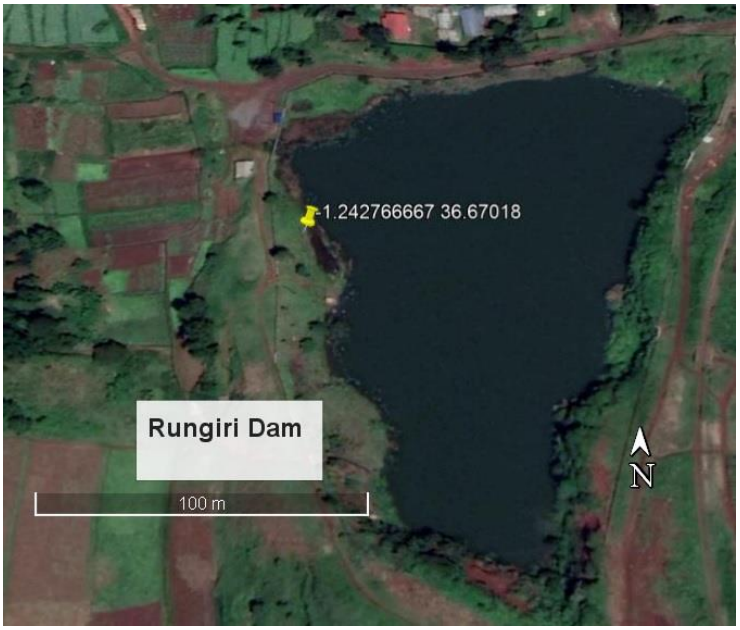


Plate 63: Map of Rungiri dam, located at latitude (-1.2427) and longitude (36.6701) sitting at an altitude of 1986.5 m a.s.l. The catchment has some agricultural activities, fringing macrophytes and with very clear waters

Table 63. Socio-ecological findings of Rungiri dam

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.51	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	14.62
Trophic State Index (TSI)	48.6	40 - 50 (Mesotrophic)	Can support a fair amount of productivity.	
Ammonium (µg/l)	50.9	2000 ug/l	Within the recommended limit for fish growth	
Dissolved Oxygen (DO) (mg/l)	7.6	5 and above mg/L	Favorable level for fish growth	
Temperature (^{0}C)	20.8	20 and above mg/L	Within preferred temperature for fish growth but close monitoring required if warm temperature adaptive fish is to be farmed.	
pH	8.9	6--9	Best growth	
TN:TP	1770.7	10 - 30	Phosphorus limiting. This would impede the growth of algae.	
Secchi Depth (m)	1.1	0.35 – 0.5	Water is too clear. Inadequate productivity.	
Fish condition factor	N/A		No fish available for analysis	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	20	10^3 – 10^4	1. Fenced water dam formally quarry mine. 2. Stocked with fish. 3. Used for recreational activities. 4. Protected and managed by a community youth group.	
Phytoplankton Shannon index H	1.58478			
Phytoplankton abundance (Ind.L-1)	918	300 and above	Suitable for fish farming	

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Zooplankton abundance (ind.L-1)	237.4	100-500	Suitable for farming of fish species for the area	
Zooplankton Shannon index H	1.22			

The microbial contaminants measured through fecal coliform counts were below maximum threshold and therefore suitable for maximum performance of fish culture. Both phytoplankton and zooplankton abundance and diversity were found to be above the lower threshold and hence suitable for both fish growth and reproduction. There is abundant food and diverse species to prey on. Diatoms were the most predominant and are the species most preferred by fish. The moderate zooplankton Shannon - Weiner index indicates moderate diversity. The trophic state index (TSI) shows a fair amount of productivity. Although Secchi depth indicated less turbidity implying low primary productivity. Phosphorus required for algal growth was extremely limiting and could be negatively impacting algal proliferation. No fish was caught for analyses. However, the ecology of the dam would support fish culture with minimal supplementary feeding. The ecology of any given dam can be quite dynamic and one-time sampling can only give a snapshot picture of productivity which should be confirmed through a follow-up study.

iii) Tigoni

Plate 64. Map of Tigoni dam, located at latitude (- 1.1409) and longitude (36.6732) sitting at an altitude of 2095.8 m a.s.l. The catchment is densely forested with some agricultural activities undertaken in the basin. The water is used for domestic and irrigation purposes.

Table 64. Socio-ecological findings of Tigoni dam

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.40	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	19.56
Trophic State Index (TSI)	64.4	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium (µg/l)	16.6	2000 ug/l	Within the recommended limit but only for those practicing semi-intensive type of aquaculture	
Dissolved Oxygen (DO) (mg/l)	7.8	5 and above mg/L	Favorable to fish growth	
Temperature (^{0}C)	21.4	20--31 for warm temperature adaptive fish <20 for cold adaptive fish	Within preferred temperature for warm adaptive fish but require close monitoring.	
pH	8.7	6--9	Best growth	

TN:TP	23.5	10 - 30	No limiting nutrients. Can support diverse population of algae	
Secchi Depth (m)	1.1	0.35 – 0.5	Water is too clear. Inadequate productivity.	
Fish condition factor	N/A		No fish obtained for analysis	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	26	$10^3 – 10^4$	1. Dense forest around the dam. 2. Used for irrigation activities. 3. Domestic water abstraction. 4. Stocked with Crayfish, other fisheries can be farmed.	
Phytoplankton Shannon index H	4.90897			
Phytoplankton abundance (Ind.L-1)	542	300 and above	Productivity is good for fish farming	
Zooplankton abundance (ind.L-1)	277.7	100-500	Recommended for fish farming	
Zooplankton Shannon index H	1.182			

The fecal coliform count was below the recommendable threshold and highly permissible for fish culture. Plankton, both phytoplankton and zooplankton, were abundant and diverse enough. This is an indicator of sufficient natural food to support optimal growth and reproductive performance. The ambient waters were of high integrity hence the high diversity. In the phytoplankton composition, the toxin producing dinoflagellates were the most abundant. Copepoda were the most predominant zooplankton species. The water's trophic index observation, a measure of biological productivity, was eutrophic indicating a fairly high productivity sufficient to support a significant level of fish culture. Other water quality variables like DO, temperature, pH, TN:TP and ammonium were within recommendable ranges and highly suitable for fish culture especially tilapia. There were no fish caught but all limnological indicators show that the dam is highly conducive for fish farming and can support high growth performance of tilapia. This study should be replicated in order to better understand the dynamics of the dam.

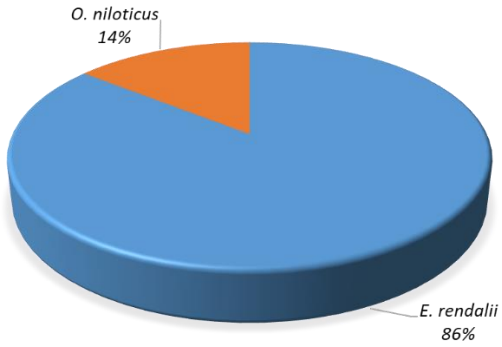
iv) Twiga Dam

Plate 65. Map of Twiga 1 dam, located at latitude (- 1.1199) and longitude (36.9811) sitting at an altitude of 1533.5 m a.s.l. The catchment has dense settlement, rocky, and with some agricultural activities

Table 65. Socio-ecological findings of Twiga dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.48	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	12.59
Trophic State Index (TSI)	46.8	40 - 50 (Mesotrophic)	Can support a fair amount of productivity.	
Ammonium (µg/l)	36.6	2000 ug/l	Within the recommended limit	
Dissolved Oxygen (DO) (mg/l)	7.0	5 and above mg/L	Favorable to fish growth	
Temperature (^{0}C)	22.4	20--31 for warm temperature adaptive fish <20 for cold adaptive fish	Preferred temperature for fish growth but require close monitoring	
pH	8.2	6--9	Best growth	
TN:TP	42.4	10 - 30	Phosphorus limiting. This would impede the growth of algae.	
Secchi Depth (m)	1.1	0.35 – 0.5	Water is too clear. Inadequate productivity.	
Fish condition factor	2.15 (*T.r*)	2.9 - 4.8	Fair performance of the fish species. Recommended for stocking/culture with *O. n* and *C.g* at semi intensive levels	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	15	10^3 – 10^4	A recreational site. High potential for Fish farming.	
Phytoplankton Shannon index H	1.80			
Phytoplankton abundance (Ind.L-1)	193	300 above	Can support fish farming although primary productivity is low and needs to be enhanced	
Zooplankton abundance (ind.L-1)	289	100-500	Can support good secondary production necessary for fish production	
Zooplankton Shannon index H	1.08			

Microbial contamination indicator using fecal coliform count was observed to be low and below the threshold. This low measurement would result in low pathogenic infections of the cultured fish. Phytoplankton abundance was below the threshold suggesting that fish culture especially for the juveniles that prefer algae would thus require supplementary feeding. The zooplankton population and diversity were good enough to sustain better performance of fish farming. The plankton productivity was therefore moderate. The trophic state index of Twiga dam was observed to be mesotrophic and could support a fair amount of biological productivity, a fact that is supported by microscopic examination of phytoplankton abundance which was moderate. Other limnological parameters were conducive for good performance of fish culture except for secchi depth and phosphorus limitation. Present results would recommend supplementary feeding but replicate studies are necessary before any conclusive recommendation. The biological productivity was moderate and could only support fair growth performance. At this point supplementary feeding can be recommended.



Conclusion and recommendations

Kiambu County had four dams namely: Kimunyu water pan, Rungiri dam, Tigoni dam and Twiga dam. From the results, Tigoni dam had the most suitable parameters for fish farming. Rungiri and Kimunyu water pans rank second and third based on the carrying capacity index respectively since although no fish was found in these dams, there was a positive social indication on fisheries investment potential. Twiga dam ranked the least in fisheries prospects, probably due to its high eco- tourism bias as an alternative livelihood. Microbial contamination indicators using fecal coliform count was observed to be low and below the threshold. This low measurement would result in low pathogenic infections of the cultured fish. Phytoplankton abundance was below the threshold, suggesting that fish culture, especially for the juveniles that prefer algae would thus require supplementary feeding. The zooplankton population and diversity were good enough to sustain better performance of fish farming. The plankton productivity was therefore moderate. The trophic state index of Twiga dam was observed to be mesotrophic and could support a fair amount of biological productivity, a fact that is supported by microscopic examination of phytoplankton abundance which was moderate. This dam provided unique recreational and touristic potential thus socio-economics activities such as water sports and sport fishing, agroforestry and erection view-points should be explored.

3.2.7 Kajiado County

i) Enkaroni

Plate 66. The dam is located in Kajiado central sub-county, around GPS point, -2.0438, 36.7246, with a water depth of 3.3m and muddy substrate. A shallow Water pan used by the community, the dam is being used as an animal watering point, and Located in a semi-arid area.

Table 66. Socio-ecological findings of Enkaroni dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.44	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	12.47
Trophic State Index (TSI)	63.5	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium (µg/l)	70.9	2000 ug/l	Within the recommended limit	
Dissolved Oxygen (DO) (mg/l)	6.3	5 and above mg/L	Favorable to fish growth	
Temperature (^{0}C)	24.1	20--31 for warm temperature adaptive fish <20 for cold adaptive fish	Good for fish growth	
pH	7.6	6--9	Best growth	
TN:TP	4.6	10 - 30	Nitrogen limited. This can promote the growth of undesirable algae like cyanophytes	
Secchi Depth (m)	0.3	0.35 – 0.5	If turbidity is from phytoplankton, the dam is in good condition.	
Fish condition factor	1.58 (*O. n*)	2.9 - 4.8	Poor performance of the fish species. Need to consider supplemental feeding prior to restocking. Alternatively, semi intensive culture of this species can be done in the dam.	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	2200	10^3 – 10^4	1. A shallow. Water pan used by community, 2.Animals watering point Located in a semi-arid area	

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Phytoplankton Shannon index H	3.73767			
Phytoplankton abundance (Ind.L-1)	168	300	Suitable for fish farming although productivity needs to be enhanced	
Zooplankton abundance (ind.L-1)		100-500	Fish food is fairly available and can be supplemented with artificial diets	
Zooplankton Shannon index H				

The dam is located in a semi-arid climatic condition. The limnological parameters measured were fairly good for fish farming. Trophic index, ammonium, dissolved oxygen, temperature, pH and secchi depth were all within permissible limits. However microbial contamination, though within permissible limits, was comparatively high compared to other dams and this could be attributed to extensive animal husbandry within the catchment. This coupled with a possible higher water temperatures fluctuations and the shallow water depth may impose health risk to the resident fish. If the dam is to be used for fish farming, necessary security measures needs to be undertaken to mitigate on the fecal influxes into the dam. The existing habitat characteristics can fairly support good environmental condition for *Oreochromis niloticus* farming. The poor condition factor could have been influenced by stress from exogenous factors like dam morphology, climate variability and lack of quality food. The exact cause should be further researched.

ii) Iyarat Water Pan

Plate 67. The dam is located in Kajiado West sub-County, around GPS point, -2.0387, 36.6527, with a water depth of 3.5m and muddy substrate. The pond area is well fenced. A shallow water pan used by the community for animal watering point, and Located in a semi-arid area.

Table 67. Socio-ecological findings Iyarat dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.40	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	8.32
Trophic State Index (TSI)	66.4	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium (µg/l)	33.4	2000 ug/l	Within the recommended limit	
Dissolved Oxygen (DO) (mg/l)	6.2	5 and above mg/L	Favorable to fish growth	
Temperature (^{0}C)	22.7	20--31 for warm temperature adaptive fish <20 for cold adaptive fish	Preferred temperature for growth but require close monitoring	
pH	8.1	6--9	Best growth	
TN:TP	1.0	10 - 30	Nitrogen limited. This can promote the growth of undesirable algae like cyanophytes	
Secchi Depth (m)	0.4	0.35 – 0.5	If turbidity is from phytoplankton, dam is in good condition.	
Fish condition factor	N/A		No fish were obtained for analysis.	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	250	10^3 – 10^4	1.Fish pond, not stocked, 2.Fenced and liners not managed	
Phytoplankton Shannon index H	2.54273			
Phytoplankton abundance (Ind.L-1)	178	300 and above	Suitable for fish farming although diversity of phytoplankton is good for fish	
Zooplankton abundance (ind.L-1)		100-500		
Zooplankton Shannon index H				

The reported water quality parameters can support fairly high productivity, but nitrogen level is quite limited thus can promote the growth of undesirable algae like cyanophytes. Although the reported microbial indicators indicate that the dam is not polluted by activities within and around the dam. As in other dams in Kajiado, this dam is also being used for animal watering.

Conclusively, the dam cannot be suitable for fish cage culture or pen culture as they may be faced with frequent destruction by animals. Therefore, restocking could be the best option**.**

iii) Kiserian

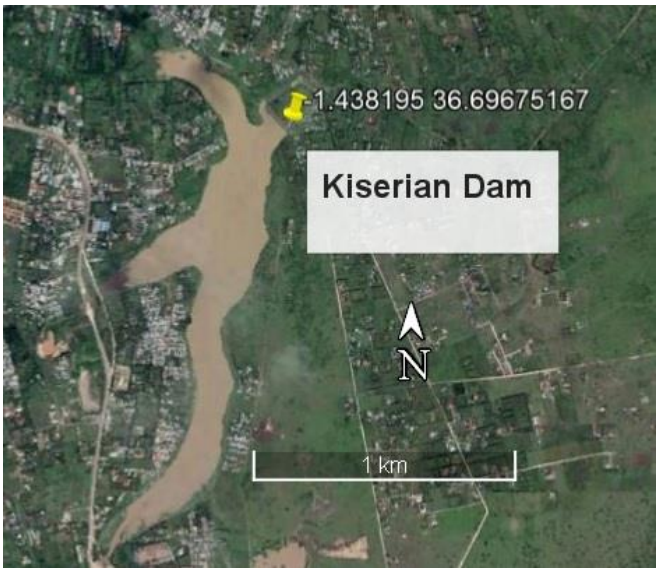


Plate 68. The dam is located in Kajiado North sub-County, around GPS -1.4381, 36.6967, with a water depth of 4.4m and sandy substrate. Management under Kajiado North Water catchment. Forested all round with settlements

Table 68. Socio-ecological findings Kiserian dam

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.48	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	522.95
Trophic State Index (TSI)	47.9	40 - 50 (Mesotrophic)	Can support a fair amount of productivity.	
Ammonium (µg/l)	158.4	2000 ug/l	Recommended for fish that thrives well in cold temperatures	
Dissolved Oxygen (DO) (mg/l)	7.3	5 and above mg/L	favorable to fish growth	
Temperature (^{0}C)	23.3	20--31 for warm temperature adaptive fish <20 for cold adaptive fish	Good for warm temperature adaptive fish under close monitoring	
pH	8.5	6--9	Best growth	
TN:TP	298.3	10 - 30	Phosphorus limiting. This would impede the growth of algae.	
Secchi Depth (m)	1.1	0.35 – 0.5	Water is too clear. Inadequate productivity.	
Fish condition factor	N/A		Fish were not available for analysis.	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	0	10^3 – 10^4	1.Forest all round with settlements 2. Three natural rivers, flowing in. 3. Source of Water treatment plant to Kajiado north sub-county. 3.High potential for fish growing	
Phytoplankton Shannon index H	2.5965			
Phytoplankton abundance (Ind.L-1)	161	300 1nd above	Suitable for fish but productivity needs to be enhanced	

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Zooplankton abundance (ind.L-1)	250	100 - 500		
Zooplankton Shannon index H	1.001			

The reported water quality parameters can support fairly high productivity, but Phosphorus limiting. This would impede the growth of algae. Noted inadequate productivity, meaning that if fish is to be farmed food must be supplemented for profitable fish growth. Reported microbial indicators depicted that the dam is not polluted by activities within and around. Kajiado is located within a semi-arid climatic set-up making the water temperature suitable for tropical fish farming. Given that the dam is recharged from an underground spring, the water was clear with low primary productivity. However the zooplankton population and diversity was within range for fish farming. Since the dam water is being used to supply water to the surrounding urban developments, cage culture or pen culture may not be preferred for this dam. *Oreochromis niloticus* would be a good candidate for the dam.

iv) Olmirrui

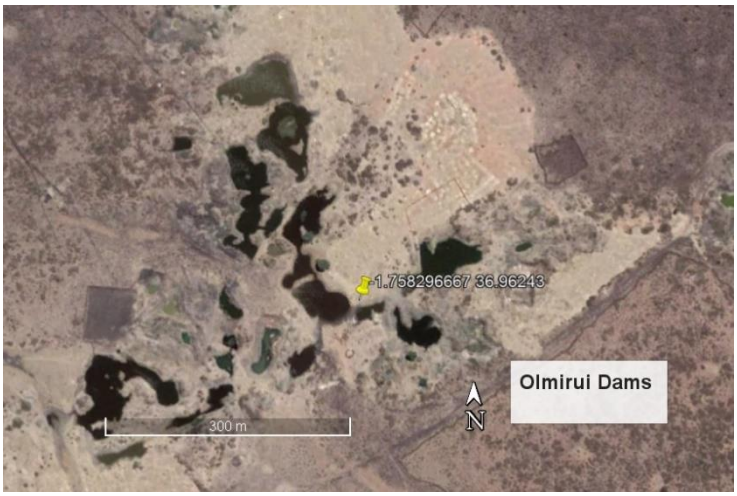


Plate 69. The dam is located in Kajiado East sub-County, around GPS -1.7583, 36.9625, with a water depth of 3m and sandy substrate. The dam is located in a semi-arid area. Series of water pans that were formerly quarry. Field for grazing animals. The dam is stocked with various species of fish.

Table 69. Socio-ecological findings Olmirui dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.45	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	0.23
Trophic State Index (TSI)	57.6	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium (µg/l)	60.3	2000 ug/l	Within the recommended limit	
Dissolved Oxygen (DO) (mg/l)	7.0	5 and above mg/L	Favorable to fish growth	
Temperature (^{0}C)	20.3	20--31 for warm temperature adaptive fish <20 for cold adaptive fish	recommended for warm temperature adaptive fish under close monitoring	
pH	7.9	6--9	Best growth	
TN:TP	19.9	10 - 30	No limiting nutrient. Can support diverse population of algae	

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Secchi Depth (m)	0.4	0.35 – 0.5	If turbidity is from phytoplankton, dam is in good condition.	
Fish condition factor	2.75 (*O. n*), 0.66 (*C.g*)		O. n perfomance is relatively good, showing potential for semi intensive culture. *C.g* perofmed poorly.	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	160	$10^3 – 10^4$	1.Series of Water pans/formerly quary, 2.Animals grazing 3. Stocked with fish, Tillapia (ON), Labeo, Clarias, Burbus spp. High potential for fish farming	
Phytoplankton Shannon index H	4.76855			
Phytoplankton abundance (Ind.L-1)	952	300 and above	Diversity and productivity is good for fish farming	
Zooplankton abundance (ind.L-1)	236.7			
Zooplankton Shannon index H	1.038			

The reported water quality parameters can support fairly high productivity, no limiting nutrient as such can support diverse populations of algae. Noted adequate productivity, meaning that if fish is to be farmed less food supplements may be required for the profitability of fish growth. Reported microbial indicators depicted that the dam is not polluted by activities within and around. The resident fishes especially the *Oreochromis niloticus* was performing relatively good and with proper management can perform much better. Proper security measures like fencing should be put in place.

v) Olokii (Isinet Kalesirwa)

Plate 70. The dam is located in Kajiado South sub-County, around GPS -2.683, 37.5155, with a water depth of 2.5m and sandy substrate. The dam is located in a semi-arid area and is still under construction though had been stalked with *Clarias* spp. The dam is well fenced with a gate and restricted access. Small seasonal stream flowing in acts as the main source of water apart from surface runoff. Commercial agricultural cultivation of tomatoes is the main user of water from the dam. No grass nor trees around.

Table 70. Socio-ecological findings Olokii dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.47	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	23.27
Trophic State Index (TSI)	66.0	50 - 70 (Eutrophic)	Can support fairly high productivity	

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Ammonium (µg/l)	68.4	2000 ug/l	Within recommended limit	
Dissolved Oxygen (DO) (mg/l)	7.61	5 and above mg/L	Favorable to fish growth	
Temperature (^{0}C)	20.3	20--31 for warm temperature adaptive fsh <20 for cold adaptive fish	preferred for warm temperature adaptive fish under close monitoring	
pH	9.1	6--9	Slow growth	
TN:TP	2.0	10 - 30	Nitrogen limited. This can promote the growth of undesirable algae like cyanophytes	
Secchi Depth (m)	0.2	0.35 – 0.5	Turbidity becoming excessive.	
Fish condition factor	0.86 (*C.g*)	2.9 - 4.8	Poor performance by this species. However, it can be considered for semi intensive culture since it is endemic here.	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	60	10^3 – 10^4	1.Fenced with gate and restricted access 2. Dam still under construction, but had been stocked. 3. Small seasonal stream flowing in. 4. Small agricultural activities for Tomato growing. 5. No grass nor trees around. When properly managed has high potential for fish growing.	
Phytoplankton Shannon index H	3.07269			
Phytoplankton abundance (Ind.L-1)	108	300 and above	Productivity is low for proliferation of algae enhancement	
Zooplankton abundance (ind.L-1)	205			
Zooplankton Shannon index H	1.137			

The reported water quality parameters can support fairly high productivity, nitrogen limited, this can promote the growth of undesirable algae. Noted excessive turbidity. Microbial indicator observation depicted that the dam is not polluted by activities within and around. The dam is well managed by the communities residing within the village. Given that the dam is still under construction, the socio-ecological attributes are bound the change with time and therefore a preferable fish candidate cannot be suggested at the moment. There is need to undertake a follow-up study to ascertain the ecological status after the construction is over.

Conclusion and recommendations

Kajiado lies within a semi-arid climatic condition, but with great potential for aquaculture activities. The water quality of many dams were suitable for fish farming but with some dams having challenges with seasonality. Water sources in many dams were through surface run-offs which in some instances could bring fecal contaminations from animal farming and wildlife within the catchments into the dams. The best candidate for culture in most dams would be *Oreochromis niloticus* but this would require proper management and security measures to be put in place. Kiserian dam had the highest potential and Iyarat dam had the lowest.

3.2.8 Machakos County

i) Katangi

Plate 71. Map of Katangi dam, located at latitude (- 1.4092) and longitude (37.6899) sitting at an altitude of 1237.6 m.a.s.l. The catchment is within a semi-arid environment with acacia trees, some cyperus trees, bare soil and rocks. The area is sparsely populated. The dam is used for domestic and watering cattle.

Table 71. Socio-ecological findings Katangi dam

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.47	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	15.90
Trophic State Index (TSI)	55.3	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium (µg/l)	22.2	2000 ug/l	Within recommended limit	
Dissolved Oxygen (DO) (mg/l)	6.8	5 and above mg/L	favorable to fish growth	
Temperature (^{0}C)	22.4	20--31 for warm temperature loving fish <20 for cold loving fish	Preferred for fish growth	
pH	8.04	6 --- 9	Best growth	
TN:TP	32.4	10 - 30	Phosphorus limiting. This would impede the growth of algae.	
Secchi Depth (m)	0.5	0.35 - 0.5	Phytoplankton becoming scarce.	
Fish condition factor	1.7 (*O.v*)	2.9 - 4.8	Poor performance of the species. Restocking with *O.n* and culture at semi intensive level recommended.	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	3000	10^3 – 10^4	Open water pan next to a shopping center, domestically used. Eroded embarkments High potential for fish farming.	
Phytoplankton Shannon index H	5.19			
Phytoplanktonabundance (ind.L-1)	1257		There is good diversity and primary production is good for fish farming	
Zooplankton abundance (ind.L-1)	175.0	100-500	Conducive for fish farming since prey organism are fair abundant	
Zooplankton Shannon index H	1.16			

Fecal coliform counts were very high in Katangi dam but still lower than the uppermost threshold. The dam is isolated and the high microbial counts could be emanating from the fecal matter from cattle that are watered from this dam. This may to a small scale increase the risk of pathogenic infection. Plankton population and diversity were supported by the well-established primary productivity and conducive waters. The fairly good biological productivity would support the fisheries without supplementary feeding. Chlorophytes dominated the phytoplankton community followed by Cyanobacteria. The zooplankton community composition was dominated by copepods. The measure of trophic state index (TSI) indicated eutrophic condition and is therefore able to support good level of biological productivity. This would form food base for the secondary and tertiary organisms. All other physico-chemical parameters of DO, temperature, pH and ammonium were within recommendable levels except for TN:TP ratio that was slightly phosphorus limiting. Otherwise, the water quality was generally good for fish husbandry. The *Oreochromis variabilis* (*O. v*) that was caught in this dam was performing below threshold and this may be due to stress extraneous factors like dam geomorphology, climatic factors, pressure from exploitation or bias sampling. According to the observed ecological conditions, the dam is a good candidate for *Oreochromis niloticus* farming but a detailed follow-up study is recommended to establish the cause of poor performance of *Oreochromis variabilies* under existing favorable water quality status.

ii) Kwale Dam

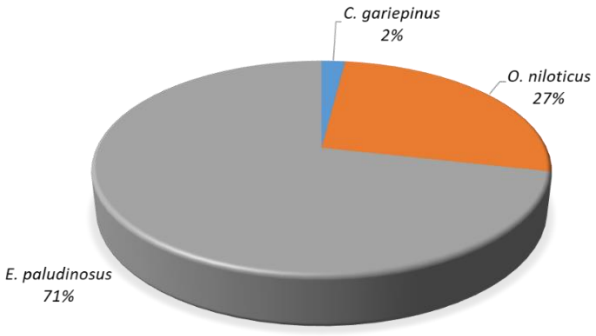
Plate 72. Map of Kwale dam, located at latitude (-1.2100) and longitude (37.2104) sitting at an altitude of 1501.3 m a.s.l. The catchment is within a grassland vegetation with acacia trees rocks and bare soil. The area is sparsely populated with some agricultural activities. The water is highly turbid. The dam is used for domestic and watering cattle.

Table 72. Socio-ecological findings Kwale dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.47	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	32.08
Trophic State Index (TSI)	65.3	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium (µg/l)	59.7	2000 ug/l	Within recommended limit	
Dissolved Oxygen (DO) (mg/l)	6.8	5 and above mg/L	favorable to fish growth	
Temperature (^{0}C)	22.4	20--9	Preferred temperature for fish growth	
pH	8.2	6--9	Best growth	
TN:TP	2.8	10 - 30	Nitrogen limited. This can promote the growth of	

			undesirable algae like cyanophytes	
Secchi Depth (m)	0.2	0.35 - 0.5	Turbidity becoming excessive.	
Fish condition factor	1.43 (*E.*p), 2.13 *(O.n*)	2.9 - 4.8	*E. p* performed poorly while *O. n* had a fair performance. Restocking or semi intensive culture with *O. n* recommended since *E. p* is a low value species.	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	600	$10^3 – 10^4$	Big water pan for animals, domestic use and small irrigation use, eroded embankments Good potential for fish farming	
Phytoplankton Shannon index H	5.93754			
Phytoplankton abundance (ind.L-1)	1137	300 and above	Primary productivity is conducive for fish farming	
Zooplankton abundance (ind.L-1)	210.2	100-500	Conducive for fish farming since there is diversity of secondary producers	
Zooplankton Shannon index H	1.029			

The microbial contamination was below the threshold but fairly high relative to other dams. This could be emanating from fecal matters from cattle, since the dam is used for watering cattle. Primary production of the phytoplankton and zooplankton abundance reflected the high eutrophic status and thus exhibited high biological productivity which are food for fish. Algal species richness varied between Euglenophytes, Diatoms, Zygnematophyceae, Chlorophytes and Cyanophytes. These varieties form good species as food for fish except for cyanophytes. Copepods were the most dominant zooplankton species. The waters were eutrophic with fairly high biological productivity enough to support good growth and reproduction of fish. Temperature, DO and ammonium values were within range and could support best growth and reproduction especially of tilapia. Nitrogen concentrations were limiting and could encourage the growth of undesirable nitrogen fixing cyanophytes. Generally, the dam is productive and would not require supplementary feeding. The two species i.e. *Oreochromis niloticus (O. n*) and *Enteromius paludinosus* (*E. p*.) exhibited poor growth. This may be due to over-exploitation or the biasness in sampling*. Oreochromis niloticus* still forms the best candidate for culture in this dam. Replicate sampling needs to be done in order ascertain the best suited species for the dam and the growth performance.



iii) Muoni

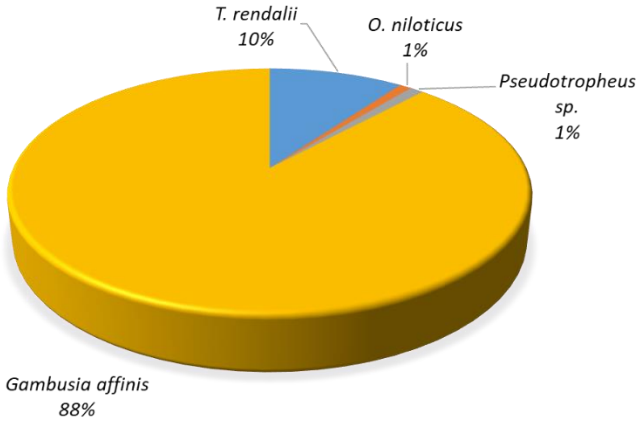
Plate 73. Map of Muoni dam, located at latitude (-1.4342) and longitude (37.3192) sitting at an altitude of 1649.1 m a.s.l. The catchment is sparsely populated, forested with blue gum trees and fringing macrophytes. There are some agricultural activities. The water was highly turbid.

Table 73. Socio-ecological findings Muoni dam

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.48	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	29.76
Trophic State Index (TSI)	53.2	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium (µg/l)	10.9	2000 ug/l	within recommended limit	
Dissolved Oxygen (DO) (mg/l)	6.3	5 and above mg/L	Favorable to fish growth	
Temperature (^{0}C)	21.2	20--31 for warm temperature loving fish <20 for cold loving fish	Preferred temperature for fish growth	
pH	8.1	6--9	Best growth	
TN:TP	23.0	10 - 30	No limiting nutrients. Can support diverse population of algae	
Secchi Depth (m)	0.7	0.35 – 0.5	Water is too clear. Inadequate productivity.	
Fish condition factor	2.22 *(*Haplochromines), 2.17 *(O. n*)	2.9 - 4.8	Both species performance was fair. Restocking with *O. n* is recommended.	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	10	10^3 – 10^4	Dam for water treatment supply for the Sub-County-Machakos. Good embarkment and macrophytes protecting surface runoffs. High potential for Fish farming	
Phytoplankton Shannon index H	4.28			
Phytoplankton abundance (ind.L-1)	251		Can support fairly fish farming since proliferation of algae was noted	
Zooplankton abundance (ind.L-1)	362.5	100-500	High diversity and abundance of zooplankton will favour Juvenile growth rate.	

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Zooplankton Shannon index H	1.68			

The fecal coliform counts were fairly low making the water quality low in microbial contaminants. This would reduce fish infections by pathogens. Phytoplankton abundance was slightly below the threshold value but with good diversity implying that the integrity of the water body was good. Zooplankton abundance and diversity was within optimal range. Diatoms, the most preferred algae by fish were the most predominant. Copepods were the predominant zooplankton species. The trophic state index of Muoni dam was eutrophic with an ability of supporting fairly good biological productivity. Other limnological parameters of DO, temperature, pH, ammonium and TN:TP ratio were within optimal levels. The integrity of the waters was therefore conducive for aquaculture practice and would require none or minimal supplementary feeding. Though the growth was below optimal recommendable range, the performance was fairly good. The fair growth may have been necessitated by biased sampling and a follow-up study is necessary in order to affirm the results. Nevertheless, *Oreochromis niloticus* would provide higher growth performance under the prevailing conditions.



iv) Muthetheni

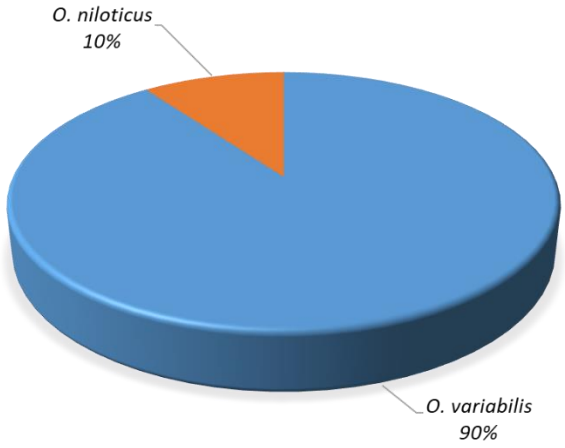
Plate 74. Map of Muthetheni dam, located at latitude (- 1.4935) and longitude (37.5136) sitting at an altitude of 1223.5 m a.s.l. The catchment is within a semi-arid area, bare soil, rocks, sparsely populated and with shrubs and acacia trees. The water was turbid.

Table 74. Socio-ecological findings Muthetheni dam.

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Socio-economics	0.51	0.4 ≤ Low-scale commercial < 0.6	Recommended for low scale commercial fish farming	27.91
Trophic State Index (TSI)	57.3	50 - 70 (Eutrophic)	Can support fairly high productivity	
Ammonium (µg/l)	46.6	2000 ug/l	Within recommended limit	
Dissolved Oxygen (DO) (mg/l)	5.39	5 and above mg/L	favorable to fish growth	
Temperature (^{0}C)	24.0	20-31 for warm temperature adaptive fish <20 for cold adaptive fish	Favorable to fish growth	
pH	8.2	6---9	Best growth	
TN:TP	18.8	10 - 30	No limiting nutrients. Can support diverse population of algae	
Secchi Depth (m)	0.4	0.35 – 0.5	If turbidity is from phytoplankton, the pond is in good condition.	
Fish condition factor	1.87 (*O.n*), 1.81 (*O.v*)		Poor performance by both species. Semi intensive culture of *O.n* is recommended in addition to restocking with preferred species.	
Microbial contamination indicators (Fecal Coliforms) cfu/100 ml)	1200	10^3 – 10^4	Water pan for domestic use. Not fenced and is open from all ends. Highly suitable for fish farming	
Phytoplankton Shannon index H	2.084			
Phytoplankton abundance (ind.L-1)	126	300	There is diversity of phytoplankton which enhances primary productivity hence it suitable for fish farming	
Zooplankton abundance (ind.L-1)	240.2	100-500	There is diversity and abundance which enhances secondary productivity for fish prey	

Parameter	Observed value	Reference value	Remarks/interpretation	Carrying capacity (mt)
Zooplankton Shannon index H	1.116			

Relative to other dams the fecal coliform counts were high but still within allowable concentration levels. The water pan is used as a source of water for domestic and cattle use and fecal matter from the cattle could be contributing to the high counts. The high coliform counts combined with the high water temperatures may highly promote the pathogen infections. Pathogenic infections needs to be examined. The phytoplankton composition was largely dominated by chlorophytes followed by cyanophytes. High abundance of these blue green and green species is a sign of nutrient enrichment that supports proliferation of these species. As for zooplankton community, like other dams, copepods were the most predominant followed by cladocera and rotifers in that order. The trophic state index, a measure of biological productivity, was fairly high enough to support optimal growth of fish by providing sufficient food. The ammonium nutrient that is essential for algal growth and other physico-chemical variables like DO, temperature, pH and TN:TP ratio were within allowable range. The waters were therefore good for fish husbandry. *Oreochromis niloticus* thatr prefers warm water conditions for optimal performance would provide a better canduidate for culture. Although data indicates that *Oreochromis niloticus* (*O. n*). and *Oreochromis variabilis* (*O. v*) were not performing to expectation, this could be attributed to other temporal extraneous factors that needs to be examined further. Otherwise the water quality is good for tilapia growth especially *O. niloticus*.



Conclusion and recommendations

The climate of Machakos County is mild, and generally warm and temperate. The average annual temperatures are warm enough to sustain a husbandry of an array of fresh water fishes. The observed physico-chemical measurements of most dams sampled were favorable for fish husbandry with an exception of microbial contaminant readings. Though below upper threshold limit, the measurements were fairly high and may promote pathogenic infection to the cultured fishes. The trophic status were fairly good and supported very high biological productivity. Plankton abundance and diversity were also within permissible ranges. Although the limnological parameters are promising, fishes performed below expectation. Further detailed studies is recommended to ascertain the causative factors.

4 Lessons learnt

a. Fisheries

The performance of tilapia and catfish species were much better in warmer areas such as the Western region and drier parts of Central region (Machakos, Kajiado and drier parts of Tharaka Nithi and Embu Counties) than the cooler areas mostly found in the Central region. These drier parts of the Central region (Kajiado, Machakos and parts of Tharaka Nithi) also exhibited features similar to the western region such as shallowness of dams and prevalence of fish diseases. However, there is need for further research in order to establish the actual source of this stress factor impacting the performance of fish species, especially, because the water quality parameters in these areas are summarily good.

It was realized that contrary to general assumptions that dam species are dominated by finfish species some dams registered shellfish species as dominant.

b. Ecology

Since sampling was undertaken during a period of extensive rains and flooding in the entire country, the estimated sizes of the dams are expected to be much larger than the average prevailing sizes provided in this study.

The emergence of some dams, either through mining activities like in Kaguru dam or inexplicable appearances like in Ahiti Ndomba dam, need further studies and unique management strategies. Further, productivity indicators in the newly formed dams were relatively low, although the water quality looked very promising for fish culture.

c. Aquaculture

Owing to the physico-chemical and geomorphological characteristics of most of the dams assessed, including prospects for livelihood improvements, many dams were found suitable for various scales of aquaculture production. On the contrary though, many other dams had cages already deployed within them without adequate scientific guidance or adherence to set regulations, thus posing serious threats to the respective dam's ecology.

d. Socioeconomics

The specific mainstay of local livelihoods and cultural eating habits were found to shape the interest and participation of communities in fisheries development initiatives within the dams. In general, livestock and farm based agricultural communities' perceived fishing and fish farming as less meaningful entrepreneurial ventures within their environs. This implies that there would be a need for adequate sensitization in order to present the prospects from fisheries as a viable livelihood alternative in order to deconstruct the induced socio-cultural orientations.

Further, from preliminary observations some dams provided more prospects for livelihood improvement from other socio-economics activities other than capture or culture fisheries development. For instance, most urban dams were suited for eco-tourism activities. It would therefore prove wiser to adapt fisheries development to the socio-economic dynamics of the dam's situation, for instance, sport fishing in a tour-centric location.

e. Small Water Bodies management

There were huge disparities in terms of the efficiency of dam management aspects such as coordination, group cohesion and community mobilization. There was a correlation between occurrence of cage aquaculture establishments within dams and the existence of clear management structures. The dams which exhibited clear management structures also had their aquatic habitats cleaner and better protected than those which had poorly structured management.

Whereas many dams had good community participation and even ownership, specific dams which fell within government protected areas had access limitations to the community. In some instances, the access was completely denied to the adjacent community. Experience and research concur that co-management of resources with adjacent communities is the best resource management strategy viable in this modern era where the pressures and dynamics of natural resource exploitation grow more complex by day.

It was observed that most dams lacked critical navigation skills and habitat infrastructure necessary for marine safety and efficient fisheries development. These skills and infrastructure included vessels, gears, diving skills, life jackets fencing, among others

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Appendices

Appendix 1

KENYA MARINE AND FISHERIES RESEARCH INSTITUTE

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When replying please quote
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For: *Dr. Aura*
Please address your reply to
DEPUTY DIRECTOR

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KISUMU
KENYA
DATE: 21/12/2020

The Director
Kenya Marine and Fisheries Research Institute
Headquarter and Mombasa Centre
P.O. Box 81651 080100
MOMBASA

RE: SUBMISSION OF TECHNICAL REPORT FOR PC PERIOD 2020-21 – ON THE ECONOMIC POTENTIAL (FISHERIES CARRYING CAPACITY) OF SMALL WATER BODIES IN SIAYA, KAKAMEGA, MIGORI, NYERI, MERU AND EMBU, AND DISSEMINATION TO STAKEHOLDERS FOR DEVELOPMENT OF BLUE ECONOMY UNDER MID-TERM EVALUATION

The above refers,

KMFRI Freshwater systems (FWS) is in the process of implementing the 2020-2021 PC on **"on the economic potential (fisheries carrying capacity) of small water bodies in Siaya, Kakamega, Migori, Nyeri, Meru and Embu, and dissemination to stakeholders for development of blue economy".**

Herein attached is the technical report showing the progress and status, which highlights activities involved in assessment.

We therefore submit this report for your perusal and for mid-term evaluation. Your support is highly appreciated.

Thank you.

Dr. Christopher M. Aura (PhD)
Deputy Director, FWS

Appendix 2: FACT SHEET

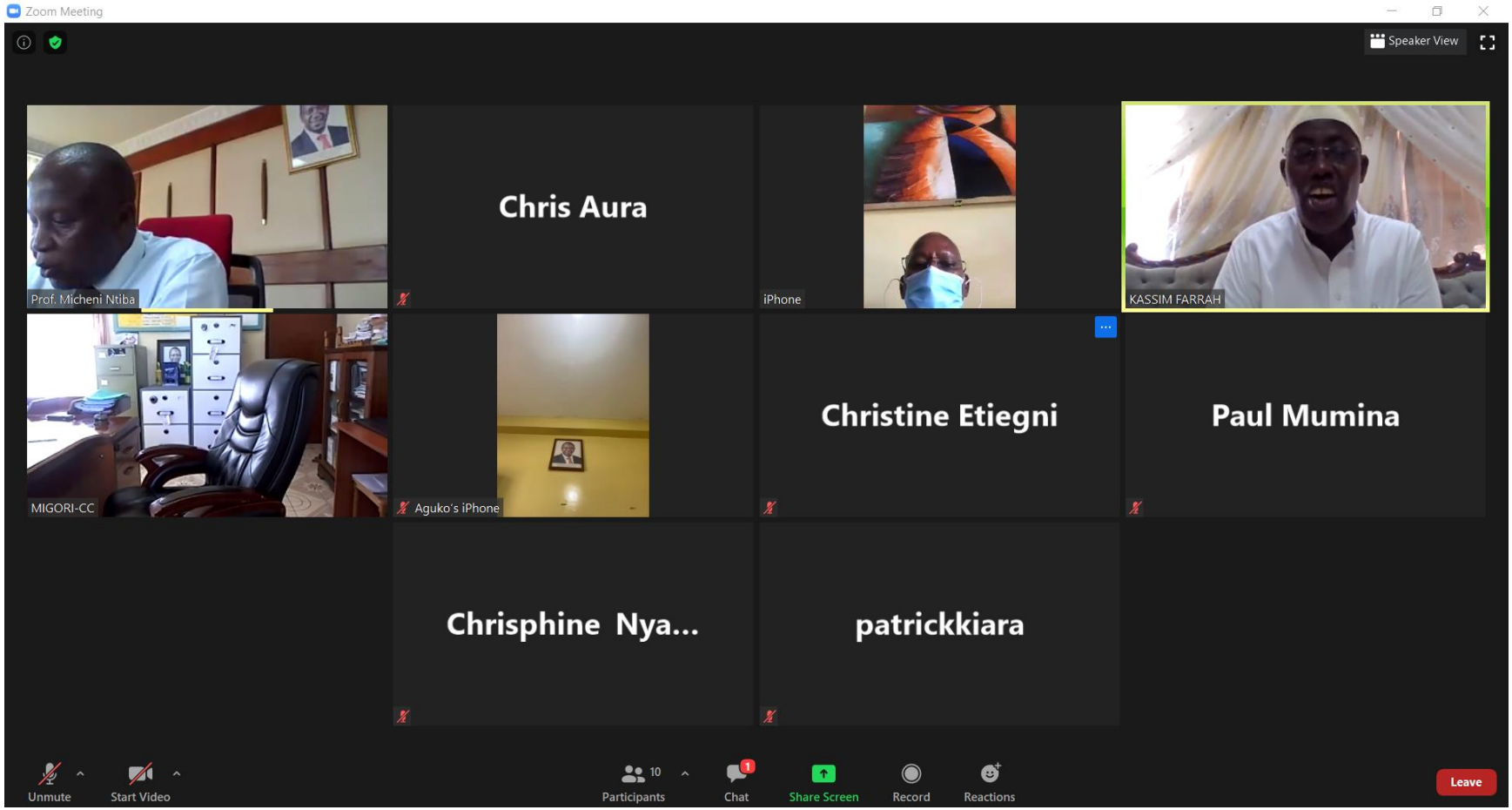
AQUACULTURE BUSINESS DEVELOPMENT PROGRAMME (ABDP)

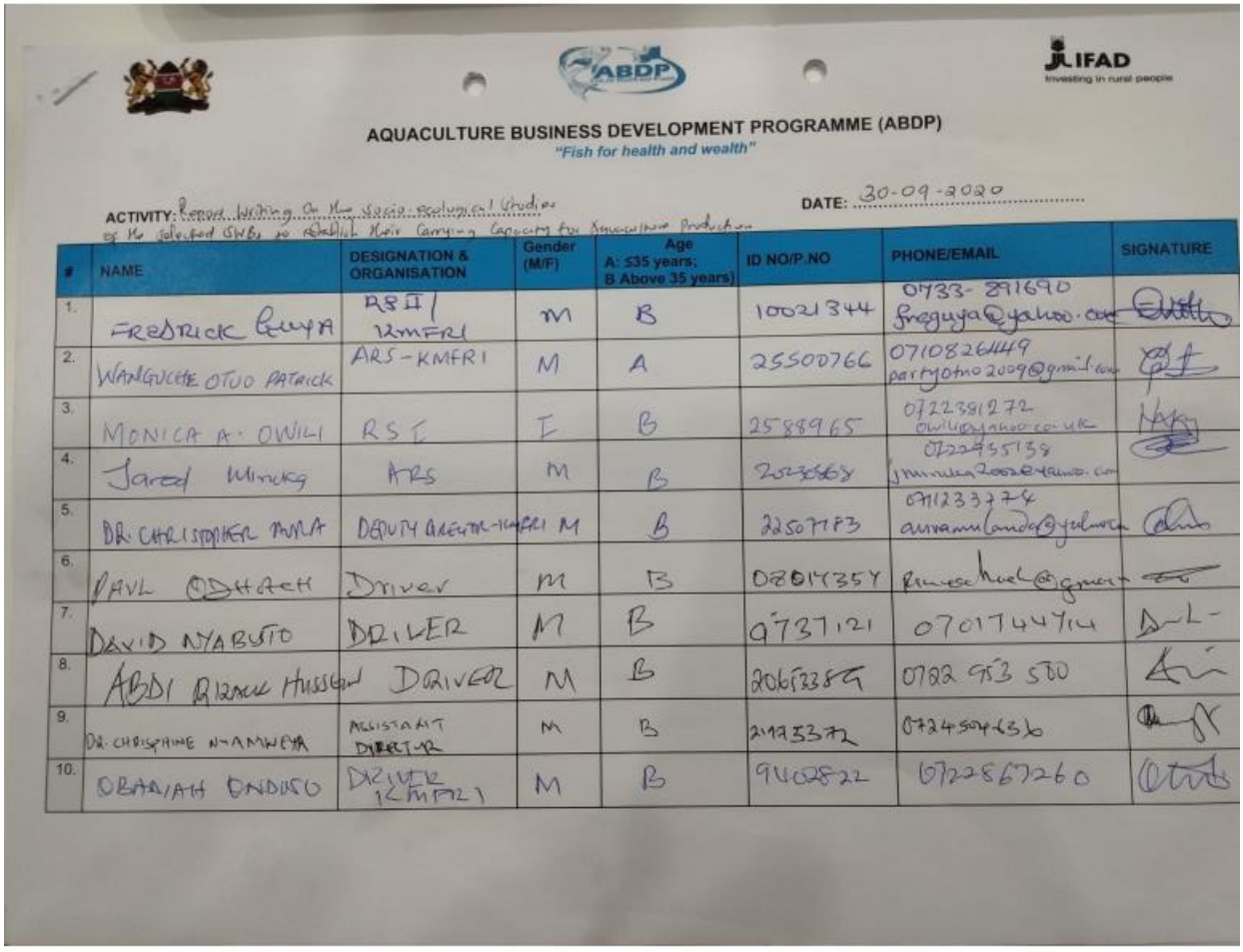
FACT SHEET

The socio-ecological studies of selected Small Water Bodies (SWBs, dams and reservoirs) in order to establish their carrying capacity for fisheries and aquaculture production

November 2020

Appendix 3: DISSEMINATION





AQUACULTURE BUSINESS DEVELOPMENT PROGRAMME (ABDP)

"Fish for health and wealth"

ACTIVITY: Report Writing On Rapid Socio-ecological Studies of the Selected CIGBs to Establish their Carrying Capacity for Sustainable Production

DATE: 30-09-2020

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10.	OBARIAH ONDIEK	DRIVER KMFRI	M	B	9402822	0722867260	

Appendix 4: Features of Small Water Bodies and tabulated values of carrying capacity of the sampled dams and small water bodies

REGION	County	Name of Small Water Body	Size (ha)	Area	Depth (Actual)	SI	TSI	Carrying capacity (mt)
Western	Busia	Buhuyi Dam	5	50000	2	0.47	0.576	8.1216
	Busia	Changara dam	0.84	8400	4	0.51	0.65	3.34152
	Busia	Munana Dam	10	100000	3	0.51	0.54	24.786
	Busia	Namalenga Dam	8.5	85000	2.5	0.56	0.6	21.42
	Busia	Namonye	5	50000	2	0.41	0.54	6.642
	Homabay	Kobodo dam	2.5	25000	2	0.41	0.54	3.321
	Homabay	Konyango Dam	7	70000	1.5	0.55	0.64	11.088
	Homabay	Yao Kosiga Dam	8	80000	6	0.48	0.68	47.0016
	Homabay	Kouma dam	1.8	18000	5	0.38	0.5	5.13
	Homabay	Oseno dam	20	200000	2	0.54	0.58	37.584
	Homabay	Pap Orage pan	1	10000	1.5	0.52	0.66	1.5444
	Homabay	Ramula dam	3	30000	1.5	0.56	0.6	4.536
	Homabay	Yongo dam	8	80000	1.5	0.5	0.58	10.44
	Kakamega	Mumonyonzo	1.5	15000	1	0.5	0.67	1.5075
	Kakamega	X-Rasa dam	2	20000	1.5	0.49	0.6	2.646
	Kakamega	Lugulu small sam	1.4	14000	3	0.45	0.62	3.5154
	Kakamega	Lumino	7	70000	1	0.48	0.62	6.2496
	Kakamega	Musembe Dam	6	60000	3	0.53	0.59	16.8858
	Kisii	Ibeno	2	20000	1	0.47	0.73	2.0586
	Kisumu	Buoye	0.8	8000	1.5	0.44	0.59	0.93456
	Kisumu	Hejope dam	0.5	5000	2	0.6	0.66	1.188
	Kisumu	Huma self help group	1	10000	1	0.48	0.53	0.7632
	Kisumu	Kere dam	0.26	2600	1.5	0.48	0.61	0.34258
Western	Migori	Konyona dam	0.25	2500	2	0.43	0.66	0.4257
	Migori	Gwitembe	1	10000	1.5	0.49	0.57	1.25685
	Migori	Karamu dam	18	180000	2	0.63	0.58	39.4632

REGION	County	Name of Small Water Body	Size (ha)	Area	Depth (Actual)	SI	TSI	Carrying capacity (mt)
	Migori	Mahena dam	1	10000	2	0.47	0.65	1.833
	Migori	Silanga Mubachi dam	11	110000	2	0.49	0.61	19.7274
	Migori	Nyamome dam	8	80000	3.5	0.51	0.6	25.704
	Migori	Olasi	20	200000	2	0.53	0.66	41.976
	Migori	Siabai dam	3	30000	1	0.49	0.62	2.7342
	Migori	Silanga dam	6	60000	2	0.49	0.51	8.9964
	Siaya	Mauna Dam	15	150000	2	0.54	0.51	24.786
	Siaya	Nyadong	2	20000	1	0.45	0.56	1.512
	Siaya	Nyagoko Dam	8.6	86000	1.5	0.46	0.68	12.1054
	Siaya	Ochot Dam	11	110000	2.5	0.48	0.48	19.008
	Siaya	Uranga Dam	11	110000	3	0.51	0.52	26.2548
Central	Embu	Gitaru Dam	290	2900000	9.1	0.55	0.54	2351.35
	Embu	Ithatha Dam	3.3	33000	1.6	0.47	0.54	4.02019
	Embu	Kamburu	1125	11250000	15.1	0.54	0.55	15135.9
	Embu	Kindaruma Dam	1000	10000000	3.5	0.51	0.45	2409.75
	Embu	Masinga Dam	12000	120000000	5.7	0.52	0.48	51217.9
	Kajiado	Enkaroni Dam	5	50000	3	0.44	0.63	12.474
	Kajiado	Iyarat Water Pan	3	30000	3.5	0.4	0.66	8.316
	Kajiado	Kiserian Dam	41.8	418000	18.1	0.48	0.48	522.948
	Kajiado	Olmirrui Dam	0.1	1000	3	0.45	0.58	0.2349
	Kajiado	Olokii Dam (Isinet Kalesirwa)	10	100000	2.5	0.47	0.66	23.265
	Kiambu	Kimunyu water pan	0.27	2700	3	0.51	0.52	0.64444
	Kiambu	Rungiri Dam	3	30000	6.5	0.51	0.49	14.6192
	Kiambu	Tigoni Dam	10.19	101900	2.5	0.4	0.64	19.5648
	Kiambu	Twiga Dam	3	30000	6.2	0.48	0.47	12.5885
	Kirinyaga	Ahiti Ndomba Dam	2	20000	4.4	0.48	0.43	5.44896
	Kirinyaga	Kangai	0.53	5300	2.4	0.55	0.52	1.09138

REGION	County	Name of Small Water Body	Size (ha)	Area	Depth (Actual)	SI	TSI	Carrying capacity (mt)
	Kirinyaga	Karura Dam	10	100000	1.7	0.52	0.52	13.7904
	Kirinyaga	Njuki-ini Dam	2	20000	4.3	0.52	0.51	6.84216
	Kirinyaga	Thiba Dam	0.75	7500	1.5	0.61	0.65	1.33819
	Machakos	Katangi Dam	5	50000	4.1	0.47	0.55	15.8978
	Machakos	Kwale Dam	10	100000	3.5	0.47	0.65	32.0775
	Machakos	Muthetheni Dam	10	100000	3.2	0.51	0.57	27.9072
	Machakos	Muoni Dam	13	130000	3	0.48	0.53	29.7648
	Meru	Kaguru Dam	1.5	15000	1.5	0.46	0.46	1.4283
	Meru	Nguthuru Laingo	6.5	65000	1.5	0.53	0.54	8.37135
	Meru	Nkunga Sacred Lake	68	680000	1.5	0.55	0.41	69.003
	Meru	Ontulili Dam	68	680000	1.5	0.53	0.42	68.1156
	Nyeri	Chinga Dam	175.0	1750000	2.8	0.54	0.5	396.9
	Nyeri	Gaikuyu Dam	0.59	5900	2.2	0.54	0.43	0.90419
	Nyeri	Guara Dam	2	20000	2	0.54	0.58	3.7584
	Nyeri	Hohwe Dam	3	30000	3.6	0.47	0.4	6.0912
	Nyeri	Ichamara Dam	2	20000	2	0.57	0.31	2.1204
	Nyeri	Kiboya Dam	0.85	8500	2	0.42	0.33	0.70686
	Nyeri	Kiunyu Dam	0.85	8500	1	0.51	0.55	0.71528
	Nyeri	Njengu Dam	9	90000	3.1	0.57	0.42	20.0378
	Tharaka Nithi	Gatonto Dam	0.75	7500	2	0.47	0.14	0.2961
	Tharaka Nithi	Ndetha Dam	0.75	7500	2	0.47	0.59	1.24785

Appendix 2: Some of the field work pictorial presentations

No.	County	Photo/Activity
1	Tharaka Nithi	
2	Embu	 Group Photo Ithatha dam

No.	County	Photo/Activity
3		 Courtesy call County Fisheries Director –Embu
4		 Group Photo Kamburu dam-Embu County

No.	County	Photo/Activity
5	Kiambu	 Socio-economic data collection Kiambu County

No.	County	Photo/Activity
6	Kiambu	 Group Photo Kiambu County
7	Busia	 Courtesy call Busia County Fisheries Office

No.	County	Photo/Activity
8	Busia	 Macro-invertebrates sampling-Busia County
9	Kisumu	Fish Sampling Hejope dam Kisumu County 

No.	County	Photo/Activity
10	Siaya	 Loading fishing canoe –Siaya Fisheries County office

No.	County	Photo/Activity
11	Siaya	 Fish Sampling-Mauna dam -Siaya County

No.	County	Photo/Activity
12	Kajiado	 Courtesy call Kajiado County Fisheries Office

No.	County	Photo/Activity
13	Kajiado	 Fish Sampling Olmirui dam Kajiado County

No.	County	Photo/Activity
14	Machakos	 Courtesy call Machakos County Fisheries Office
15	Machakos	 Group photo Kwale dam Machakos County

No.	County	Photo/Activity
16	Migori	 Sampling using Rubber dingy at Nyamome dam Migori County

Appendix 3: Fish species sampled during the expedition

Fish	Counties	English Name	Common name	Scientific name	Water body/Dams
	1. Nyeri 2. Kirinyaga 3. Kajiado 4. Nyeri 5. Machakos 6. Kiambu 7. Kakamega	Haplochromis	Fulu	*Pseudotropheus sp*	Guara dam, Ichamara dam, Kiunyu dam, Karura dam, Rungiri dam, Muoni dam, Mumunyonzo dam ,
	1. Nyeri 2. Kiambu 3. Kakamega	Crayfish		*Procambarus sp*.	Kiboya dam, Tigoni dam, Mumunyonzo dam ,

Fish	Counties	English Name	Common name	Scientific name	Water body/Dams
	1. Nyeri 2. Kirinyaga 3. Meru 4. Tharaka-Nithi 5. Embu 6. Kiambu 7. Kajiado 8. Machakos 9. Kisii 10. Homabay 11. Migori 12. Kisumu 13. Kakamega 14. Busia	Tilapia	Ngege	*O. niloticus*	Kiboya, Guara, Chinga, Ichamara, Njengu, Kiunyu, Hohwe, Kangai, Thiba, Karura, Nkunga, Ndetha, Ithatha, Masinga, Twiga, Rugere , Enkaroni, Olmiriu, Muooni , Muthetheni, Ibeno, Kobodo dam, Konyango, Yao Kosiga, Pap Orage, Ramula, Kamaru, Mahena, Nyamome/Yao Kokech, Siabai, Huma self-help group, X-Rasa, Munana dams
	1.Nyeri 2.Kirinyaga 3.Machakos	Tilapia	Mbiru	*O. variabilis*	Chinga, Kiunyu, Karura, Katangi, Muthetheni, Uranga dams
	Embu	Tilapia		*Oreochromis mosambicus*	Kamburu, Gitaru and Kindaruma dams

Fish	Counties	English Name	Common name	Scientific name	Water body/Dams
	1.Kirinyaga 2.Homabay 3.Migori 4.Kisumu 5.Kakamega 6.Siaya 7.Busia	Tilapia	Opat	*O. leucostictus*	Karura, Kobodo dam, Konyango, Yao Kosiga, Konyona, Kamaru, Silanga Stella, Silanga Mubachi, Nyamome/Yao Kokech, Olasi, Siabai, Hejope, Huma self-help group, X-Rasa, Uranga. Buhuyi and Munana dams
	1.Nyeri 2.Migori 3.Kakamega 4.Siaya	Tilapia		*Coptodon zilii*	Ichamara, Njengu, Kiunyu, Nyamome/Yao Kokech, Chekalini/Musembe and Ochot dams
	1.Embu 2.Kiambu 3.Machakos	Tilapia		*T.rendalii*	Kamburu, Gitaru, Twiga and Muooni dams
	1.Kiambu 2.Nyeri	Cray fish	Okela	*Cambarus sp*.	Kiboya and Njengu dams

Fish	Counties	English Name	Common name	Scientific name	Water body/Dams
	Nyeri	Sun fish		*M. salmoides*	Njengu dam
	1.Nyeri 2.Kirinyaga 3.Embu 4.Kajiado 5.Machakos 6.Homabay 7.Migori 8.Kakamega 9.Siaya	Cat fish	Mumi	*C. gariepinus*	Kiunyu, Hohwe, Karura , Gitaru, Olmiriu, Kwale Kobodo, Konyango, Yongo, Olasi, X-Rasa, and Uranga dams
	1.Nyeri 2.Embu	Red-finned barbus		*E. apleurogramma*	Hohwe and Kindaruma dams

Fish	Counties	English Name	Common name	Scientific name	Water body/Dams
	1.Kirinyaga 2.Machakos 3.Kakamega 4.Busia	Mosquito fish		*Gambusia affinis*	Thiba, Muooni , Chekalini/Musembe, Ochot and Changara dams
	1.Embu 2.Kajiado 3.Homa Bay	Labeo	Ningu	*Labeo victorianus*	Gitaru, Olmiriu and Yao Kosiga dams
	1.Embu 2.Kajiado 3.Machakos 4.Homabay 5.Migori	Barbus	Fuani	*Enteromius paludinosus*	Kindaruma, Olmiriu, Kwale Kobodo dam Konyango, Pap Orage, Yongo and Olasi dams
	Kisii		Ningu	*Labeo altianalis*	Ibeno shallow water dam

Fish	Counties	English Name	Common name	Scientific name	Water body/Dams
	1.Kisumu 2.Siaya	Mudfish	Kamongo	*P.aethiopicus*	Uranga and Hejope dams
			Adel	*Barbus sp.*	Kamburu dam

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MOMBASA

RE: SUBMISSION OF TECHNICAL REPORT FOR PC PERIOD 2020-21

The above refers,

KMFRI Freshwater systems (FWS) have successfully implemented the 2020-2021 PC on **"the economic potential (fisheries carrying capacity) of small water bodies in Siaya, Kakamega, Migori, Nyeri, Meru and Embu, and dissemination to stakeholders for development of blue economy".**

Herein attached is the technical report and fact sheet, which highlights activities involved.

We therefore submit this report and fact sheet for your perusal and dissemination to the relevant stakeholders. Your support is highly appreciated.

Thank you.

Dr. Christopher M. Aura (PhD)
Ag. Director - FWS

Ag. Director FWS
Disseminate
21/5/2021

Aquaculture Business Development Programme (ABDP)

ABDP is a joint programme between the Government of Kenya and the International Fund for Agricultural Development (IFAD). The programme is national in scope but targeting counties with high aquaculture potential including concentrations of aquaculture activity, high production, existing infrastructure (processing, marketing and research), adequate water resources and marketing potential.

The Programme goal is set as "reduced poverty and increased food security and nutrition in rural communities", and the corresponding development objective as "to increase the incomes of rural poor households involved in aquaculture in the targeted counties and the food security and nutritional status of the wider communities".

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