DOCUMENTATION OF AQUAPARK MODEL: A CASE STUDY OF BUSIA COUNTY

Aquaculture Business Development Programme (ABDP)

MAY 2022

Declaration

We, the selected staff from Busia County Government Directorate of Fisheries, Kenya Marine and Fisheries Research Institute (KMFRI), Aquaculture Business Development Programme (ABDP) participants, Kenya Fisheries Service (KeFS) and State Department for Fisheries, Aquaculture and Blue Economy (SDFA&BE) herein submit a technical report on the emerging aquaculture innovations focusing on aquapark model being implemented in Busia County. 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 staff from Busia County Government Directorate of Fisheries, Kenya Marine and Fisheries Research Institute (KMFRI), Kenya Fisheries Service (KeFS) and State Department for Fisheries, Aquaculture, and the Blue Economy (SDFA&BE) for their valuable contribution.

Citation

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Letter of Submission

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

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

In-line with the aforementioned, Busia County Government Directorate of Fisheries was supported by Kenya Marine and Fisheries Research Institute (KMFRI), ABDP, Kenya Fisheries Service (KeFS), SDFA & BE participants in the "*Documentation of the Aquapark Model: a case study of Busia County*" for potential sustainability and adoption.

The purpose of this letter is therefore to submit the technical report and a brief of the study to your office for further actions.

Thank you

Dr. Christopher M. Aura (PhD)
Director, Freshwater Systems Research
FOR: DIRECTOR GENERAL/CEO-KMFRI

Executive Summary

In this study context, aquaparks refers to an aggregation of production systems where several smallholder fish farmers are grouped together and assisted to produce in large quantities. This is an emerging technology in the region that has been adopted by the County Government of Busia through the Directorate of Fisheries. Cognizant of the declining fisheries globally, the aquapark model was identified as a method that can help in enhancing production of fish to meet the increasing fish consumption demand. In the implementation of this system, the county has made use of both ponds and cage-based production systems. The model has enabled the farmers enjoy some benefits such as acquisition of inputs, combined management, and provision of extension services among others. It is against this backdrop that the Aquaculture Business Development Program (ABDP) supported a field activity to assess the performance of the model for possible adoption of this system in other areas. Both primary and secondary data on socioeconomics, water quality and environment, fisheries and aquaculture were collected and analyzed using standards methods and procedures. Through aggregated aquaculture systems which co-creates a large-scale commercialized enterprise, the study further noted increased cohesion, marketing, extension services, sharing of best practices and experiences, and economies of scale in production and marketing. Though the assessment noted better performance of lake-based aquapark in comparison to the land-based system - indicative of a flushing effect of natural lake-water, there is huge potential of about 24.0 tonnes per year if all the land-based ponds are utilized consisting of over 100 ponds measuring 300 m^2 each with adherence to good aquaculture management practices. Water quality parameters were optimal for both land-based and lake based aquaparks for good performance of Nile tilapia (*Oreochromis niloticus*). The study recommends specific strategies for upscaling of this technology in the county and beyond including adoption use of monosex fingerlings.

1.0 Introduction

1.1 Background Information

Fisheries and aquaculture make a critical contribution to global food systems, providing nutrition and employment to millions of people. Fish contributed 17% of animal-based protein and 7% of all proteins consumed by the global population and provides about 3.2 billion people with almost 20% of their average per capita intake of animal protein (FAO, 2020). With diminishing returns of global capture fisheries, aquaculture currently contributes half of the fish produced for human consumption (Bush and Oosterveer, 2019; Aura et al., 2020). Aquaculture is the world’s fastest growing food industry, with over 600 aquatic species farmed globally (FAO, 2018). During the past two decades, the aquaculture sector has evolved from having a relatively minor role to playing a mainstream part in the global agri-food system. Future expansion of fish food is expected to come from aquaculture (Anderson et al., 2017; Aura et al., 2018). For instance, aquaculture production is projected to increase from 60 million tons (mt) in 2010 to 100 mt in 2030, and up to 140 mt by 2050 (FAO, 2020).

In Africa, about 6 million people derive their livelihoods from fisheries and aquaculture sectors and the number is steadily increasing. In most Sub-Saharan African (SSA) countries, Kenya inclusive, aquaculture is dominated by both extensive and semi-intensive practices (Béné et al., 2016), which has resulted in low unit production and often fall short of the projected demand for human population. To fulfil the demands of the future, aquaculture must follow the three pillars of sustainability and be economically, socially and environmentally friendly: (i) Economic: aquaculture must be a viable business opportunity with a positive long-term outlook; (ii) Social: aquaculture must be socially responsible and contribute to community health and well-being; and (iii) Environmental: should not create significant disruption to the ecosystem or be responsible for the loss of biodiversity or significant pollution impact (Bhari and Visvanathan, 2018).

In Kenya, aquaculture is predominantly small-scale in scope, which continue to contribute significantly to food security and nutrition, livelihoods, economic development, social capital, biodiversity conservation and climate change resiliency (Obiero et al., 2021a). Over the past two decades, Kenya's aquaculture sector has progressed from a minor player to a key component of the country's fish food system (Obiero et al., 2021a). Aquaculture is now recognized as a source of food security, poverty reduction, and job creation in Kenya's Vision 2030, as well as the continental aspiration of Agenda 2063, the United Nations 2030 Agenda for Sustainable Development, and the East African Community Vision 2050, in which member countries aspire to become middle-income countries (AUC-NEPAD, 2014). Through the supportive government policies and substantial public investments, aquaculture production in Kenya increased rapidly from less than 1,000 tonnes in 2006 to 24,000 tonnes in 2014 (Obiero et al., 2021a) including in regions of the country with little history of fish production or consumption (Ole-Moiyoi, 2017).

In the past 5 years the output from aquaculture nationally has increased steadily from the year 2017 to 2021 (Figure 1). Although capture fisheries presently remain the dominant supplier of fish in Kenya, the maximum sustainable yields (MSY) for most rivers and lakes in Kenya have been exceeded and fish output from these sources plateaued over the past 5 years. Aquaculture is viewed as an alternative to bridging the widening gap between fish demand and its supply in Kenya (Obiero et al., 2019a).

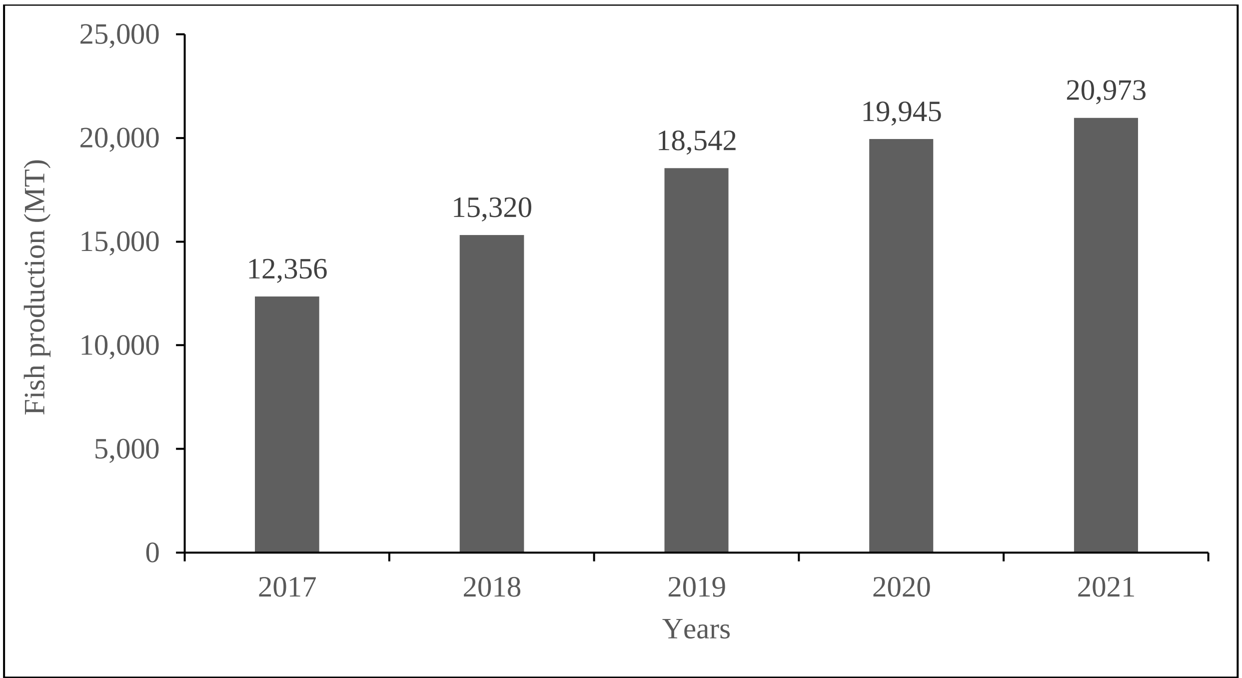

Figure 1: National aquaculture production trends in Kenya (Source of data: KNBS, 2022)

Aquaculture has a great role to play in achieving multiple SDGs, including SDG 1 and 2, by making fish available and affordable to combat malnutrition and alleviate nutritional deficiencies. For instance, aquaculture provides a significant socioeconomic contribution in rural communities which can play a role in reducing poverty. As the industry expands, jobs in aquaculture will be instrumental in providing support to individuals across the country and may ultimately help to reduce poverty (Aura et al., 2018; Munguti et al., 2021). In terms of promoting health and wellbeing, consumption of fish and fish products is associated with many health benefits. They are a rich source of protein containing all essential amino acids in addition to essential fats including omega-3 fatty acids, vitamins and minerals.

Rapid growth of the aquaculture industry has been enabled through the expansion of aquaculture production areas, intensification of production systems, and adoption of new technologies and systematic improvement of existing technologies that brought control over husbandry and production processes (Kumar and Engle, 2016; Henriksson et al., 2018). Since land and water are becoming scarce due to competition from other sectors and resource users, climate smart aquaculture technological innovations and management practices (CSA-TIMPs) have been promoted to achieve sustainable intensification of aquaculture. These include the development of model farms with recirculating aquaculture systems (RAS), tank-based systems, hydroponics and aquaponics, as well as high density, high carrying capacity intensive production in cages in lakes and reservoirs (Obiero et al., 2021b).

As a result of declining agricultural productivity, low farm level productivity, food insecurity, and land fragmentation, Busia County rolled out Aquaparks that entails an aggregation of fishponds or cages within a specific area for efficient production and management. In this study context, Aquaparks refers to an aggregation of production systems where several smallholder fish farmers are grouped together and assisted to produce in large quantities. This is a new technology that has been adopted by the County Government of Busia through the Directorate of Fisheries. In the implementation of this system, the county has made use of both ponds and cage-based production systems.

1.2 Aquaculture Park Business Model

Currently, the farming environment in Busia County is characterized by highly fragmented production structure with tiny farms that average 1.7 acres per farmer. This kind of production limit smallholder farmers profit margins due to the high cost of production which is the single largest bottleneck to increasing primary production and productivity amongst the farmers. Busia County has significant potential for development of a commercial aquaculture industry. Over the past 5 years, the county initiated a supportive policy frameworks and financial services to maximize the physical potential and thereby promote profitable aquaculture business entities in the County. However, there still exists key constraints hindering the development of commercial aquaculture which include access to: (a) high quality and affordable seed (b) high quality and affordable feed (iii) flexible and affordable capital (iv) timely, accurate and accessible information; and (v) efficient input supply and marketing system.

An important solution to these constraints would be the development of 'Aquaculture Parks', under a public private partisanship (PPP) where the government supports developments providing basic infrastructure for fish farmers, similar in concept to business parks. This model has been rolled out in the Open waters of Lake Victoria at Mulukoba Beach (Bunyala Sub-County) and at Bukani Aquapark (Samia Sub-County) and is being rolled out in all Sub Counties of Busia County. The key features of the Aquaparks are:

(a) The Department of fisheries using farmer organizations to leverage on challenge of fragmented production structure.
(b) The farmer organizations comprising smallholder farmers are organized in a given space to establish an aggregated production park.
(c) A business management service provision unit is then established comprising of technical staff of a directorate to offer management service to the farmer organizations.
(d) The small holder farmer organization is then supported with seed capital to start-up an aggregated large-scale production enterprise.
(e) The enterprise is managed on behalf of the "investor" small scale farmers at a service fee by the business management service unit.

The County Government of Busia in collaboration with Kenya Marine and Fisheries Research Institute (KMFRI) and universities in the region, have been implementing validation of Climate Smart Fish Marketing, Value addition and Post-Harvest Technologies for Improved Food and Nutrition Security through the Kenya Climate Smart Aquaculture Project (KCSAP) Adaptive Research Project funding. KCSAP has also funded various Sub-projects in Aquaculture Value chain in Busia County with the aim of increasing fish productivity and build resilience to climate change risks.

The KCSAP project funded the construction of on land aquaparks including 100 earthen ponds at Bukani in Samia sub-county, 100 ponds in Kamarinyang in Teso South sub-county and 70 ponds in Siunga in Butula sub-county. Open water aquaculture parks (fish cages) have also been installed in the Lake Victoria waters (243 cages) to increase fish productivity and build resilience to climate change risks. Besides these aggregated aquaculture production units, other aquaculture enabling infrastructure developed by the County include furnishing of

Wakhungu Hatchery with a Recirculatory Aquaculture System (RAS) to boost the production of quality fish fingerlings to a capacity of 1.5 million fingerlings per annum in Samia Sub-County and establishing a satellite nursing hatchery in Okerebwa in Teso South Sub County. In addition, the project also supported Nasewa fish feed production plant through installation of a pelletizer machine for production of quality floating pellets. A new fish eatery was also established at Wakhungu Fish Farm to increase per capita consumption of fish, to provide market for the table size fish and enhance uptake of fish value addition technologies and innovations to the beneficiary communities. The aquapark concept is illustrated in the diagram below (Figure 2).

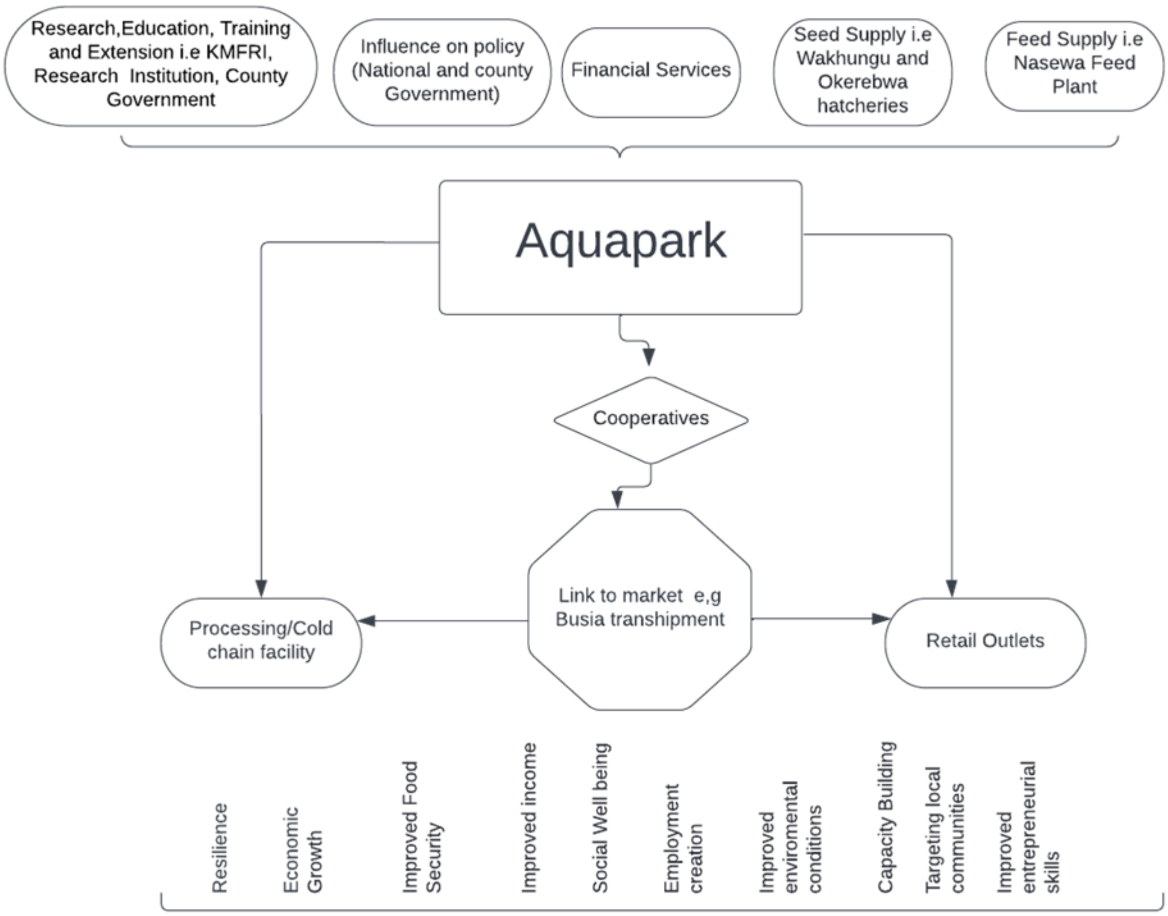

Figure 2: Aquapark components, value chain linkages and outcomes in Busia County.

Aquaparks are thus envisioned as a potential solution to the issues that impede the development of the country's aquaculture sector. Furthermore, Aquaparks are projected to solve the limitations to aquaculture development in Kenya (County Government of Busia, 2022). This system is beneficial due to centralized pond management, quick access to inputs, market access, extension services, and fish processing/value addition. The model and implementation arrangements make use of out-grower schemes/nuclear schemes, which are projected to foster a domestic subsector that will serve as a sustainable and inclusive economic opportunity. The production is coordinated to provide a consistent supply of fish products throughout the growing season. In most situations, the production units are owned by the community. In addition to supplementing diminishing wild fish stocks, the aquapark model presents itself as a new source of income in Busia County. A significant increase was witnessed in aquaculture production from 2017 to 2019 but declined in the year 2020 and 2021 due to restrictions imposed during the Covid-19 pandemic which hindered access to fingerlings.

The model has attracted the attention of Aquaculture Business Development Programme (ABDP). The programme supports smallholder aquaculture farmers but can support other emerging aquaculture technologies. In this context, the program engaged the Busia County Directorate of Fisheries and to be supported by Kenya Marine and Fisheries Research Institute (KMFRI), Kenya Fisheries Service (KeFS) and State Department for Fisheries, Aquaculture and Blue Economy (SDFA&BE) to conduct a feasibility study to ascertain the potential of the model to be adopted elsewhere as aquaculture production avenue with the aim of empowering women and youths, improve nutrition and job creation through trade and recreational activities. The main objective of this study was to undertake a documentary of the aquapark (land and lake based) technology in Busia County, Kenya. The information will be useful in providing scientific, commercial and policy foundation for advising relevant stakeholders and offering insights into the success and sustainability of the model, as well as a path for acceptance and up-scaling in the Programme's participating counties.

2.0 Materials and Methods

2.1 Study area

The study on the Aquapark model in Busia County was conducted at the lake cage-based system located at Mulukoba Beach in Lake Victoria and 3 pond-based system aquaparks at Bukani in Samia Subcounty, Siunga in Butula Sub- County, and Kamarinyang in Teso South Sub-County (Figure 3). The aquaparks at Mulukoba Beach and Bukani are already operational while the rest are still under initial stages of construction. The Bukani aquapark comprising 100 ponds constructed on community land, are all owned by the community members. The Park has a Management Committee which is drawn from the community and Busia County Government officials.

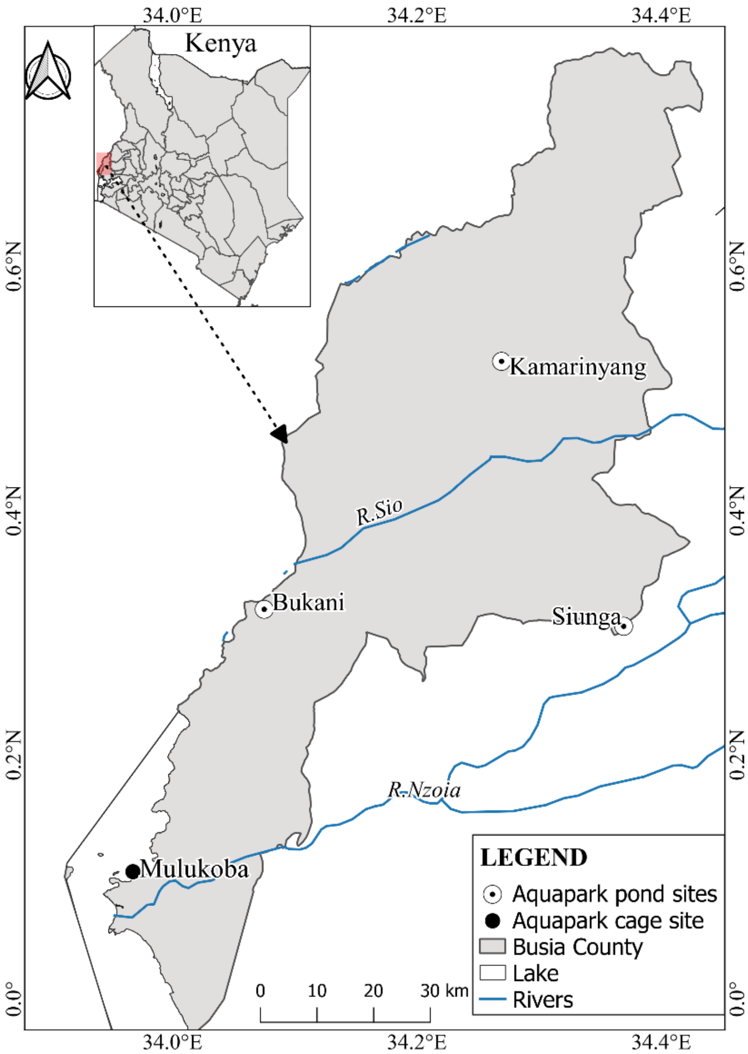

Figure 3: Map of the study locations for the aquapark assessment showing the land based sites; Kamarinyang, Bukani and Siunga and the Lake based one at Mulukoba beach.

Busia County borders Bungoma County to the north, Kakamega County to the east and Siaya County to the southeast. It is also bordered to the south by Lake Victoria with River Nzoia in Budalangi and River Sio in Samia flowing into the lake. The County has approximately 893,000 people and spans about 1,700 km^2 making it one of the smallest counties in Kenya (County Government of Busia, 2022).

In general, Busia County produces fish from both capture fisheries and aquaculture with Lake Victoria as the main source of fish in the county. The fish traded across the markets in Busia are valued at approximately Kshs 1.2 billion annually (Busia County Integrated Plan, 2018). The Directorate of Fisheries in the County Government of Busia supports over 1000 people directly as fishermen and 1,895 fish farmers and a total of 2,464 ponds (597 stocked fish ponds). The non- stocked ponds was mainly due to unavailability of aquaculture inputs occassioned by the Covid-19 pandemic. It also supports over 20,065 people directly and indirectly working as fishers, traders, processors, suppliers and merchants of fishing accessories and employees and their dependents (County Government of Busia, 2022). In 2019, fish production from inland capture fisheries contributed 5,004,810 kg of the county's total fish earnings amounting to Kshs 509,152,638 with the principal fishery being that of Lake Victoria. Aquaculture production amounted to 151,200.20 kg earning farmers Kshs 74, 640,827, a 66.4% increase from the previous year. Capture fisheries production also increased by 2.6% owing to the weekend ban giving room for reproduction and growth of smaller fish and introduction of fish cages where fishermen have shifted to aquaculture in the open waters hence reducing pressure on capture fisheries.

2.2 Data collection

2.2.1 Socio-economic data collection

The socio economics data was collected using a semi-structured questionnaire, focus group discussion (FGD) and key informant interviews (KIIs). The tools were used to collect information on sociodemographic, technical, economic, and production data using Kobo Collect mobile application. Purposive sampling was used because it is beneficial in cases where a desired sample must be reached rapidly, and proportionality is not the primary consideration. The study used a cross-sectional survey design to collect data from randomly selected fish farmers using a pre-tested semi-structured questionnaire. Statistical data analysis was done for production, employment status and financial implication of different aquapark production systems (cages and ponds) using STATA Version 17 and Microsoft Excel. Both Strengths, Weaknesses Opportunities and Threats (SWOT) and Political, Economic, Social, Technological, Environmental and Legal (PESTEL) analyses were also undertaken. Descriptive analyses were done using counts, means, percentages and presented in tables and figures. Secondary data from Busia County reports were used to complement primary data. The gross margin was calculated as the difference between total revenue and total cost of production.

2.2.2 Water quality parameters and nutrients

Assessment of water characteristics followed published standard methods for aquatic environmental studies (APHA, 2012). Portable water physico-chemical electronic sensor-based probe was be used to take measurements at every sampling site. Data was immediately captured on field data sheets. The main physical and chemical parameters measured were column depth (m), Temperature, Dissolved Oxygen (DO), Conductivity, pH, Turbidity (Formazin Turbidity Units (FTU), Salinity (ppt), Oxidation-Reduction Potential (ORP) and Total Dissolved Solids (TDS). Levels of Nitrogen (ammonium-NH_4^+-N; nitrite-NO_2^--N; nitrate-NO_3^--N; total nitrogen-TN), Phosphorus (soluble reactive phosphorus-SRP; total phosphorus-TP), Silicate species, Chlorophyll-*a* and Total Suspended solids (TSS) concentrations were analyzed for all the study sites.

2.2.3 Primary productivity (Phytoplankton)

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 microscopy 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).

2.2.4 Secondary Productivity (Zooplankton)

Zooplankton samples were collected using Nansen type plankton net of 60μm 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 Microbiology

Water samples for bacteriological assessment were collected directly into 500 ml aseptic plastic bottles for the bacteriological quality assessment. Each bottle was corked and labelled with full details of the site, time, and date of collection and transported to the laboratory in a cooler box for analyses. The parameters for pollution addressed were Total coliforms and Fecal coliforms using standard procedures (APHA, 2012).

2.2.6 Fish sampling

Fish samples from the aquaparks and were collected using seine nets and scoop net. The fish caught were then identified to species level. For the purposes of determining the length-weight relationship and condition of the species, individual total and standard lengths were taken to the nearest centimeter (cm) using a fish measuring board, and weights taken to the nearest gram (g) using a digital weighing scale. The fish were then gutted to reveal their sex and maturity stage. The stomach was carefully removed and preserved using 10% formalin before transporting to the lab for stomach content analysis.

The length-weight relationship (LWR) for each species was expressed by a logarithmic transformation of the equation to determine the wellness of the fish:

$W = aL_b$ (Pauly, 1983) ………...................................... (ii)

which results into a straight line described by the equation:

Log W = log a + b (log L) …………….…………… (iii)

where *W* is the Weight, *L* is the total length, '*a'* is the intercept, and '*b'* is the slope of the regression line.

Condition factor, a suitable indicator of the well-being of a fish, was calculated using the relative condition factor formular (Kn): Kn = WŴ⁄ where W is the weight of an individual fish and Ŵ = aLn is the calculaated length-specific mean weight from the LWR as described in Le Cren (1951).

Specific growth rate (SGR) was calculated using the formular by Lugert et al. (2016)

$SGR = \frac{\log(Wt) - \log{(Wi)}}{t} \; X100$ ……………………………………………………………….(iv)

where Wi is the initial stocking weight of the individual fish specimens, Wt is the final weigth upon retrieval and t is the stocking time period in terms of days.

3.0 Results and Discussion

3.1 Land based aquapark

Busia County has established Bukani Aquapark in Samia (100 ponds), Kamarinyang in Teso South Sub-County (100 ponds) and Siunga Aquapark in Butula (70 ponds) and Teso South (with 100 ponds) Sub Counties. The goal of the county is to establish aquaparks in all the seven sub counties of Busia. Aquaparks act as mothership to linking small holder aquaculture groups which are satellite to the aquapark.

3.1.1 Socioeconomics characteristics of respondents

Out of the sampled population, 52% of respondents were females (Table 1). This is contrary to previous studies reporting that fish farming is male dominated (Obiero et al., 2021; Ole-Moiyoi, 2017) and an indication of a model that is supportive to marginalized groups such as women. Notwithstanding, there were few young people (<35 years) engaged in the operations of the aquaparks (ca. 10%) though at the construction states of the land-based aquaparks over 300 youths were involved in the pond construction. Lack of interest in aquaculture among the youth poses a challenge to the industry's social survival (Obwanga and Lewo, 2017). To this end, aquaculture may modify its business model by investing in profitable and sustainable climate smart technologies and innovations to appeal to the youth such as the aquapark model. This is because youths are more innovative and desire to stay current with new technologies (Koundouri et al., 2006). Majority of farmers (86%) had completed secondary school implying that their literacy level is relatively high. According to Uaiene et al. (2009), education allows farmers to receive, evaluate, and respond to new information considerably more quickly than their less-educated peers. Similarly, majority (33%) of the fish farming households were composed of 4 to 5 members. A large household tends to provide free labor for farm operations.

Table 1: Summary of socio demographics of the respondents from Bukani Aquapark in Samia Sub-County, in Busia County.

Variable		Proportion (n=21)
Gender	Female	52%
	Male	48%
Household Size	1-3	10%
	4-5	33%
	6-7	19%
	8-10	19%
	>10	19%
Education	Primary	5%
	Secondary	86%
	Tertiary	10%
Age	26-33	10%
	34-41	19%
	42-49	24%
	>50	48%

3.1.2 Economic characteristics of Land based Aquaparks

Key parameters like production system, fingerling type, culture period, pond size, total number of ponds stocked, stocking density, cost of fingerlings, size at stocking, survival rate, product, selling price and feeds were used to get the status of fish production. For the hundred (100) ponds in Bukani aquapark. Results indicate that there is potential of culture of tilapia, catfish and other indigenous species to contribute to increasing aquaculture production in the County. Success in the land base aquapark will be attributed to (i) Central management of the aquapark by project management committee, (ii) Coordinated synchronized stocking of ponds with quality inputs, (iii) Establishment of the flood control dyke at the aquapark, (iv) Fencing of the aquapark and (v) Installation of Electricity. In the 2019/2020 production cycle, fifty (50) ponds were stocked while in 2020/2021 production cycle sixty-four (64) ponds were stocked resulting in an increase of fish production by 2.25 tonnes/year. This implies that utilization of all the 100 ponds would lead to an increase of production to 24.0 tonnes/ year if all the good aquaculture management practices are adhered to. Other factors which could have led to low production of fish in the aquaparks in the initial production cycles include:

a. *Natural calamity- Flooding:* Seventeen (17) ponds had their fish swept away by floods from River Sio and introduction of predators into the pond. However, flood control dyke has been constructed at the aquapark to prevent negative effects of floods.

b. *Lack of cover nets:* Most of the farmers lacked cover nets resulting in low yield. On the contrary, the experimental ponds used by KMFRI produced relative better yield as they had cover nets. Currently Aquaculture Business Development Program (ABDP) has supported farmers with predator control kits to prevent predation and fencing of the aquapark.
c. *Non synchronized stocking regime* for the ponds during the initial phase of production in 2019/2020. Currently coordination and synchronized stocking is being done.
d. The low growth rates in the initial phase of production were due to high cost of feeds owing to farmers going long distances to accessing quality fish feeds. This forced farmers to underfeed their fish and some even harvesting before maturity. As a result of this, the County Government of Busia in its support to small holder fish farmers has established Nasewa fish feed plant to produce quality subsidized fish feeds.
e. Most of the farmers used mixed sex fingerlings which could have also contributed to the low growth. This is attributed to the fact that female tilapia spends more energy in egg production and mouth-brooding hence exhibiting a lower growth rate (Chakraborty et al., 2011). Sex-reversed tilapia is a highly promising technology for application in the production of monosex Nile tilapia in Kenya and can result in substantial yields since it is highly adaptable to different agro-ecological zones (Opiyo et al., 2020). To this end, the County Government of Busia has established Wakhungu hatchery and its satellite Okerebwa with a production capacity of 1.5 million annually to produce certified quality monosex fingerlings to help smallholder farmers in increasing fish production in the County.
f. Low fish farm gate prices in the initial phase. This has however been curbed by the support of Aquaculture Business Development Program (ABDP) where the Directorate of Fisheries Busia has established a coordinated marketing structure and linkages from the grassroot level at the Smallholder Aquaculture Groups (SAGs) to the larger Busia Fish Farmers Cooperative Union to aid in the marketing of fish following synchronized stocking.

The study findings provide empirical evidence of the current annual turnover, given the yield and the selling price of fish for the two production cycles. In 2019/2020, for instance, the annual turnover (with the selling price of 180 Kshs/kg) was Kshs 608,400 and in 2020/2021 the annual turnover (with the selling price of 195 Kshs/kg) was Kshs 1,097,850 against an annual turnover of production capacity and SP = 300 Kshs/kg of 7,200,000. When the benefits are shared in the household (average household size of 4), the values implies that food, nutrition, and income security will not be achieved if the selling price remains constant.

Table 2: Summary of the first and second phase of fish production at Bukani Aquapark in Samia Sub-County in Busia County

Key parameters	**2019/2020** **n = 21**	**2020/2021** **n = 21**
Production system	Semi intensive tilapia production	Semi intensive tilapia production
Fingerling type	Monosex/Mixed	Monosex/ Mixed/YY/ KMFRI trial
Culture period	8 months	8 months
Pond size	300 m^2	300 m^2
Total number of ponds (stocked)	50	64
Stocking density	1000	1000
Cost of fingerling	Kshs 4	Free (KMFRI)/ Kshs 4
Size at stocking	5 g	5g
Survival	50%	55%
Product	135 g Tilapia	160 g Tilapia
Selling price	180 per kg	195 per kg
Feed	300 kg Local commercial feeds/pond/year and Fresh water shrimps	250 kg Local commercial feeds/pond/year and Fresh water shrimps
Production capacity [a*]	24.0 tons /yr	24.0 tons /yr
Yield	3.38 tons /yr	5.63 tons /yr
Deficit	20.63 tons /yr	18.371 tons /yr
Current Annual Turnover (Given the current SP Kshs/kg)	608,400	1,097,850
Annual Turnover given the production capacity (with SP = 300 Kshs/kg)	7,200,000	7,200,000

[a]*= Assuming (100 ponds x 800 fish (i.e., 80% survival) x 300 g table size fish)/1000000 = 24.0 tonnes (Source: Survey data, 2022).

Majority of the farmers obtained start-up capital from grants (82%), with only a smaller portion sourcing from their personal savings (18%) (Figure 4). The farmers were supported by a project known as Kenya Climate Smart agriculture Project (KCSAP). KCSAP project supported the Department of Agriculture, Livestock and Fisheries within the Directorate of Fisheries through proposal funding to develop an aquapark with 100 ponds, office, store and fish eatery. Direct beneficiaries' farmers are the landowners while indirect beneficiaries are the communities around the aquapark. KCSAP project also supported farmers with initial startup seeds and feeds. For sustainability the proceeds from the sells will be ploughed back into production and the remaining shared as will be agreed by beneficiaries.

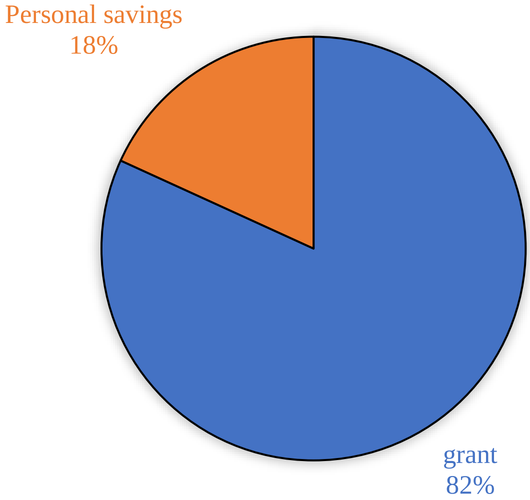

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Figure 4: Source of capital for the individuals at the aquapark in selected sites in Busia County.

3.1.3 SWOT - PESTEL Analysis of the Aquapark Model in Busia County

The interpretation of the results of the SWOT and PESTEL Analysis leads to the general conclusion that the aquapark concept might be built sustainably. To do so, the detected and evaluated unfavorable political, economic, sociological, technological, environmental, and legal factors should be minimized or eliminated, while the positive features should be reinforced and utilized. The findings of this study could help decision makers make informed decisions and choices that can be included into a strategic planning framework.

Table 5: SWOT - PESTEL analysis of the land based, and water based aquapark highlighting some of the key entry points aquaparks in Busia County could tap potential (strengths and opportunities).

Indicator	**Strengths**	**Weaknesses**	**Opportunities**	**Threats**	**Program of Action and reaction**
Political	• Existing favourable county frameworks that are pro aquaculture e.g., CIDP (County Integrated Development Plan) • Goodwill from the national and county government		• Political stability		Gradual adoption of strategic interventions until post-election
Economic	• The aquaculture labor market sector requires employment • Minimal capital investment • Access to local and the Busia Regional Cross border fish transhipment market • Hospitality and ease of doing business environment	• Market competition with wild catch • High competition with imported cheap Tilapia fish • The Tilapia size < 160 g from the land based aquapark may be outcompeted with wild catch and imported Tilapia fish of varied sizes/grades. • Non-optimal use of both land-based and water-based aquapark (< 64 operational ponds and 15 operational	• Development of new processed products • Construction of several ponds sharing dykes reduces the relative investment costs	• Increased import of Tilapia products competing local farmed fish • Rising cost of production inputs	• Brand development for farmed fish by producers to increase markets. • Producers and governments partnership to improve the value chain • Financial support mechanisms i.e feed subsidy can facilitate aquaculture development • The optimal market size can be larger and can target specific national markets • All the ponds and cages should be stocked to realize the benefits of having aggregated units at one place.

		cages) lead to minimal contribution of tilapia to aquaculture production in the county			
Sociological	• Moderate Social acceptance of the model by farmers • High consumer preference for Tilapia • Aquapark construction is technology labor intensive and creates jobs in rural areas • The focus is on smallholder farmers • Presence of a health-conscious population	• Youth's reluctance to embrace aquaculture	• Increasing human population		• Capacity-building efforts aimed at promoting group cohesion, skills, and an appropriate community participation and involvement framework are required
Technological	• Presence of aquaculture enabling infrastructure e.g. Hatcheries, Fish Feed Processing Plant, Fish eatery • Competent technical staff offering backstopping to management of the aquapark		• Presence of public and private R&D and innovation institutions with supporting Technologies Innovations Management Practices (TIMPs)		The model can be promoted for investment
Environmental	• Sustainable production, utilization, and optimization of resources • Adequate water all year round to support aquaculture	• Inadequate infrastructure and capacity for regular water quality monitoring • Inadequate fish disease surveillance,	• Declining capture fisheries	• Disease outbreaks can cause massive losses • Flooding • Abandoned metallic cages in the	• Sex-reversed tilapia is a highly promising technology for application in the production • The model has potential to increase income

	• Geographical positioning Busia makes the climate conducive for supporting aquaculture	monitoring, and control • Fish with a population of mixed sexes.		lake may lead to water quality issues	and reduce pressure on the lakes' natural resources
Legal				Lack of intellectual property protection e.g the aquapark model	• Technology training should be carried out by the county government of Busia • Compliance with the law in protection of intellectual property rights • Develop of Busia Intellectual Property right policy in liaison with KIPI

3.2 Lake-based Aquapark

Open water fish cage enterprise is one of the flagship projects in Busia County. The concept of the aquapark was started in 2018 by the County Government of Busia to increase fish production and productivity in the County and increase Lake Victoria fish production. Currently, the open water aquaculture park at Mulukoba in Bunyala Sub County of Busia has 243 installed cages. In the year 2020, the open water cage project supported 214 pupils to transition to form one. In 2021, a further 240 pupils joining were supported by the program to join secondary schools. This brings the total number of students supported from Budalangi and Funyula sub counties to 454. The total disbursed fees so far from the cage enterprise is Kshs 4,676,000 for the 454 students (Busia County Magazine, 2021). In total, 35 tons of fish have been harvested valued at 9 million shillings.

3.2.1 Gross Margin (GM) Analysis

The GM for different community owned cages (5x5x3m; 4x4x3m and 4x2x3m) were determined and are presented in Table 3. Results indicate 4x4x3m cages have better returns (Gross margin) compared to the other cage sizes. Further, there is evidenced differences in fish prices for cage and land based aquapark with land based aquapark fetching relatively low prices. Survival rate is also relatively higher in cages than pond based aquaparks. It is however important to note that the ecological conditions are different in the two set ups.

Table 3: Financial implication for different size community owned cages supported by the County Government of Busia at Mulukoba beach cage site in Bunyala sub-county.

	Indicator	Value	Value	Value
Description of indicators	Cage size (m)	5x5x3	4x4x3	4x2x3
	Number of cages	19	2	5
	No of fish stocked per cage	8000	6000	3000
	Average price of fingerlings at stocking	8	8	8
	Size of the fingerling (g) at stocking	5	5	5
	Survival rate (%)	65	65	80
	Time taken to harvest (months)	9	8	9
Sunken cost	Cost of cage construction [a*]	140,000	100,000	35,000
Variable costs	Cost of fingerlings	64000	48000	24000
	Cost of feeds	370000	206550	149000
	Cost of labor	30000	10400	11246
	Cost of transport	9000	5200	893
	Cost of security	9000	9000	9000
	Other input e.g extension	2200	1750	1750
	Total Variable cost	**484,200**	**280,900**	**195,889**
Total Revenue	Quantity (Number) of fish harvested	5,200	3,950	2,400
	Price per kilo of fish	300	300	300
	Total weight at Harvest (kg)/Production per cage	2249	1750	890
	Total production for all cages	42,731	3500	4460
	Value of fish per harvest/ cage, (Ksh)/Yr	**674000**	**525000**	**267000**
	Gross Margin per cage (Kshs)/Yr	**189,800**	**244,100**	**71,111**
	Gross Margin for all cages (Kshs)/Yr	**3,606,800**	**488,200**	**355,555**

a* for a first-time investment the gross margin would be less the cost of construction
b* The Gross Margin is for all the number of cages in the respective categories

Table 4 indicates the projected quantity and value of fish from the lake based aquapark if fully stocked. Overall, bigger cages (5x5x3 m) (n = 108) have a greater potential production and value slightly more than the smaller size cages sizes.

Table 4: Projected quantity and value of fish from lake based aquapark at Mulukoba beach cage site in Bunyala sub-county if fully stocked.

Cage size	**5x5x3**	**4x4x3**	**4x2x3**	**2.5x2.5x2.5**	**2x2x2**
Number of cages	108	2	11	36	60
Number of fish harvested/Cage	5200	3950	2400	1953	1000
Total weight at Harvest (Kg)/Year/Cage	2249	1750	890	1270	650
Total production Kg/Year	**242,892**	**3,500**	**9,790**	**45,720**	**39,000**
Value – Kshs/Year					
Farm gate price (Kshs)	300	300	300	300	300
Total Ksh/Year	**73,353,384**	**1,050,000**	**2,937,000**	**13,716,000**	**11,700,000**

Finally, the community through the BMU is involved in the operations of the cages that is, as feeders, security, and as casual laborers during harvesting. The county government gave the initial startup infrastructure support. Cages belong to the Beach management unit Network drawn from the 20 beaches of Busia County and management is under the BMU network leadership structure. The schematic arrangement is presented in Figure 5.

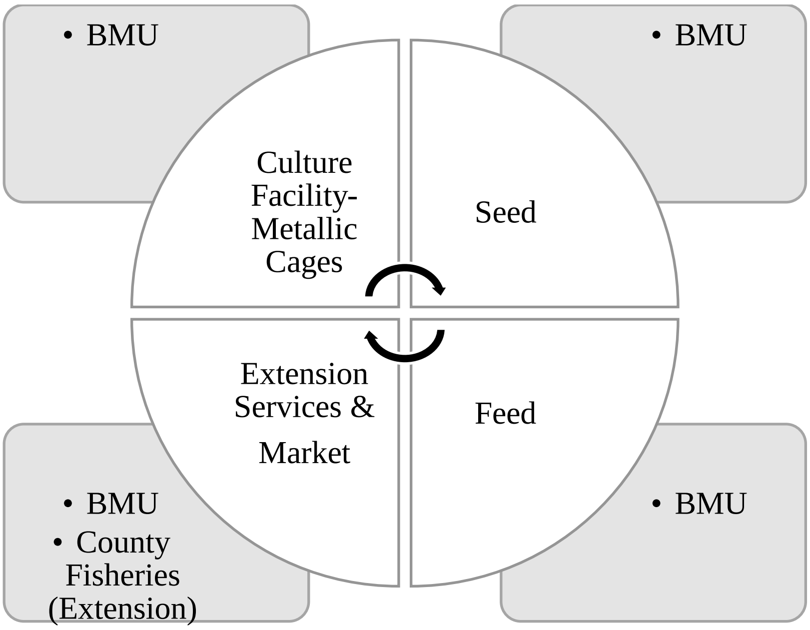

Figure 5: Model of inputs use and source, for open water based aquapark at Mulukoba in Bunyala Sub County of Busia County.

3.3 Water Quality and Nutrients in the land and water based aquaparks

Four (4) Aquapark establishments were assessed in Busia County during the survey. Three of these were land-based: Kamarinyang, Siunga and Bukani. Out of this, only one site had active ponds (Bukani). The summary and mean concentrations of physico-chemical parameters vis a vis the thresholds for selected attributes at the land based Bukani Aquapark is presented in Table 6. Temperatures range observed was between 27^0C and 32^0C on the land-based aquaparks. Dissolved Oxygen (DO) levels varied from near anoxia concentration of 2.29 mg L^{-1} at the inlet to 8.13 mg L^{-1} within the active ponds. The pH, conductivity and salinity were constant across the transects. Fish's tolerance to pH fluctuations decreases with increasing temperatures. Ammonium concentration was below 50 µgL^{-1} which is optimal for fish growth.

Table 6: Summary and mean concentrations of physico chemical parameters Vs thresholds for selected attributes at the inlet, inside ponds and outlets for the land based Bukani Aquapark, Busia County.

Selected water quality and Nutrients parameters	**Aquapark site**			**Limits/Range for optimal growth**	**Discussion**
	Inlet	*Active ponds*	*Outlet*		
Temperature (°C)	27	31.2	30.45	Optimal range is 22°C-29°C	Temperature range observed is optimal for the culture of fish
Dissolved Oxygen (DO) (mgL^{-1})	2.29	8.13	5.175	> 3 mgL^{-1}	DO levels within the ponds are optimal for growth, reproduction and health
pH	6.57	6.28	6.36	Optimal pH 7-9	pH levels within the ranges recommended for tilapia growth (6 to 9)
Salinity (ppm)	0.17	0.16	0.14	19 ppm	Salinity range acceptable
Ammonium (µg L^{-1})	21.77	25.1	35	Up to 7.1 mg/L. Optimum is <0.05	Ammonium concentrations recorded within active ponds (0.025 mgL^{-1}) below threshold considered lethal for *O. niloticus* culture

The lake based aquapark sites were generally located in shallow waters, within littoral zones with maximum depths ranging from 4.7 to 7.5 m at Mulukoba. Physico-chemical attributes were tabulated against recommended thresholds/range and limits for key attributes for optimal growth in tilapia (Table 7). The mean values recorded for Temperature, Dissolved oxygen, pH, Salinity and ammonium were all within the ranges required for the optimal performance of cultured species at the cages as represented in Table 7.

Table 7: Summary and mean concentrations of physico chemical parameters Vs thresholds for selected attributes at Mulukoba Aquapark, Busia County.

Selected water quality and Nutrient parameters	**Mulukoba Aquapark site**	**Limits/Range for optimal growth**	**Discussion**
Temperature (°C)	27.70 ±0.17	Optimal range is 22°C-29°C	Temperature range observed is optimal for the culture of *O. niloticus*
Dissolved Oxygen (DO) (mg/L)	5.23±0.70	>3 mgL^{-1}	DO levels optimal for proper growth, reproduction & health
PH	6.40±0.12	Optimal pH 7-9	pH levels within the range for the culture of *O. niloticus* (6 to 9)
Salinity (ppm)	0.06±0.05	19 ppt (El-Sayed 2006)	Salinity range acceptable
Ammonium (µg L^{-1})	17.34±6.48	Up to 7.1 mgL^{-1}. Optimum is <0.05	Ammonium concentration recorded within the sampled cages below threshold considered lethal for Tilapia

The zooplankton community in land-based aquaparks was dominated by copepods, mainly the Cyclopoid nauplii accounting for 50% of the population, followed by Cyclopoid with 22.47% and Cladocera at 10.1%. The rest of the zooplankton was Rotifera with a total contribution of 17.4%. This taxon had the highest species richness with 10 species recorded. In general, copepoda dominated the inlet section of the aquapark by contributing over 72% of the population. Cladocera contributed about 10% of the population. Copepoda and cladocera had very low species richness of 1 to 4 species and low species diversity. Table 8 summarizes the various key indicators showing the observed values, their impacts and mitigation measures for both the land based and lake based aquaparks. For the land based aquaparks yet to be stocked (Kamarinyang and Bukani), the water quality parameters, primary (phytoplankton) and secondary (zooplankton) productivity indicated conducive environments for culture of fish. However, the microbial indicators showed that there could be an influence from the surrounding catchment areas, as seen by the total and fecal coliform counts. An interesting observation made in the Bukani aquapark was that there was a drastic decline in Cyanophyte and diatom population as the water moved from the inlets into the ponds before exiting through the outlets. This could be an indication of the cleaning effect of the aquapark.

Table 8: Summary of the various key indicators showing the observed values, their impacts and mitigation measures for both the land based and lake based aquaparks. The table shows the primary productivity (phytoplankton), secondary productivity (zooplankton) and microbial contamination (total and fecal coliform) for the land based (Bukani, Kamarinyang, Siunga) and lake based aquapark (Mulukoba).

Aquapark site	**Indicator**	**Selected sub indicators**	**Comments**	**Significance**	**Discussion**
Bukani	Zooplankton	Copepods	Dominant zooplankton; lowest species diversity	Relatively good secondary productivity	Suitable for aquaculture production in ponds especially for the juvenile stages of growth
		Cladocerans	Adequate quantities at the ponds	Have high nutritional value as live fish for aquaculture	
		Rotifera	Low abundance but highest species diversity		
	Phytoplankton	Diatoms	Abundant	Indicative of good environmental conditions	Good levels for proper growth and development of the cultured fish
		Cyanobacteria	Present; not recommended	Clog gills; can affect fish growth	Enhance pond aeration and water movement to discourage their proliferation
		Chlorophytes	Increased at the ponds and outlets	Nutrient availability in the ponds	Good levels for proper growth and development
	Microbial contamination	Total coliforms	65 CFU/10ml.		
		Fecal coliforms	15 – 34cfu/10ml; above recommended ranges	Contamination with human wastes	Mitigate against the influence of human influence from adjacent human activity
Kamarinyang	Zooplankton	Copepods	Dominant zooplankton	Conducive secondary productivity	Good secondary productivity available at the inlets to support growth of the fish.
		Cladocerans			
		Rotifera	High species richness; low contribution		
	Phytoplankton	Diatoms			The high abundance of cyanophytes is indicative of dirty water at the inlet 1. Inlet 2 had relatively lower cyanophytes. Inlet 2 could should be considered for
		Cyanobacteria	Most abundant in the water inlet 1		
		Chlorophytes			

					inlet into the Kamarinyang aquapark. There should be better management of the ponds.
	Microbial contamination	Total coliforms	Above recommended ranges		
		Fecal coliforms			Mitigate against the influence of human influence from adjacent human activity
Siunga	Zooplankton	Copepods	Dominant zooplankton	Adequate secondary productivity	Good secondary productivity for fish culture
		Cladocerans			
		Rotifera	High species richness; low contribution		
	Phytoplankton	Diatoms	Low		Good primary productivity for fish culture. Presence and abundance of Euglenophytes indicative of good water quality
		Cyanobacteria	Relatively high		
		Chlorophytes	Low		
		Euglenophytes	Most abundant		
	Microbial contamination	Total coliforms	65 CFU/10ml		Levels within the recommended range
		Fecal coliforms	Above recommended ranges		Mitigate against the influence of human influence from adjacent human activity
Mulukoba	Zooplankton	Copepods	Relatively low secondary productivity in the cages as compared to the sites away from the cages	Adequate secondary productivity	There is a need to enhance secondary productivity in the cages to supplement the supplemental exogenous feeds
		Cladocerans			
		Rotifera			
	Phytoplankton	Diatoms	Most dominant; Low contribution for the enclosed sections but high contribution at the open waters		More wave action at the open waters could be the reason due to re suspension of the relatively dense diatoms making them more available to the fish.
		Cyanobacteria	Abundant at the sites	Affect fish growth; are harmful algal blooms	Need for better water flow to get rid of excess nutrients
		Chlorophytes			
	Microbial contamination	Total coliforms	The values observed are above the recommended values		Human influence from adjacent activities should be checked to ensure they don't influence the water used in the culture and consequently end up in the fish cultured.
		Fecal coliforms	Above recommended ranges		

With the growing cage aquaculture development in Lake Victoria, Kenya, its sustainability would require adoption of an ecosystem approach to aquaculture. Although this may be challenging, it entails a definition of ecosystem boundaries, estimation of the environmental carrying capacity and adaptive farming that ensures the ecosystem services are preserved/guaranteed. Environmental capacity in this regard entails; the rate at which nutrients can be added without triggering eutrophication, the rate of organic flux to the benthos without major disruption to natural benthic processes, or the rate of DO depletion that can be accommodated without causing mortality of the indigenous biota. Farms operating with minimal negative impact to the environment are bound to be more productive with reduced fish kills from environmental degradation.

3.4 Fish sampling in Land based Aquapark

Bukani land based aquapark in Samia Sub County, Busia County hosts 100 ponds. Water streams into the enterprise from an inlet close by and flows by gravity to the various ponds. The aquapark has ponds with various pond owners and at various stages of development; pre stocked, newly stocked, nursery ponds and grow out ponds. Out of the active ponds available during this survey, only two ponds could be sampled for fish. The optimal conditions for proper performance of tilapia have widely been documented (El Sayed, 2006) and consequent losses in yield have also been studied. This study sought to investigate the performance of fish in the aquaparks and point to the gaps therein.

3.4.1 Length-weight relationship (LWR) and condition factor

The Length-weight relationship (LWR) of a fish is a reliable parameter in portraying the growth pattern and growth performance of fish in different culture systems (Bolger and Connolly, 1989; Da Costa and Araujo, 2003). When the value of *'b'* i.e., the slope of the regression line is 3, the fish is growing isometrically i.e., there is a uniform increase in length and weight as it grows. When $b \neq 3$ It is indicative of allometric growth (Aura et al., 2011). There are two types: negative allometric growth and positive allometric growth. Negative allometric growth i.e., $b < 3$ the fish increases faster in length than weight while with positive allometric growth i.e., $b > 3$ the fish increases in weight faster than length as it grows (Riedel et al., 2007). The b values for pond 1 and pond 2 at Bukani land-based aquapark were 2.73 and 2.87 (Table 9) further analysis i.e., one-sample t-test revealed that they were not significantly different from the hypothesized value of 3 Pond 1 ($T = -2.92$, $p = 0.22$), Pond 2 ($T = 16.23$, $p = 0.24$) indicating isometric growth.

The mean relative condition factor Kn for specimens sampled in the two ponds was approximately 1.00 ±0.02 and 1.00 ±0.02 (Table 10) for ponds 1 and 2 respectively. The condition factor is a parameter that depicts the well-being of a fish and reflects the current feeding conditions of the fish (Le-Cren, 1951). Therefore, it can be used to determine whether the fish are utilizing their feeding source (Weatherlley, 1972; Lizama and Ambrósia, 2002; Gomiero et al., 2008). The relative condition factor of 1.00 for both ponds 1 and 2 indicated that the cultured fish were well fed and in healthy condition.

Table 2: Length-weight relationships *O. niloticus* from Pond 1 and 2 at Bukani land based aquapark in Samia Sub County, Busia County.

	Stations		TL (cm)		L-W parameters			
County		N	Min	Max	a	b	r^2	p-value
Busia	Bukani Pond 1	15	12.9	16.9	-1.18	2.73	0.83	<0.001
Busia	Bukani Pond 2	15	12.9	21.6	-1.58	2.87	0.95	<0.001

Where N = sample size; a = is a scaling constant for weight at length of fish.
b = is a shape parameter indicating body form of fish/allometry, b = 3 Isometric growth, b < 3 negative allometric growth, b >3 positive allometric growth.
r^2 = coefficient of determination, it ranges from 0-1 when r^2 <0.5 the correlation between length and weight is weak, r^2 >0.5 the correlation is strong.
P-value is a statistical measure of significance when p < 0.05 indicates that the correlation between length and weight is significant >0.05 is not significant.

Table 3: Mean relative condition factor (Kn) for *O. niloticus* samples from Pond 1 and 2 at Bukani land based aquapark in Samia Sub County, Busia County

	Stations			Condition Factor (Kn)	
County		N	Mean ±SE	Min	Max
Busia	Bukani Pond 1	15	1.00 ±0.02	0.83	1.14
Busia	Bukani Pond 2	15	1.00 ±0.02	0.85	1.18

Where N = sample size; Min = Minimum Kn; Max = Maximum Kn.
Condition factor (Kn) is a value indicating the wellbeing of a fish, when Kn <1 fish is unhealthy and not well fed, when Kn >1 fish is healthy and well fed

3.4.2 Length-Frequency distribution of *O. niloticus*

This computation was conducted to establish the size distribution of the fish. Pond 1 had many individuals within the 17cm size class, while few individuals fell in the 13cm size class. In pond 2 most individuals fell in the 15cm class (Figure 6). The fish species being cultured in Bukani aquapark was composed of 100% *O. niloticus* in both ponds. *O. niloticus* has been proposed as the best species of culture in the western region, considering the conducive environmental conditions in this region, which would ensure optimal performance of the species (Genschick et al., 2021). However, it is worth noting that improved strains of *O. niloticus* existing in various parts of Kenya (GMT® from the Fishgen Ltd. (UK, YY-technology), Til Aqua Silver NMTTM (YY-technology) and *O. niloticus*, a synthetic domesticated stock with fish derived from Lake Victoria, Lake Kyoga, and Lake Turkana) have been said to have better performance as compared to the ordinary *O. niloticus*. It is recommended that improved versions, under similar conditions can give better growth/performance compared to the current strain in use in this enterprise.

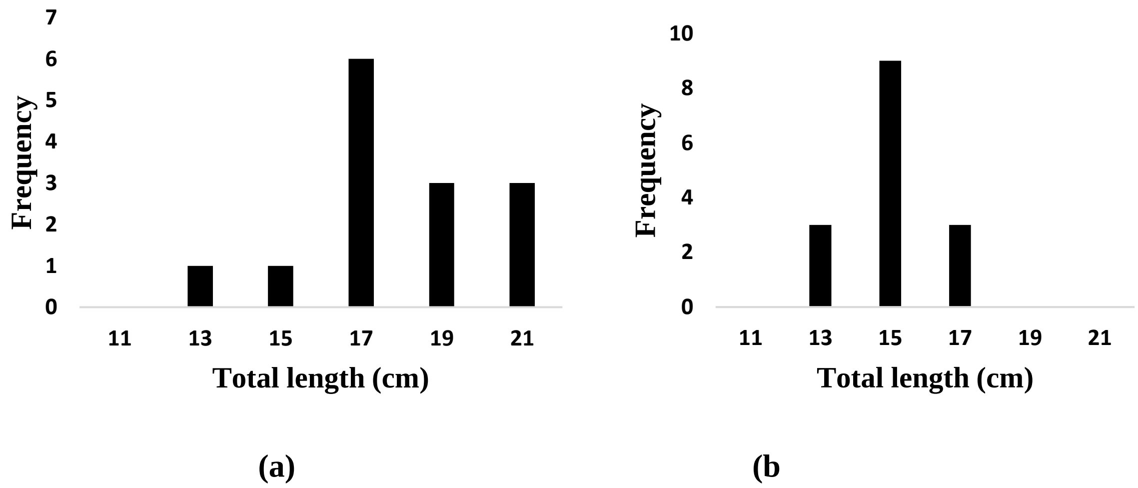

Figure 6: Length-Frequency distribution of *O. niloticus* in the sampled ponds at Bukani Aquapark; showing Pond 1 (a) had smaller fish compared to Pond 2 (b).

3.4.3 Growth performance - specific growth rate

The mean specific growth rate (SGR) for pond 1 and 2 in this survey was 1.20 ± 0.01. These ponds were stocked with mixed sex populations; however, higher values can be achieved for monosex populations e.g., 1.83 as reported by Githukia et al. (2015) and 2.78 by Omweno et al. (2020). The type of feed (Opiyo et al., 2014) and Physico-chemical parameters of water quality (Makori et al.,2017), usually affect the SGR of *O. niloticus*. Therefore, enhanced feeds and improved pond management practices will realize better performance.

3.4.4 Stomach contents analysis

Depending on the system of culture (intensive or extensive) the diet composition of farmed fish varies. The fish from the 2 ponds indicated that most of the diet was composed of fish feeds (Figure 7). Insects, microcystins/algae, plant remains, Caridina and rice bran were other diet compounds found in the stomach contents.

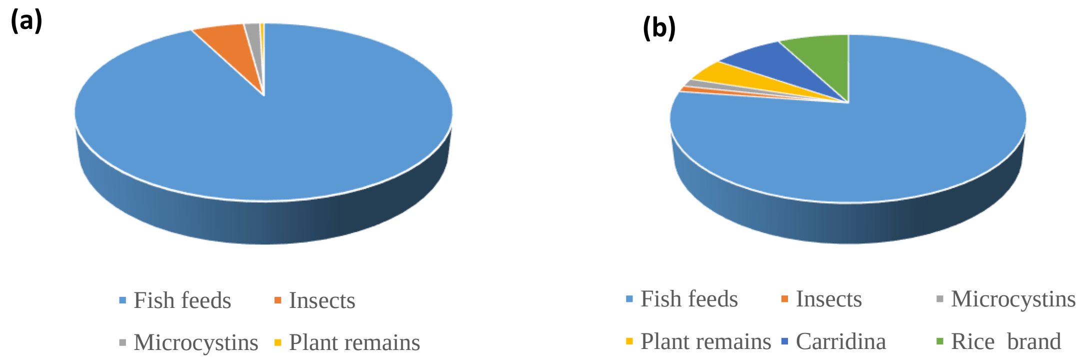

Figure 7: Stomach contents of sampled fish at Bukani Aquapark for Pond 1 (a) and Pond 2 (b). Pond 2 fed on a wider variety of food items

Fish feed and nutrition account for between 40 -50% of the variable production costs in a fish farm (Craig and Helfrich, 2002; Munguti and Charo-Karisa, 2011). Most farmers try to look for alternatives to commercial feeds to cut costs. This can be counterproductive to the farmer in that giving poor feeds makes the growth poor and consequently, the cycles become longer, and the farmer could end up making losses. In addition, different formulated feeds result in different growth performances according to Munguti et al. (2014) and Opiyo et al. (2018). This would imply that for farmers in this enterprise to optimize production, it is vital to invest in quality feeds. Feeding of fish using Caridina has also been seen in several cage fish farmers (Orina et al., 2018) who look at it as a cheap, available source of feed but at the end the growth is sub-optimal.

Sampled fish from the 2 pond sites showed a 100% maturity, with a population of mixed sexes. This represented 53% males (pond 1) and 47% females (pond 2) and 60% males and 40% females (pond 1). It is recommended to have all males/mono sex for a productive aquaculture venture to ensure that the food and energy are generated for growth and development. The present study showed a less than desirable growth which could be attributed to possible energy diversion into reproduction. Famers are advised to source farm inputs from certified sources. For tilapia culture, it is recommended that farmers keep all-male tilapia/practice monoculture. This is because having mixed sexes would result in the expenditure of energy on reproduction, resulting in slow/ stunted growth (Githukia et al., 2015). The present study found that the fish farmers sourced their fry from Wakhungu hatchery.

3.5 Fish sampling in Lake based Aquapark

Mulukoba Aquapark in Busia is a model of an aggregation of ponds at one point. This model is supposed to ensure better management in terms of pooling some resources (for instance security) together and ensuring that some inputs (for instance feeds) are not easily wasted away since they can flow to the next cage, if not utilized in the subject cages receiving the inputs. The study was only able to access the cages owned by the private investors, and not those owned by the county due to logistical challenges on site.

3.5.1 Length-weight relationship and condition factor

The b value for the Mulukoba aggregated cages was 2.89, which was not significantly different from the hypothesized value of 3 (T = -1.22, p = 0.11 (Figure 8). This is therefore indicative of isometric growth (Riedel et al., 2007). The mean relative condition factor Kn was approximately 1.03 ± 0.02, an indication that the fish were in a good physiological condition. However, with consistent standard cage management including quality feeds will improve the condition since the food reserves accrued through feeding are able to increase the fish's condition (Anani et al., 2010).

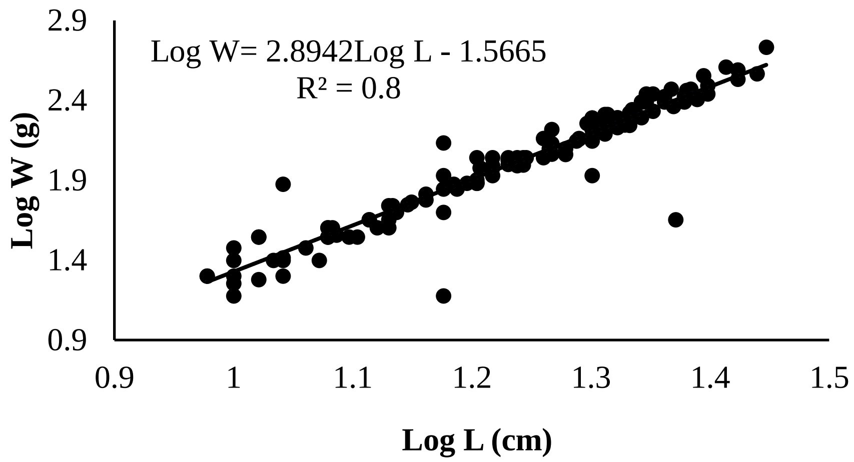

Figure 8: Length-weight relationship of *O,niloticus* from aggregated cages at Mulukoba lake-based aquapark in Busia county.

3.5.2 Specific Growth Rate

The Specific Growth Rate (SGR) for fish in these cages was 0.86 indicating that the fish grew at a rate of 0.89 daily. This value for Tilapia is relatively low, which shows that the growth of the fish in a day was below optimal. Various factors can be attributed to the sub-optimal performance including quantity and quality of feed. Additionally, less than optimal ecological conditions have been cited as contributing factors to low SGR (Al Hassan et al., 2018). Therefore, good management practices are recommended to enhance performance.

3.5.3 Length-Frequency distribution

Fish from Mulukoba aggregated cages were composed of various size classes as depicted in Figure 9. The majority of the individuals were aggregated in the mid-section (16.55 and 20.22 cm) in length and fewer at the extremes (lowest 8.5 cm and highest 28.55 cm).

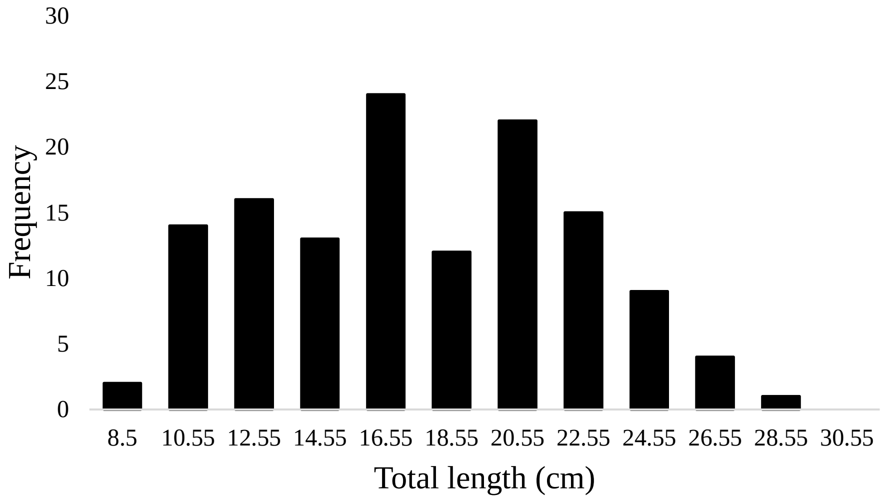

Figure 9: Length frequency distribution of fish at Mulukoba Aquapark

3.5.4 Stomach contents

The Diet of fish at Mulukoba was composed of 2 main items; Fish feeds and Insect remains with the fish feeds having the biggest proportion (Figure 10). This reveal investors were informed on the issue of fish feeds, ensuring that they only availed fish feeds for their stocks, and not substitutes like Caridina, as seen in other cage farms (Orina et al., 2018).

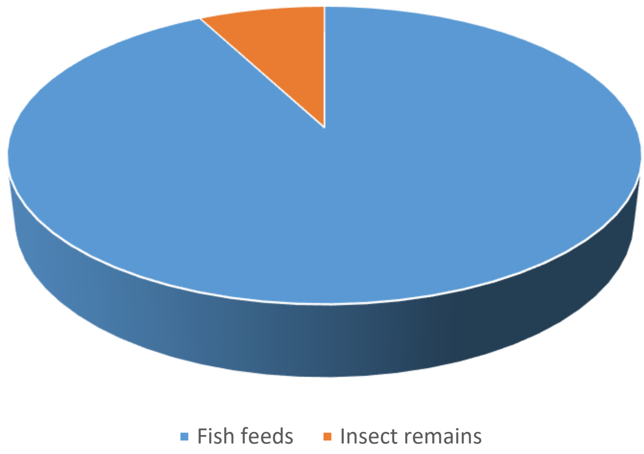

Figure 10: Stomach composition of fish at Mulukoba Aquapark

4.0 Conclusion and Recommendations

4.1 Conclusions

The concept of aquapark is still an emerging venture in the country, with projections indicating the potential to increase production per unit area while ensuring efficiency in utilization of inputs and space. From the study, the results generally show that there is potential of culture of tilapia, catfish and other indigenous species to contribute to increasing aquaculture production in the County. Success in the land base aquapark could be attributed to enhanced management of the aquapark by project management committee (PMC), coordinated synchronized stocking of ponds with quality inputs, establishment of the flood control dyke at the aquapark, fencing of the aquapark to control predation and unnecessary movements within the aquapark and installation of electricity, security and lighting systems.

From the study, the water quality and nutrient parameters were within the recommended ranges for culture of *O. niloticus*. However, the mean count of fecal coliforms in the water samples was statistically significantly high and exceeded the limits recommended for aquaculture. Fish performance was relatively good, judging from the condition factor though better performance can be achieved through strict adherence to good pond management practices. The survival rate of mixed sex *O. niloticus* in this investigation was relatively low (< 55%). This led to the initial annual turnover for the first two production cycles in the land based aquapark to be relatively low owing to low yield (output) and the selling price (180 Kes/Kg). Generally, the model has a lot of potential in realizing increased production of fish in the county and the country as a whole.

4.2 Recommendation

To commercialize the aquapark aquaculture enterprise for increased incomes, improved food security and nutritional status of the wider communities of poor rural smallholder fish farmers and for replication opportunities in other counties, we recommend the following to be adopted:

1. **Government Ministries Departments and Agencies (MDAs)**

- ✓ County and National Governments to develop a strategic paradigm shift in the small holder aquaculture development policy supporting components of the aquapark concept and approaches to enable aggregated production of fish under a fragmented land tenure. Such policies can touch on access to credit facilities and access to aquaculture inputs (including subsidies).

- ✓ The County Government to continue investing in other aquaculture enabling infrastructure i.e., fish hatcheries, fish feed plants, market structures and fish processing facilities. The hatcheries to enhance production of monosex Nile tilapia and can result in substantial yields since it is highly adaptable to different agro-ecological zones.
- ✓ State Department for Fisheries Aquaculture and the Blue Economy (SDFABE) in collaboration with KMFRI and KeFS to cushion farmers from undue competition from imported fish, by developing policies touching on the importation of fish into the county (and may be regulating fish importation into the country in general).
- ✓ National government through the State Department for Fisheries, Aquaculture and the Blue Economy to promote fair trade and marketing of fish from aquaculture and protect the fish farmers from fish imports as per the existing standards and guidelines on fish for market access
- ✓ The County Government to put flood control mitigation measures since flooding was cited as a problem in the land based aquapark for instance control the inflow or reinforcement of the dykes to prevent losses arising from loss of stocks due to floods.
- ✓ The County Government to increase fisheries development prospects, capacity-building efforts aimed at promoting group cohesion, skills, and an appropriate community participation and involvement framework
- ✓ The county government to ensure all the ponds and cages are stocked to realize the benefits of having aggregated units at one place.
- ✓ The county government to promote sustainable quality seed production and timely stocking
- ✓ State Departments for Fisheries Aquaculture and Blue Economy in collaboration with KMFRI and KeFS to develop biosecurity measures and regular monitoring of water quality variables to promote best management aquaculture practices within the aquapark.
- ✓ State Departments for Fisheries Aquaculture and Blue Economy in collaboration with KMFRI and KeFS to support training and capacity building of Fisheries and Aquaculture technical officers on operating commercial enterprises and running of successful aquaculture businesses together with best pond management practices and marketing.

- ✓ The National government to promote best aquaculture production models through development of resilient policies that promotes sustainable aquaculture
- ✓ County governments to promote cooperatives movement among fish farmers

2. Aquaculture stakeholders and industry

- ✓ The aquaculture industry stakeholders to promote social inclusion among the beneficiaries within the aquaculture value chain i.e., involvement of youth, women and vulnerable marginalized groups.

3. Development partners

- ✓ Development partners to provide financial support mechanisms to have the idea replicated in other areas since the model has potential to increase income and reduce pressure on the lakes' natural resources
- ✓ Development of affordable and responsive financial products that cushions fish farmers from risk and uncertainties

4. Research and Higher Learning Educational Institutions

- ✓ Research and higher learning training institutions to develop training of trainers (ToT) modeules and manuals to train and build capacity of fisheries technical officers on operating commercial enterprises and running of successful businesses coupled with best pond management practices and marketing

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APPENIDX 1: PICTURES OF AQUAPARK

Plate 1: Production ponds at the land based Bukani Aquapark, Busia.

Plate 2: Crop farming adjacent to the production ponds at the land based Bukani Aquapark, Busia.

Plate 3: Socioeconomics data collection by staff from KMFRI and KeFS at Bukani Aquapark, Busia.

Plate 4: Water quality sampling at Bukani aquapark (a), Kamarinyang inlet (b) and Siunga inlet (c).

Plate 5: Aerial view of Siunga aquapark earthen ponds.

Plate 6: Aerial view of Kamarinyang' aquapark under construction.