

Current status of freshwater fish hatcheries, broodstock management and fingerling production in the Kenya aquaculture sector

B M Nyonje, M A Opiyo¹, P S Orina², J Abwao³, M Wainaina and H Charo-Karisa⁴

Kenya Marine & Fisheries Research Institute, Mombasa Centre, P O Box 81651-80100, Mombasa, Kenya

marybede@gmail.com

¹ **Kenya Marine & Fisheries Research Institute, National Aquaculture Research Development & Training Center, P O Box 451 -10230, Sagana, Kenya**

² **Kenya Marine & Fisheries Research Institute, Kegati Aquaculture Research Center, P.O. Box 3259-40200, Kisii, Kenya**

³ **Kenya Marine & Fisheries Research Institute, Sangoro Aquaculture Research Station, P. O. Box 136-40111, Pap-Onditi, Kenya**

⁴ **State Department for Fisheries and Blue Economy, Ministry of Agriculture, Livestock and Fisheries, P.O. Box 58187-00200, Nairobi, Kenya**

Abstract

Recent rapid developments within the aquaculture sector in Kenya have necessitated increased production of quality broodstock and fish seed in the hatcheries. This study assessed the status of fish hatcheries, broodstock management and fish seed production in Kenya. Through structured questionnaires and personal interviews, data were collected from fish hatcheries across the country and analyzed using descriptive and inferential statistics.

The survey indicated that Kenyan hatcheries are mostly owned by private fish farmers (82%) and only a few (18%) are owned by the government institutions. The hatcheries are located in the regions of the country with high aquaculture activities and the number increased from 21 in 2009 to 147 in 2012 and 127 in 2015. The main fingerlings produced in Kenyan hatcheries are Nile tilapia (*Oreochromis niloticus*) and African catfish (*Clarias gariepinus*) fingerlings. The hatcheries have a production output of 23 million of *O. niloticus* fingerlings and 2 million of *C. gariepinus* annually. The quantity of fingerlings produced in each hatchery correlated positively with the number of facilities within the hatchery ($r = 0.80$, $P < 0.05$). Broodstock management strategies put in place by farmers include using broodfish for a maximum of 3 years and obtaining quality broodstock from government authenticated sources. The government is currently championing the development of fish seed standards, to improve the quality of fish seed. Major constraints experienced by the hatchery owners include high mortalities during larval rearing phase, inadequate supply of hatchery inputs and equipment, high costs of larval fish feeds and inadequate technical advice on emerging technologies.

Introduction

Capture fisheries production has leveled off and is no longer considered capable of sustaining the supply of fisheries products needed to meet growing global demand of fish (BÃ©nÃ© and Heck 2005). Since capture fisheries has become static since 1980's, aquaculture has been responsible for the growth in fish supply for human consumption (FAO 2014). Global fish production from aquaculture currently stands at 76.6 million tonnes representing 45% of the total fish production (FAO 2017). Aquaculture plays a leading role in the fight against food insecurity, malnutrition and poverty globally (BÃ©nÃ© and Heck 2005; Ogello and Munguti 2016; Golden et al 2017). However, the growth of aquaculture has been hindered by numerous challenges including; inadequate supply of quality fish seed and feeds (Little 2004), non-availability of working business and marketing models and inadequate local technical capacity in fish production (Hishamunda et al 2014).

Aquaculture production in Kenya has grown over time since 1950s with the main cultured species being Nile tilapia (*Oreochromis niloticus*) (75%) and African catfish (*Clarias gariepinus*) (15%) (Ngugi and Manyala 2004). The production escalated from 4,000MT in 2007 to 24,096 MT in 2014 due to government support through the Economic Stimulus Program- Fish Farming Enterprise Productivity Program (ESP-FFEPP) initiated in 2009 with an aim to commercialize fish farming (SDF 2016). However, production reduced to 18,656 MT in 2015 and further to 14, 952 MT in 2016 (KNBS 2017). The drop in production was attributed to poor soil water retention capacities, poor extension services, expensive quality feed, inadequate supply of quality fish seed and changes in governance that meant reduced focus on aquaculture by several county governments (SDF 2016). The decrease in production notwithstanding, aquaculture is one of Kenya's vision 2030 flagship projects, thus the sector is expected to grow with private investors putting more capital in fish farming and hatchery business (Nyonje et al 2011).

Quality seed production and broodstock management is an important aspect that should be considered for effective utilization and management of fish genetic resources (Bostock et al 2010; Lind et al 2012). Although Kenya has a number of fish hatcheries, some fish farmers still obtain fish seed from recruits in their ponds after harvest (Opiyo and Charo-Karisa 2012). In most scenarios, the fish seed collected from recruits are stunted and inadequate to cater for the farmer's needs (FAO 2007). Collection of fingerlings from the wild is also unreliable due to seasonality, variability in sizes and quality, possibility of entry of diseases, and difficulty in determining the age of the fingerlings (Hecht 2006; Charo-Karisa et al 2011). Reliance on government hatcheries for provision of fingerlings most of the time is unsustainable due to poor infrastructure, use of poor quality broodstock and impure strains, inadequate funding and unnecessary bureaucracy leading to difficulty in effective quality control (Charo-Karisa et al 2012). The poor structures in seed production have led to farmers stocking fry and fingerlings whose quality cannot be ascertained.

The recent rapid growth of aquaculture in Kenya has called for high demand of quality fish seed for the commonly cultured species; African catfish and Nile tilapia to meet the rising demand for production of table size fish as well as broodstock for development of seed for new species (Charo-Karisa et al 2012). The ESP-FFEPP of 2009 created an annual demand of over 50 million fish fingerlings (Charo-Karisa et al 2010). This high demand led to investment in seed production by the private fish hatcheries resulting to an increase in the number of hatcheries producing Nile tilapia and African catfish seed from 21 in the year 2009 to 147 in the year 2012 (Charo-Karisa et al 2012), and to 127 in 2015 (Opiyo et al 2015). Increase in the number of hatcheries calls for proper broodstock management and quality control to ensure production of quality seed since fish farmers view fast

growth rate and good survival rates as most important traits of a good quality fish seed (Oyieng et al 2013). The problems of quality seed in aquaculture has been reported to be as a result of lack of genetic management and poor hatchery procedures which has resulted to degradation of the performance of many farmed species through inbreeding, genetic drift and uncontrolled hybridization (Bostock et al 2010). There exist a gap in knowledge of the fish hatcheries operations in Kenya and scanty information exist on broodstock management and fingerling production for freshwater fish in Kenya. This study examines the status of fresh water fish hatcheries, fingerling production and the issues that need to be addressed in production of quality fish seed. This knowledge is required in strengthening breeding programs and establishment of fish breeding and seed production structure that will ensure quality seed production in Kenya.

Materials and methods

Field survey

A field survey was conducted to determine the status of hatcheries, broodstock and seed production in Kenya between the year 2012 and 2016. All operational hatcheries registered by the State Department for Fisheries and the Blue Economy in different parts of the country were visited and their managers interviewed. A semi structured questionnaire with both closed and open ended questions was used as the survey instrument. The questionnaire used was developed and piloted at the National Aquaculture Research Development and Training Centre (NARDTC), Sagana hatchery. Fish sampling was also carried out in each hatchery to ascertain the quality of the broodfish and fingerlings. In each hatchery, broodfish were sampled using a seine net and 30 fish from a population of 100 fish were randomly picked per pond/tank in each farm for weight measurements using an electronic balance (readability 0.01g) (model KERN 572-33, Germany). The breeding facilities, equipment present in the hatcheries were recorded and were assessed for compliance with the minimum requirements set by the State Department for Fisheries and the Blue Economy (Opiyo et al 2017). The actual quantities of fingerlings produced and the annual production capacity of each hatchery were recorded.

Data analysis

The data collected included the GPS location of the hatchery, year of establishment of the hatchery, education level of the hatchery managers, sources of broodstock, husbandry practices, hatchery inputs, sales and fingerling production output data and seed production techniques. Total seed production from the hatcheries was based on the number of seed output from each hatchery. Results were analyzed using descriptive and inferential statistics. Pearson correlation coefficient was used to analyze the relationship between quantity of seed produced and the facilities available in the hatchery. Coded data was statistically analyzed using SPSS Version 20 software.

Results

Fish hatchery establishment

Most of the hatcheries in Kenya were established between 2009 and 2011. There was a recorded national rapid growth in the number of hatcheries from 21 in 2009 to 147 by 2012 (Figure 1). The foundation broodstock for these farms originated mainly from Lakes Victoria and Kyoga as wild stock. These broodfish were domesticated, multiplied and cross-bred with the domesticated stocks obtained from the government fish farms. The largest government hatchery is the National Aquaculture Research Development and Training Centre (NARDTC) Sagana, with a production output of 16 million fingerlings annually while the largest private hatchery is Dominion Fish Farm with a production

output of 8 million fingerlings annually. There exist some other middle scale hatcheries in the country with a capacity of fingerling production ranging between 200,000 to 1 million annually. In 2016 many hatcheries stopped operating and the number of hatcheries dropped from 152 to 125 (Figure 2).

Figure 1. Year of establishment of new freshwater fish hatcheries in Kenya from 1948 to 2016

Figure 2. Changes in number of operational freshwater fish hatcheries from 2009 to 2016

Majority (82%) of the fish hatcheries in Kenya were owned by private farmers; the government owning the smallest share (18%) of the hatcheries in the country. Private hatcheries were either owned by groups of like-minded persons (59%) or individually (23%). Their distribution were mainly in the areas where fish farming is well established especially in the Western and Central regions. None of the hatcheries were located in the Arid and Semi-arid areas in the Northern region of Kenya (Figure 3), while the Coastal region had the lowest number of hatcheries.

Figure 3. Map of Kenya showing the distribution of fresh water fish hatcheries in 2016
(adapted from <http://amip.nardtc.org/> 2016)

Hatchery equipment and facilities

All the hatcheries surveyed met the necessary minimum requirements for operations as per the guidelines by the State Department for Fisheries and the Blue Economy, with an exception of graders and water quality meters (Table 1). These hatcheries differed in the number of ponds and tanks in place with most hatcheries having between 1-5 ponds and tanks typically designated for breeding, nursery and holding facilities (Table 2). The large-scale commercial hatcheries including NARDTC Sagana, Makindi farm and Dominion fish farms were the only farms with more than 25 ponds and tanks. There was a positive and significant correlation between the number of facilities owned and number of fingerlings sold per year with hatcheries that had more facilities reporting higher production levels ($r = 0.80$, $p < 0.05$). This indicated low intensification of fingerling production in the hatcheries.

Table 1. Equipment and facilities recorded to be present in freshwater fish hatcheries.

Hatchery facilities	Present in hatcheries	
	Frequency	Percent
Oxygen cylinder	82	64
Seine nets	92	72

Scoop nets and perforators	83	65
Packaging bags	93	73
Screens for inlets/outlets	98	77
Hapa nets	35	27
Weighing balance	19	15
Incubation facilities	9	7
Water holding facilities	7	6
Graders	4	3
Water quality meters	1	1

Table 2. Number of ponds and holding tanks recorded in freshwater fish hatcheries

No. of ponds and tanks	Breeding ponds		Nursery ponds		Holding Tanks	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
0	0	0	8	8	14	16
1 – 5	70	59	76	78	59	67
6 – 9	19	16	8	8	10	11

10 – 14	10	9	1	1	1	1
15 – 20	8	7	1	1	1	1
> 20	10	9	3	2	2	2

Status of broodstock strains and management in freshwater hatcheries

Broodstock in the freshwater hatcheries were Nile tilapia (*O. niloticus*) and African catfish (*C. gariepinus*) originally from Lake Victoria. These fishes were locally domesticated in the fish farms in several parts of the country. So as to support production of good quality seed, Jambo fish farm imported a superior breed of *C. gariepinus* from the Netherlands in 2011 while African catfish from Indonesia were also introduced to the biggest government farm NARDTC Sagana in 2011 on a government to government collaboration. A total of 388,085 *O. niloticus* broodstock and 42,502 *C. gariepinus* were recorded from all hatcheries surveyed. The ratio of male to female tilapia broodstock in 90% of the hatcheries was 1:1 due to the inadequate number of female tilapia broodfish. Broodstock in the surveyed hatcheries were sourced from either the wild or other fish farms. The sources of broodstock apart from L. Victoria included the major hatcheries; NARDTC Sagana, Mwea Aquafish farm and LBDA Kibos fish farm while the other lake sources were Lake Baringo and Lake Kyoga. African catfish broodfish were also obtained from Masinga dam and River Ewaso Nyiro. Most hatcheries stocked their broodfish in the year 2009, 2010 and 2011 when there was a high demand for fingerlings because of the government's Economic Stimulus Program (ESP –FFEPP).

Broodstock development and improvement was started by Kenya Marine and Fisheries Research Institute (KMFRI) in 2007 initially at Sangoro (for African catfish) and Kegati (Nile tilapia) which were later moved to Sagana in 2009. Substantial effort in broodstock improvement at KMFRI was initiated in 2010, whereby broodstock were developed through selective breeding of fish stocks from different sources. The F2 and F7 generations of the broodstock were multiplied and distributed to other hatcheries in 2011 and 2016 respectively to ensure adequate fingerling production and to shorten the distances for transporting fish seed from the hatcheries to the grow-out farms. A private farm, Dominion fish farms in Western Kenya also begun a cohort mating breeding program in 2007 which was to serve Western Kenya regions.

The rearing practice common in the hatcheries for *O. niloticus* broodfish was stocking ponds at a density of 2-3 fish m⁻². The health of the broodfish was assured by adequate feeding with quality feed prepared by the hatcheries for a sufficient time prior to spawning. The practice in most hatcheries was the separation of the male and the female fish for two to four weeks to increase chances of mating when paired. The males and females were placed in separate ponds or hapas depending on the preference of the farmer; some farmers kept the fish together due to space constraints or inadequate facilities. The tilapia broodstock were either paired together in ponds or in breeding hapas where the farmers harvest fingerlings every spawning cycle and hold the fingerlings in nursery ponds. In all hatcheries, the sizes of tilapia broodstock ranged between 180g to 400g while the sizes of African catfish broodstock ranged between 0.6kg to 2kg. The female *O. niloticus* broodfish were smaller in size (<203g) than the male broodfish (>300g).

Fingerling production technologies

The largest fingerling producer was NARDTC, Sagana in Kirinyaga County (Table 3). The hatcheries produced mixed sex tilapia, all-male *O. niloticus* fingerlings and catfish fingerlings. Fewer hatcheries (23%) produced African catfish fingerlings compared with *O. niloticus* fingerlings (77%). Mixed sex tilapia fingerlings were produced by 90.4% of the hatcheries while 9.6% of the hatcheries produced monosex tilapia fingerlings. The hatcheries that produced *C. gariepinus* fingerling used artificial propagation and reared fry in nursery ponds and tanks. Shell free/decapsulated artemia was used by all the hatcheries for the first feeding of fry before weaning to dry starter diets of 40-50% Crude Protein. The hatcheries graded the catfish fry once a week for the first month of rearing and fortnightly after weaning with dry feed. The survival of the African catfish fry and fingerlings ranged between 40-60% in all the hatcheries.

Table 3. Highest annual fingerling output for 10 leading freshwater hatcheries in Kenya, 2012-2016

Hatchery Name	County	Annual fingerling production output
NARDTC Sagana	Kirinyaga	16,873,000
Dominion Fish Farm	Siaya	8,536,600
Mwea Aquafish Farm	Kirinyaga	6,267,000
Jewlett Enterprises	Homa Bay	4,567,707
Thongoni Aquaculture Farm	Machakos	3,551,600
Kisii Multiplication Centre	Kisii	850,876
Murang'a Intergrated Farm	Kiambu	770,850
Lutonyi Fish Farm	Kakamega	507,600
Safe Farm	Kakamega	481,554

The monosex production technology had not been implemented by majority of the farms due to financial constraints to purchase the sex reversal hormone (17 β -methyl testosterone) and lack of adequate infrastructure. To produce tilapia fry for sex reversal, broodfish were held separately in hapas or ponds for 3 weeks prior to pairing in hapas or ponds to get the required size of fry for sex reversal. Fry were then collected and reared in hapas or concrete tanks during which they were fed with 17 β -methyl testosterone treated feed for 28 days. The fingerlings produced were sold in the local market. A total of 45,682,073 tilapia fingerlings and 3,484,303 *C. gariepinus* fingerlings were sold to fish farmers from the hatcheries in 2010 and 2011 respectively. Most of the hatcheries (98.4%) sold their fingerlings at KES 7 (US\$ 0.07) per piece. The rest of the hatcheries sold their fingerlings for between KES 3 to 5 (USD 0.03 to 0.05) per piece of fingerling. The total revenue generated from the sale of Nile tilapia fingerlings by all the hatcheries in 2014 was KES 117,971,000 (USD 1,165,040) while from African catfish the revenue generated was KES 13,993,000 (USD 138,190).

Discussion

The growth of aquaculture in Kenya led to a steady increase in the hatchery establishment from 2009 to 2014. In 2009, only 21 hatcheries producing either *C. gariepinus* or *O. niloticus* fingerlings existed (Charo-Karisa et al 2009). The demand for fish seed led to investment in seed production by private fish farmers. In line with the world's trend of private investors having the biggest share in aquaculture e.g. carps and trout, the ownership of hatcheries in Kenya followed a similar trend with other parts of the world where majority of the hatcheries were privately owned. The hatchery ownership pattern in Kenya is similar to the hatchery ownership pattern reported by Faruk et al (2012) in leading aquaculture producing countries such as Bangladesh where 88.7% of hatcheries were private. The participation of private sector in seed production is an indication of positive development towards sustainable seed production in Kenya (Orina et al 2014). Additionally, the present study established that the governments owned hatcheries were operated by government institutions including State Department for Fisheries and the Blue Economy (SDF&BE), Kenya Marine and Fisheries Research Institute (KMFRRI) and Lake Basin Development Authority (LBDA). The involvement of these three institutions in seed production follow their individual mandates including sustainable management and development of Kenyan fishery resources, undertaking aquaculture research on fish of both freshwater and marine origin and implementing sustainable development projects at the largest Lake basin in Kenya (Lake Victoria basin) for SDF&BE, KMFRRI and LBDA respectively. Most of the government farms culture *C. gariepinus* and *O. niloticus* as both species are considered the most suitable freshwater species for aquaculture in tropical and subtropical areas (El-Sayed 2002; Adewolu et al 2008). A similar scenario was reported in Uganda with government owning up to 95% of fish hatcheries until 2007 when private farmers started producing more fingerlings than the government owned farms (Mwanja 2007). Ponds are the most commonly used facilities for production of fingerlings in Kenya. Machena and Moehl (2001) reported that the use of ponds in seed production is a widely practiced culture system in Sub-Saharan Africa.

Fresh water fish hatcheries in Kenya are required by the government to have facilities such as a adequate ponds, water reservoirs, resting tanks, breeding tanks, weighing balance, incubators for hatching eggs, scoop nets, oxygen supply and fish packaging materials (Charo-Karisa et al 2012). The water reservoirs can either be plastic tanks, cemented tanks or consist of lined ponds from which the water is either pumped into breeding ponds or supplied from a tower to the breeding pond and the incubation units. The current status of hatchery facilities in Kenya can be compared to hatcheries in countries with higher aquaculture production like Vietnam (Phan et al 2010). This result

underscores further, the existing ability of the hatcheries in the country to engage in intensive seed production.

The government recommends that hatcheries in Kenya keep broodfish for 3 years before bringing in a new stock. This is to ensure high fingerling production since females older than 3 years spawn less frequently (Bhugel, 2000). The broodfish of both *O. niloticus* and *C. gariepinus* were obtained from other hatcheries or collected from the wild and the fish that adjusted to the hatchery environment and perform well became the brooders for the next generation and each new generation become even more adapted to the environment (Osure and Phelps 2006). The broodfish of *O. niloticus* were stocked in broodstock ponds at the rate of 2-3 fish m⁻². Most of the farms had the male to female ratio of their fish at 1:1. Nevertheless, the sex ratio of 1:1 of the fish in the hatcheries indicated low fingerling production per female fish during breeding and is contrary to the recommended ratios of at least a male to female ratio of 1:2 (Bhugel 2000). The findings of the study further indicate that the mating ratios of *O. niloticus* were falling short of the widely acceptable male to female sex ratio of 1:3 (FAO 1980). The recommended ratio is as a result of the low fecundity and variability in the reproduction capacity of the mouth-brooding *O. niloticus* which requires proper optimization of factors that affect seed production. According to Siddiqui and Al-Harbi (1997) and Ridha and Cruz (1999) studies in sex ratio management can improve spawning synchrony in *O. niloticus* broodstock hence boosting production.

The health of the broodfish is assured by adequate feeding with quality feed prepared by the hatcheries for a sufficient time prior to spawning. The practice in most hatcheries was the separation of the male and the female fish. The males and females were placed in separate ponds depending on the preference of the farmer; some farmers kept the fish together due to space constraints or inadequate facilities. The female *O. niloticus* broodfish were smaller in size (<203g) than the male broodfish (>300g). This could be attributed to the fact that *O. niloticus* females mature earlier at smaller sizes and produces smaller eggs but relatively more eggs than a larger fish per unit body weight (Bhugel 2000). In order to produce all-male tilapia, fry were fed immediately after yolk sac absorption on a hormone (17 α -methyl testosterone) treated feed for 4 weeks at a dose of 60 mg kg⁻¹ feed (Phelps and Popma 2000). All male tilapia were generally preferred since they grow faster than females and this reduces the problems of prolific breeding of tilapia in ponds (Ngugi et al 2007). The catfish broodstock ranged between 600g-2kg which indicated better fecundity for catfish producing hatcheries. However, the survival of catfish fingerlings was lower and ranged between 40-60%. The lower survival could be attributed to cannibalism which was experienced in most of the hatcheries as a result of low grading frequency of the fry and fingerlings. The hatcheries graded the fry and fingerlings once in week or fortnightly leading to cannibalism amongst the fry and fingerlings. Baras and Jobling (2002) indicated that routine grading has been used effectively to reduce intracohort cannibalism rates in larviculture of Dorada (*Brycon moorei*) and Catfishes (*C. funkus* and *C. gariepinus*). Inadequate grading could have result to heterogeneity in sizes of the *C. gariepinus* fry and fingerling leading to cannibalism hence low survival.

Measures to maintain quality seed production

To maintain quality of fish seed, the government established a system of authentication in which no hatchery would operate without the government ascertaining the quality of broodstock, the seed produced and availability of necessary facilities and skills. The steps followed by the system are not very far from the approach that has been followed by other major aquaculture producing countries like China. Similarities are observed on how, the government responded to seed quality problems by encouraging investment in hatcheries by the private sector; instituting seed quality control policy measures to improve seed quality management; including the establishment of fish seed certification

methods and standards; and encouraging and supporting the production and distribution of quality seed (Helfand and Levine 2004). These management strategies were aimed at maintaining the quality of broodfish and seed because poor management had led to deterioration in quality of broodstock and seed overtime. Therefore, a training program for hatchery managers was initiated at the NARDTC, Sagana in 2009 where all hatchery managers were trained on the necessary skills in hatchery operations. A seed certification and accreditation system was developed so that farmers purchasing seed from government endorsed hatcheries could trust the product. The authentication of hatchery is undertaken by the State Department for Fisheries and the Blue Economy in collaboration with KMFRI. One of the requirements for a hatchery in Kenya is that the manager should have attended a course in aquaculture and preferably should have attended a relevant diploma or a degree course. The study noted that 23% of the hatchery managers had degrees and 11% had diploma certificates of education, an indicator that hatchery management were likely to become more professionalized and are able to adopt technologies, leading to higher production of quality seed.

Hatchery authentication

Hatchery authentication is an exercise which is frequently carried out to ascertain the quality of seed produced by both the private and public hatcheries. This was instituted by the Aquaculture Economic Stimulus Programme in 2009 as a way to ensure quality of fingerlings reached the farmers. It includes the evaluation of the production capacity, production levels and the practices used in the fish farm for seed production. The qualified hatcheries are enlisted to ensure only quality fingerlings are sold to fish farmers in Kenya. Fish farmers are then advised to buy fingerlings from the government accredited hatcheries only.

Hatchery authentication criteria

The hatchery authentication criteria in Kenya involves sampling and verifying the quality of the broodstock, fingerling produced, infrastructure and equipment required for fingerling production in the hatcheries. From the year 2009, hatchery authentication has been carried out in all the fish farms intending to venture into seed production. During the exercise, data collection from the farms is done by administering a questionnaire, interviewing famers and filling in the information in the already designed questionnaire. Physical observation of the management of the culture facility, verification and evidence of the existence of the expected structures for the fish seed producers are checked. Relevant details of the farm including the name of the farmer, ownership of the farm, and the number of culture facilities in every farm are recorded and various categories such as breeding, grow out and nursery facilities present are also established. Sampling of broodstock as well as fingerlings is done by taking a representative sample from the culture facility. The fingerlings are examined for any infection or deformity. A minimum of thirty fish are taken from the breeding facilities to determine their sex, length and weight. Quality and purity of the broodstock are also established and the broodfish examined for deformities, diseases and fungal infections. Farmers are also interviewed to get the information concerning the farm.

Development of the seed standard

Seed standards were developed to guide both the farmers and hatcheries on seed quality. Seed production and availability increased as a result of adoption of improved seed production practices by the private sector. The standards were developed by KMFRI in collaboration with the Kenya Bureau of Standards (KEBS) and State Department for Fisheries and the Blue Economy. The standards developed are to be ratified by Kenya Bureau of Standards (KEBS) in order to be utilized by hatchery operators and farmers. Other measures to ensure quality is the development of guidelines to be used

by the hatchery operators. Two guidelines have been developed including good aquaculture practices for seed production in Kenya and the guidelines for fish business operators. Sensitizing farmers on their content will help the hatchery operators to produce the high quality fish seeds required by the farmers.

Fish seed development

The seed development in Kenya is being done at the National Aquaculture Research Development and training Centre (NARDTC) through selective breeding and strain improvement. The selective breeding targeted Nile tilapia (*O. niloticus*) and African Catfish (*C. gariepinus*). Proper selective breeding program for Nile tilapia was initiated in Sagana in 2011 and was aimed at improving the quantity and quality of fish seed and market size Nile tilapia fish targeting fast growth and high survival traits. The ongoing Nile tilapia breeding program at KMFRI Sagana is currently on the F7 generation. The selective breeding program found considerable effect of genotype by environment for harvest weight, growth rate and shape between monosex and mixed sex monosex and mixed tilapia (Omasaki et al 2016). An active selection for particular traits, commonly growth and survival, is associated with domestication and genotype-environmental interactions where one strain may perform best in one environment (Osure and Phelps 2006). The program need to be up-scaled and supported to supply the broodstock to multiplication centers across the country.

The survey indicated that different strains of *C. gariepinus* exist in Kenya both from within and from imported strains, these include; Indonesian, Dutch and several local strains including the Lake Victoria and River Ewaso Nyiro strain (Opiyo et al 2017). It has been established that the development and effective use of genetically improved strains is one of the most powerful technologies to achieve the fast growing strain of catfish for aquaculture development (Ponzoni and Nguyen 2008; Opiyo et al 2017). A study conducted at NARDTC indicates that Indonesian strain performed better than the Dutch and the Kenyan strain in growth performance and survival (Opiyo et al 2017). Nevertheless, genetic characterization of the different strains is required to identify the genetic difference that exists in the three strains and measures need to be taken to ensure the long-term viability of the strain.

Challenges in broodstock management and seed production

1. Lack of structural framework for the operationalization of the breeding nuclei by the government after devolution system of governance.
2. Inconsistent monitoring and evaluation of the existing hatcheries to ensure quality seed production.
3. Inadequate research funds to ascertain the quality of different strains of fish under aquaculture.
4. Lack of adequate training of hatchery operators to ensure adoption of new technologies and knowledge enhancement.
5. Low supply of hatchery inputs and equipment especially quality larval feeds and unavailability

of hatchery equipment locally.

6. Inadequate rearing facilities for selection and rearing of broodstock to reduce inbreeding problems.
7. Inadequate record keeping by the small-scale farmer-operated hatcheries.

Future prospects and recommendation in broodstock management

1. Harmonization of technical standards and guidelines for the hatchery production. It is important that such technical standards be developed, standardized, validated and harmonized with the international standards.
2. Continuous monitoring and evaluation of accredited hatcheries at different production scales to ensure production of high quality seed.
3. Strengthening of research partnerships with hatchery and nursery operators to improve quality broodstock and produce quality fingerlings.
4. Preparation of a directory of hatchery operators practicing best management practices for ease in availability of services to other farmers/hatcheries and for development programs.
5. Use of pure quality stocks which can be obtained from certified hatcheries and breeding centres.

Conclusion and recommendation

- From the results of this study, it's recommended that a system of dissemination of the improved and quality broodstock should be established through broodstock multiplication centers connected to the breeding nucleus as a necessity for the production of quality broodstock required by the hatcheries.
- Having the biggest percentage of ownership (>80%) of hatcheries in private hands require elaborate monitoring plan to regularly monitor the performance of these hatcheries and evaluation of the seed produced. The demand for male tilapia fingerlings by most grow out farmers is exerting pressure on hatcheries to produce the superior breeds.
- Ability of male tilapia fingerlings to attain the table size at the shortest time possible is viewed by many farmers as a way to optimize production and reduce cost of production.
- The accreditation of the hatcheries needs to be embedded in the fisheries regulations of

Kenya so that the fish seed quality assurance is easily implemented.

- For successful breeding programs, training of quantitative geneticists is required for continuation of the fish breeding programs.
- Measures need to be put in place by the national government to ensure quality requirements for fish seed are adhered to in order to meet the demand of the farmers.

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