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Current fish hatchery practises in Uganda: The potential for future investment

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Abstract
Demand for quality and ample fish seed is increasing, yet the country has a number of fish hatchery operators. This study set out to survey hatchery operational levels, seed production technologies and challenges. The purpose was to aid the government and investors to make better policies and informed choices respectively for aquaculture development. Most hatchery operators had some basic education but none had specialised skills in hatchery management. There were only three commercial private hatcheries, the rest were small scale. The technologies being used by most hatchery operators though appropriate were inefficient. Findings indicate that the major challenges included poor breeding and management practices, high levels of inbreeding, poor marketing of seed, employment of non-skilled personnel, high cost of broodstock management and larval rearing, poor water quality, and low larval survival rates. Interventions for improvement in fish seed production and investment opportunities in the country are discussed.

Keywords: Fish hatchery practices, challenges, remedies, investment opportunities, Uganda

1. Introduction

Fish farming in Uganda began in 1941 with the cultivation of newly imported carp from Israel [1]. In 1959-1960 a FAO- supported comparative evaluation of carp and tilapia endorsed the use of carp, which resulted in further expansion of aquaculture in Uganda. Aquaculture was further promoted under the drive for rural development, and by late 1960s the Department of Fisheries recorded up to 11,000 ponds mostly producing fish for subsistence [2]. Culturing fish in earthen ponds remains the most common production system of fish farming in Uganda [3]. Currently the government is encouraging fish farmers to move away from subsistence level fish farming to commercialized aquaculture by increasing the number and size of ponds [4]. Other more intensive culture methods are also being introduced, including cage and tank culture systems [5, 6]. Currently the most common species of fish cultured in Uganda are the North African catfish (*Clarias gariepinus*), Nile tilapia (*Oreochromis niloticus*) and carp (*Cyprinus carpio*) [1], with the North African catfish as the most popular, accounting for 60 percent of Ugandan farmed fish [7]. Aquaculture production though reported to be on the increase in Uganda, from annual production of 15,000 tonnes in 2005 to 95000 tonnes in 2010 [8] there is still an equally increasing deficit of seed for all farmed fish in the country [9]. Currently seed production from hatcheries is estimated at a national average per hatchery of 15,192 and 9,832 of fingerlings of catfish and tilapia respectively [10]. However, this is not sufficient to meet the rising fish seed demand in the country. The fish seed deficit is attributed to low levels of production technologies used in hatcheries and increased local and regional demand for the seed [1]. There is also use of un-standardized production techniques and practices where by farms and government research institutions work independent from each other without harmonization of practices. Current seed deficit is majorly exacerbated by the high mortality rates in the African catfish hatcheries in the country [1]. The biology of the latter fish makes it prone to high mortality due to complicated gut development process, starter feed preference and high sensitivity to environmental fluctuations [11]. With diversification of production systems and increased application of mainly African catfish fingerling as seed and wild predator fish harvest, where the fish is used as bait [12], the demand for fish seed is expected to increase rapidly. Nile tilapia has become a major component for cage and tank culture systems in addition to the traditional earthen pond system. Cages and tanks take about hundred times more seed than earthen ponds [13], a situation which will further escalate the seed demand unless attempts are made to enhance productivity. The types and locations of hatcheries, demographics of hatchery operators, level of training, broodstock management practices, spawning methods and general hatchery management practices used Uganda are not properly established and documented.

This study carried out a baseline survey and documentation of the hatchery technologies/practices in the country in order to generate information to assist the government and investors to plan and develop policy and make informed choices respectively for bolstering the fish hatchery industry in the country. The survey identified gaps in technologies of fish seed production in the country, which were used as basis for designing appropriate remedies and improving on the existing technologies for fish seed production. The information is important to current and intending fish farmers and potential investors in determining sources of fish seed and investment opportunities. The study was carried out in the operating hatcheries throughout the country using structured questionnaires, direct observations and face to face interviews with hatchery operators. Identified weaknesses are pointed out and possible remedies discussed.

2. Materials and Methods

To achieve the objectives, a number of operational hatcheries (Figure 1) were surveyed and information was obtained from a survey of respondents owning/managing hatcheries throughout the country. Both interviews and observational techniques were used to obtain the required primary data. Field interviews were conducted using structured and semi-structured questionnaires in the year 2012. Locations of the hatcheries were geo-referenced using Global positioning System. The infrastructure, levels and methods of seed production, species of fish handled, sources of broodstock, broodstock management practices, gender and education of operators/owners, seed marketing systems of each surveyed hatchery unit were documented.

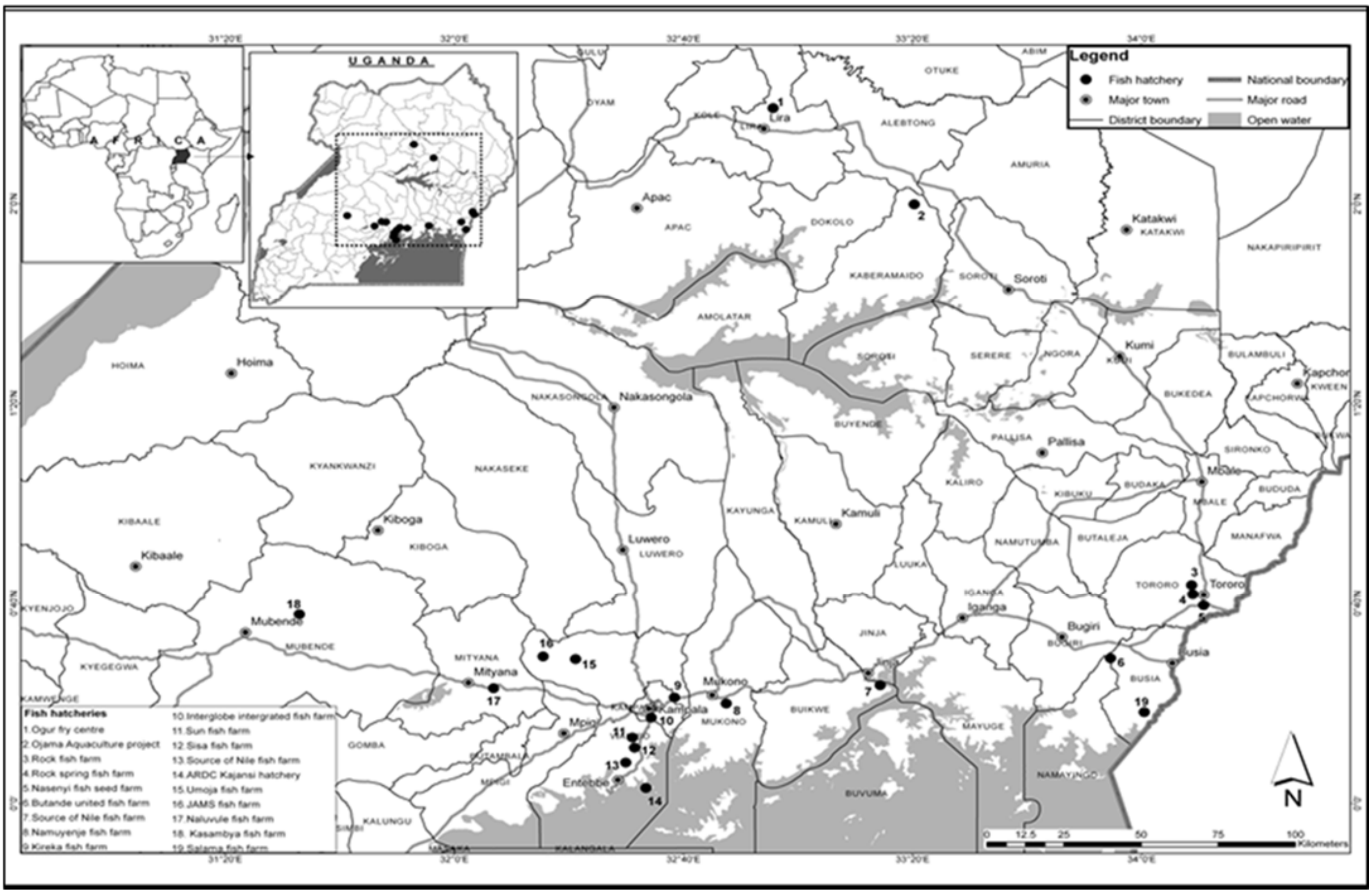

Fig 1: Map showing locations of the hatcheries in Uganda

2.1 Data analysis

Collected data were categorized and coded. Descriptive statistics were used in the analysis and the results are presented in form of tables, graphs and charts. For determining key factors that influenced fish seed production the effect of brood stock number on the quantity of African catfish seeds produced in Uganda were analyzed using the linear model. Adjustments were made for the possible clustering effects of brood stock density, brood stock age and source of brood stocks. ARDC-Kajjansi the government owned aquaculture research station was fitted in the model as reference explanatory variable for the source of brood stock. All which exhibited either singularity or co-linearity were dropped from the model. P-values of less than 0.05 were taken to indicate a significant difference. The appropriateness of the linear model was verified by looking at the distribution of errors. All statistical analyses were conducted using STATA 10 for windows [14] and SPSS version 16.

3. Results

3.1 General characteristics of hatcheries

3.1.1 Hatchery operators' demographics

Most hatchery operators are males (86.96%) (Figure 2) that could be mostly attributed to local culture practices where some jobs have been designated to particular sex.

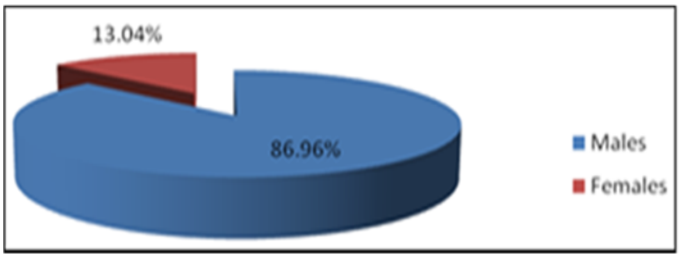

Fig 2: Showing percentage by sex of hatchery operators in Uganda.

3.1.2 Level of education of hatchery operators

Most hatchery operators (82.60%) have attained tertiary education though not aquaculture specialised qualifications (Table 1). Therefore most hatchery operators are educated and could easily understand and take up or adopt transferred technologies, though none had been trained specialised skills for either aquaculture or specifically hatchery operations and management.

Table1: Level of education of hatchery operators

Level	Frequency	%
No education	0	0
Primary	1	4.35
Secondary	2	8.70
Tertiary	19	82.60
University graduate	1	4.35
Specialised education	0	0
Total	**23**	**100**

3.1.3 Location and distribution of hatcheries

There were 35 operational hatcheries at the time of survey, with over 50% concentrated in East and Central Uganda, 11 are located in central Uganda and 8 hatcheries in Eastern Uganda (Figure 1). There are three commercial hatcheries (large-scale) in the country, two of these were located in central region, while one was found in the East producing between 500,000 and one million catfish seed annually depending on the demand.

3.1.4 Fish hatchery design and operations

African catfish hatchery was mainly practiced in rectangular concrete tanks of average total depth 0.5 meters. About 20% of the tanks were reinforced by ceramic tiles, 30% emulsion paint while 50% operate on rough concrete surface. Tilapia hatchery system was either operated on dam lined earthen ponds, cage basin ponds or in ordinary earthen pond system.

3.2 Brood stock management practices

3.2.1 Sources of brood stock

About 40% of the hatchery operators collected the brood fish from other producers, 30% procured broodstock from ARDC - Kajjansi, while 30% percent obtained the brood fish from the wild.

3.2.2 Broodstock conditioning

All hatchery operators condition their broodstock in earthen ponds under natural aeration and artificial restraints – netting of pond surface, fencing or use of hapas. The broodstock conditioning ponds are mostly small ponds 100 – 200 M^2. The conditioning period varies from farmer to farmer but on average it was done for under two weeks with few (10%) going upto a maximum of three months. for both catfish and tilapia.

3.2.3 Broodstock feeding

In most hatcheries broodstock are fed on on-farm formulated diets whose nutrient contents are not known because the feed has not been analyzed. A few hatcheries that use commercial feeds the protein content of the diets is between 30 to 35%. The daily ration of the broodstock is either determined by percentage body weight or by response. However, very few hatchery operators 3% use scientifically generated feeding chart. The feeding rates are mostly between 3 – 5% by body weight.

3.2.4 Broodstock environment management

This process includes water quality monitoring and management, sanitation measures and predator control. Most hatchery operators do not carry out water quality monitoring, but sanitation and predator control measures were emphasized by all hatchery operators. Predator control was mostly done by clearing bushes from the hatchery units and fencing of the larval nursing ponds using iron sheets.

Table 2: Proportion of methods used to induce different fish species to spawn

Species	Methods of inducing spawning		
	Environmental simulation	Hormonal	All methods
Tilapia	0(0)	0(0)	0(0)
African catfish	0(0)	34(97.14)	1(2.86)
Mirror carp	2(15.38)	2(15.38)	9(69.23)

Note: The first number outside the brackets represents the frequency while the one in bracket is the percentage.

The results show that none of the hatchery operators use any method to induce tilapia to breed (Table 2). On the other hand, African catfish is mainly induced to spawn using hormones. There is no hatchery using environmental manipulation alone to induce spawning in African catfish. However, only one hatchery was found to induce African catfish to breed using environmental manipulation and hormones (Table 2).

Interestingly, mirror carp is seemingly induced to spawn using environmental manipulation and hormones either independently or in combination. The proportion of farms/hatcheries inducing mirror carp to spawn using environmental simulation does not differ from those using hormones to induce spawning. However, a considerable number of hatcheries utilize the two methods together to effect spawning in mirror carp (Table 2).

Table 3: Types/nature of hormones used to induce fish to spawn

Hormone used	Frequency	Percentage
Synthetic	0	0.00
Natural pituitary	35	97.22
Both synthetic and pituitary	1	2.78
Total	36	100.00

The biggest proportion of hatchery operators sampled (97.22%) directly use pituitary extracts to induce fish to spawn. The use of synthetic hormones is non-existent, while the use of both synthetic and pituitary extract in combination was found in only one farm of the 36 sampled (Table 3).

3.3 Description of various methods of seed production

3.3.1 Catfish seed production methods

Two approaches were observed during the survey of the hatcheries. They include artificial and semi-natural methods. All the hatcheries surveyed were producing catfish seedlings. About 87% of the hatcheries use induced spawning and striping method of producing the catfish seed, referred to as artificial method. 13% of the hatcheries produced catfish by semi-natural (artificial) process that entailed inducing the females and placing them in ponds with males to produce naturally. Prior to spawning, most hatcheries pick the spawners according to female belly size, age and the physical size of males preferred at least 0.5 kgs.

3.3.1.1 Artificial methods of catfish seed production

The majority of the seed producers use this method. Generally this method was reported to be initially capital intensive in terms of materials, equipment and structures. However once the hatchery operator had stabilized the cost of production reduced. The procedure for inducing was labor intensive and required expertise. All hatcheries had more than two ponds for holding and conditioning the brood stock. There were no proper procedure of a adopting the brood fish for conditioning such as broodstock screening, a process that requires identification of the diseases, characteristics, the vigor and documentation of the features of the brood stock source (Melba, 2007). All the hatchery operators after picking the fish either from the neighbors or from the wild, females and males are separated and conditioned separately for not more than two weeks. 90% of the hatchery operator's use on farm made feeds to condition their brood fish while 10% of the rest use the Ugachick 30% protein fish feed. However there was no evidence of operators being aware of the ingredients in their feeds and the feed mixing ratios.

3.3.1.2 Induced spawning and incubation

All the hatchery operators induced the fish after about two weeks of conditioning. Only one hatchery reported use of GnRH hormone with a dopamine antagonist purchased from Israel, while the rest used the natural pituitary gland obtained from the sacrificed males. Operators used 1 to 2mm of pituitary extracts per Kg of broodstock to inject and induce the females to ovulate. The induced females were placed in dark colored concrete tanks and covered overnight until morning when the fish was presumed ready for striping. The gonads of the sacrificed males were kept in refrigerators and were crashed to obtain the milt. The females were striped and the eggs mixed with the milt in a bowl before they are put in an incubation tank. About 50% of the hatchery operators using this method of seed production maintained the incubation condition at between 25 ºC and 28 ºC. However, an equal number of the hatchery operators did not use any heating systems and relied only on greenhouse structure for temperature control and water quality control. Only 12% hatcheries treated the eggs with potassium permanganate after striping, majority (88%) did not treat the eggs at all. In most hatcheries hatching began 16-20 hours post fertilization.

3.3.1.3 Nursing, weaning larvae and raising the fry

After hatching the larvae fed on yolk until its exhaustion after 3 to 4 days. Weaning was done immediately on natural feeds, commercial - artemia and artificial dry feeds. However, several farms used them in combination, either artemia and dry feeds (11%), live pond organisms or dry feeds (8%), or artemia and live pond organisms (11%). About 25% and 31% hatchery operators use dry powdered feed and artemia alone respectively. About 11% used live organisms from the ponds (manure fertilized). The fry was gradually switched to feed on dry processed feeds after 3-4 days of weaning. About two weeks after hatching, 90% of the operators' transferred the fry into nursing ponds. About 10% kept the fry indoor. There was a noted variation in fry nursing structures used to keep the fry indoors. One hatchery operator used wooden tanks lined with polythene material to nurse the fry (Figure 3a) another one used indoor nursing ponds lined with polythene (Figure 3b) and the rest used indoor tanks lined with tiles. However, hatchery operators who used indoor wooden tanks and ponds reported high risks of diseases out breaks. Most operators graded and sold their fish a month after hatching.

Fig 3a: Indoor Wooden tank for nursing the larvae

Fig 3b: Outdoor variation of the wooden tank

3.3.1.4 Semi-Artificial (natural) method of catfish seed production
This method required inducing the fish with synthetic hormones or pituitary extract. The procedure is virtually similar to the method described above. About 12% of the hatchery operators used semi-artificial method to produce catfish seed. The brood females to be induced were conditioned separately from males. The operators reported that this approach strengthened the desire for males to court with the females and fertilize the ovulated eggs. After two weeks the females were induced by GnRH from pituitary extract obtained from males. The females and males that were not sacrificed were brought together in prepared ponds where fertilization occurs naturally. The ponds are fertilized with manure prior to stoking them with spawning brood fish. Ponds were provided with the vegetative substrates, which stimulate the spawning process and provide support to the sticky eggs. The parent fish was left in the pond overnight and were removed from the pond to prevent them from eating the eggs. The hatchery operators begin harvesting and grading the fry one month after the spawning.

3.3.2 Nile Tilapia seed production methods
Production of Nile tilapia seed involved the use of earthen ponds, happas, hatching trays and concrete tanks systems. Production varied differently within and between culture systems.

3.3.2.1 Sources of brood-stock
Over 70% hatcheries surveyed got their Nile tilapia brood-stocks from other fish farmers (farmer to farmer sources), 23% collected their broodstock from ARDC – Kajjansi, whereas a few (7%) collected broodstock from the wild. Most (90%) hatcheries neither screened nor quarantined the new broodstocks. They also did not have criteria for selecting broods instead mainly base on prices and proximity of the sources. Hatcheries chose broodfish of size that averaged 250 to 500g because of high efficiency in seed production. In commercial one large-scale hatchery, the operator claimed having a breeding program that selected for fast growth and color. When selecting for color a total 300 males and 300 females was selected to avoid problems of losses between the time of selection of brood stock and mating. However, this number was increased if there was greater emphasis on colour. For fast growth characters the hatchery compared groups of Nile tilapia collected from different Lakes including Victoria, Kyoga and Albert. In small scale hatcheries, farmers did not have a criterion for selecting broods but mainly target mass seed production. Mature Parent/brood stocks (> 250g) were procured and stocked directly in manure fertilized ponds for seed production.

3.3.2.2 Holding broodstock
For large scale hatcheries, broodfish were held in either ponds or concrete tanks (out-doors) prior mating, and stocked at rate of one-two male fish per four female fish m2. The broodfish were held for a period ranging two weeks to a month depending on the availability of broodstocks, facilities and the demand for seed. Small scale hatcheries held the broodstocks in one production pond without separating the sex of fish, without a definite period. Farmers hold the broods in one pond that also serves as a seed production. Most farmers did not use a specific stocking rate and the fish was held in ponds for more than six months.

3.3.2.3 Breeding pond preparation and stocking
To create a favorable breeding environment for the breeding most fish farmers used the following protocol: Standpipes (1.5 m) were installed to facilitate drainage and screening of the inlet and outlet pipes to avoid contamination of seed. Hatchery operators desilted the ponds, removed all remaining eggs/fry/ fingerlings in the pond using quick lime or builders lime (CaO) at rate of 10 kg/ 100 m2. Broodstocks were transported in buckets (10-30 kg) or oxygenated plastic tanks (1000-L) tanks that were connected to diffusers, and transported using a vehicle or by hand depending on the distance to the breeding pond. Transporting containers were used when ¾ full of fresh water with 3-5mg/l of salt added to reduce stressful conditions. Prior stocking ponds farmers starved the broodstock for one day before handling them in an attempt to avoid stressing the broodstocks. They then harvested the broodfish using seine nets and collate them in an enclosure. They placed broodstocks - males and females in a seed production pond in the ratio 1:2 while providing aeration to fish being transferred.

3.3.2.4 Seed collection/harvesting
Tilapia seed was harvested after 14 days of stocking, but prior to harvesting fish seed was starved for 24 hours to empty their stomachs. The pond was then drained, but also ensuring that there was a continuous inflow of water into the breeding pond. The screen on the outlet prevented the fry from escaping in the process. Fry collected in the catch basin was scooped out into buckets using a harvesting net, and transferred to either holding concrete tanks or happas. In large scale hatcheries a truck loaded with oxygen cylinders and diffusers transported fry from breeding ponds to holding facilities. If the objective was to produce all male tilapia then fry was subjected to hormone treatment, and if planned to be sold as mixed sex seed then the fry was raised in tanks or happas to a desired market size. To ensure the fry of the same size, plastic graders were utilized during the transfer of fry to happas or tanks from breeding ponds. Fish seed was fed on Ugachick, Ranaan or CFI-35-40% crude proteins or formulate feeds basing on the availability of raw materials [mainly mukene (fish meal), soy bean and maize meal]. In small scale production, tilapia seed was only harvested when there was market for it. Systematic production of tilapia seed was not followed, and productivity was low. Farmers produced fry or seed of mixed sizes because they did not grade it. Fry produced under such conditions was of mixed sex. Farmers feed fish with locally available feeds left overs from their homes.

3.3.2.5 All male tilapia production
Tilapia fry is subjected to a hormone treated feed that produces about 95% sex reversed fry (all males). Hatchery operators (e.g SON) use the hormone in stock solution made up of 1667 ml absolute alcohol (95%) and 10 grams 17 alpha methyltestosterone (MT) hormone. The stock solution is kept under lock and key at room temperature. The hormone impregnated feed is made by mixing 15 ml of stock solution with 1.5 kg of fry meal and stored in a well-ventilated room. Fry (< 1g) stocked in happas or tanks are fed to satiation for 21 days using a feeding ring. The fry would have reached at least 1-1.5 g which is either sold directly to other fish farmers or transferred to nursing ponds to be raised to 5-10 g (these are destined for cage farming). After the 21st day the sex reversed fry is transferred to nursery holding ponds where they were fed with a different meal without hormone. Harvesting from the tanks or happas was done in the morning (from six o'clock to ten o'clock). Prior harvesting the fry were starved on day 22. The

number of fry was estimated by volume: Finding the average number of fry per scoop and then multiply that number with the number of scoops obtained. Fry is then transported in buckets with 3-5mg/l of salt. In small scale hatcheries buckets (3/4 full of fresh water) are utilized for fry and with 5mg/l salt added and 3/4 full for brood stock with 5mg/l of salt added to reduce stress.

3.3.3 Feeding and feed management of broodstock and fingerlings

Feed cost the farmers over 60% of total expenditure hence, to ensure that there was always adequate and quality feed to meet the feeding requirements, farmers targeted feeds with low F.C.Rs and high growth rates. After stocking the ponds, juveniles were not fed for a period of 2 days (stressed fish have a low response to feeds or do not feed at all, avoid wastage of food). During the first and second week a mixture of fry meal and crumbles mixed at a ratio 1:2 respectively was used for feeding. After 2 weeks juveniles were then fed using crumbles with smaller grains. The quantity of feed applied to each pond was determined through a growth table and fish response for the large-scale hatcheries. If the response was very high then the feed amount was to be increased. Stress due to poor water quality and disease, mainly due to low temperature, pH, low dissolved oxygen and high turbidity etc, resulted into reduced response to feeds. Brood Stock feeding involved using fish feed in dry pellets form, which was broad cast over the whole pond using the feeding scoop to avoid concentrating feeds at one point since this causing crowding of the fish at one place leading to stress as the fish competed with each other for food.

Artemia and unsorted fresh water zooplankton are proportionately the most common weaner feed used for catfish external feeding. 15% of the farmers used artemia replacers in the brand of CS0 (55% C.P), imported by Balton Uganda. Other weaner feeds commonly used are the commercial fish meal powder and grain brans. The same commercial processed feeds are either alternately or saddening applied in the secondary nursing process. The African catfish hatcheries mainly operate in indoor system, while Nile tilapia hatcheries were mainly out door in earthen ponds.

3.3.4 Post hatching Larval and fry management practices

Larval and fry management practices in most hatcheries was characterized by application of simple procedures. The most common facility disinfectant used was sodium hypochlorous (JIK) while the small-scale hatcheries zygotes were not treated with any chemical therapeutant. Routine dirt scrubbing and siphoning using hard brush and plastic pipes and in very few incidences total drainage. Ammonia, water temperature and pH were the only water quality parameters that were occasionally monitored practices that may have greatly influenced larval/fingerling survival. Fingerling survival was compared amongst regions while adjusting for species using a linear model displayed in Table 4. Central region was used as a baseline for region, yet mirror carp was used as a base line for the species. While adjusting for fish species, fingerling survival was highest in central region, followed by Eastern, Northern and lowest in Western region (Table 5). Compared with the central region, fingerling survival was 6.86 ± 3.57% less in the Eastern, 8.99 ± 4.39% less in the Northern region and 10.29 ± 3.70% less in the Western region. The fingerling survival in both Northern and western Uganda significantly differed (P <0.05) from that in Central Uganda. However, survival in Eastern and Central Uganda did not differ.

Table 4: Comparison of fingerling survival by region and species

Survival in	Coefficient	Se	P -value	[95% CI]
Reference region (Central)				
Eastern	-6.86	3.57	0.060	-14.02 to 0.29
Northern	-8.99	4.39	0.045	-17.78 to -0.19
Western	-10.29	3.70	0.007	-17.71 to -2.87
Reference spp.(Mirror carp)				
African catfish	3.78	4.41	0.390	-5.05 to 12.62
Tilapia	10.86	4.62	0.020	1.60 to 20.12

Table 5: Actual fingerling survival by region and species

	Tilapia survival	African catfish survival
Region	Mean survival (± SD) %	Mean survival (± SD)%
Central	22.83 ± 24.20[b]	13.91 ± 8.98[b]
Eastern	15.00 ± 15.18[b]	6.89 ± 6.09[a]
Northern	12.97 ± 9.46[b]	4.88 ± 4.70[a]
Western	7.25 ± 1.71[a]	4.97 ± 3.27[a]
***P*-value**	<0.05	< 0.05

Note: Means bearing the same superscripts within the same column are significantly different at P < 0.05

3.3.5 Seed marketing systems

All the hatcheries surveyed produce seed for sale and stocking own-farm. The African catfish seed was mainly sold between two to three months, at which age individuals measure between 8 to 10cm. Nile tilapia seed were mainly sold based on age and body weight, mostly between 2 to 10 grams, for either pond or cage stocking. The seed prices average 200/= and 100/= for African catfish and Nile tilapia respectively. Irrespective of the region, tilapia fingerlings are sold out to farmers at a relatively small size. On average, tilapia fingerlings were sold at 4.73 ± 2.70 cm yet African catfish fingerlings were sold at 7.10 ± 3.23 cm. The size of tilapia fingerlings sold ranged from 4.25 ± 2.09cm in Eastern to 5.25 ± 3.40cm in western Uganda. However, the sizes sold across the country did not considerably differ (P >0.05). The size of African catfish fingerlings sold ranged from 5.63 ± 3.17 cm in Eastern to 9.00 ± 3.24cm in Central region (Table 6). Overall however, the size of African catfish fingerlings sold across regions does not significantly differ (P >0.05).

Table 6: Comparison of fingerling sizes (mean ± SD) cm sold by region and species

	Tilapia		African catfish	
Region	Mean length (± SD) cm	**Freq. (n)**	Mean length (± SD) cm	**Freq. (n)**
Central	4.71 ± 2.21	7	9.00 ± 3.24	8
Eastern	4.25 ± 2.09	6	5.63 ± 3.17	8
Northern	5.00 ± 1.29	3	6.00 ± 5.57	3
Western	5.25 ± 3.40	4	7.10 ± 2.01	10
Overall mean	4.73 ± 2.70	20	7.10 ± 3.23	29
***P*-value**	>0.05		>0.05	

The findings revealed that most hatcheries in Uganda were dealing with African catfish fingerling production than in tilapia (Figure 4). Mirror carp is seemingly propagated by very few farmers; only one was recorded in central region, one in Eastern and two in Western region. In this survey, there was no record of mirror carp production in Northern Uganda.

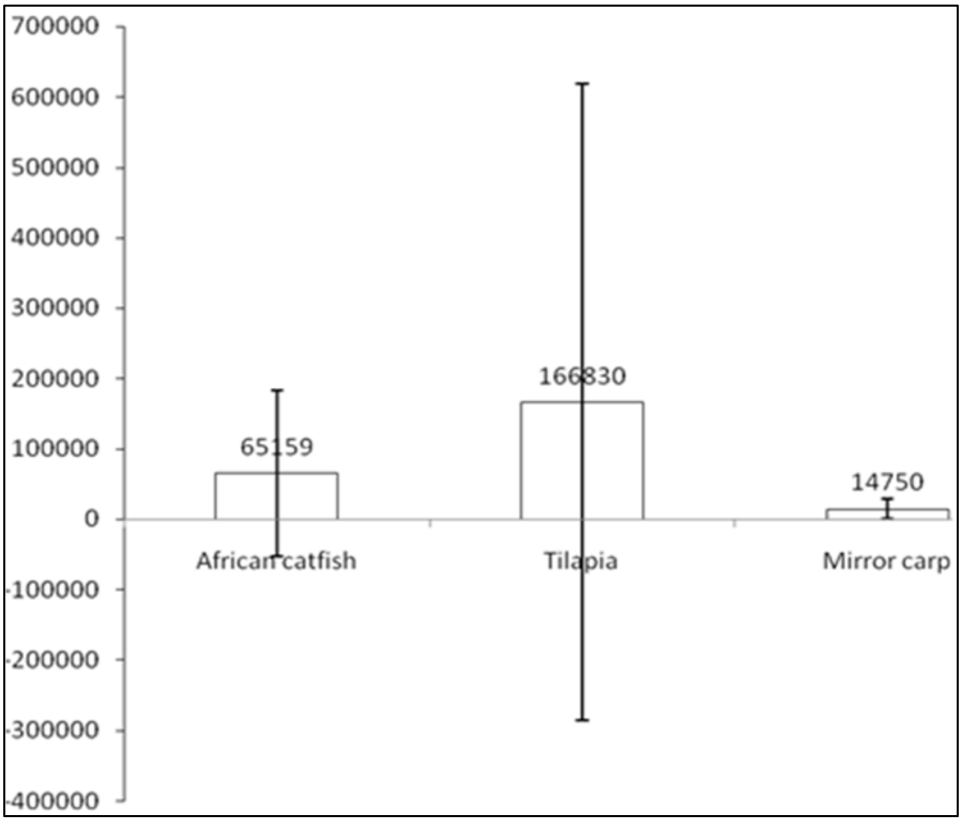

Fig 4: Average annual fingerling production in Uganda by species

3.3.6 Key factors that influenced fish seed production

The overall model explains 44.3% of the total variation in the observed number of African catfish produced. Whereas the variation explained by the model is reasonably high, it is interesting that the overall model is not significant. Besides being biologically important, none of the variables included in the model significantly contributes to the observed number of fingerlings produced. However, from the biological understanding of the subjects, the factors listed in the model greatly account for the effective quantities of fingerlings produced.

Much as no single factor had unique effect on the quantity of fingerlings produced, generally, farmers who obtained brood fish from ARDC and used them in combination with those from other sources (say On-farm & ARDC, ARDC & fellow farmers, ARDC & farmers, on-farm, and ARDC, wild &on-farm) produced more fingerlings than those who used brood fish from ARDC alone (Table 7). On the other hand, farms obtaining brood fish from other sources and used them without those from ARDC-kajjansi generally produced fewer fingerlings than those obtaining and using fingerlings from ARDC (Table 7).

While controlling for brood stock fish source, farmers using higher number of brood fish and/or relatively mature brood fish produced much more fish than those who used fewer and relatively young fish. On the other hand, an increase in brood stocking density resulted into a reduction in the quantity of fingerlings produced, but this increase was not significant ($P > 0.05$).

Table 7: The key factors that influenced fish seed production in Uganda

log (number of catfish fingerlings)	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
Brood stock number	0.00022	0.0003	0.77	0.459	-0.0004	0.001
Brood stock density	-0.427	0.265	-1.61	0.135	-1.01	0.155
Brood stock age	0.404	0.54	0.75	0.471	-0.786	1.593
Reference/baseline (ARDC)						
On farm	0.144	1.439	0.1	0.922	-3.024	3.311
Wild & on-farm	-0.299	2.772	-0.11	0.916	-6.399	5.801
On-farm & ARDC	1.421	1.909	0.74	0.472	-2.78	5.622
On-farm &fellow farmer	-0.059	1.433	-0.04	0.968	-3.212	3.095
ARDC & fellow farmers	0.659	1.716	0.38	0.708	-3.119	4.437
ARDC & farmers, on-farm	0.98	2.077	0.47	0.646	-3.591	5.551
ARDC, wild &on-farm	1.041	3.332	0.31	0.761	-6.294	8.376
_cons	9.411	1.454	6.47	0.000	6.212	12.61

4. Discussion

Fish farming in Uganda has a history dating back to 1940s, it had a slow start and until recently it was done mostly at subsistence level with fish grown majorly in earthen ponds. Fish seed was mostly distributed to farmers from government hatcheries [1]. But with the emerging commercialization of the aquaculture industry the demand for quality fish seed has increased greatly [4].

Survey findings revealed the farmers complained of lack of good quality affordable feed both for brood stock conditioning, larval weaning and advanced nursing. Some farmers said local commercial feeds did not produce good results. Larval weaning and exogenous feeding is facing difficulties as such no one is able to sustain fresh water zooplankton culture and artemia was of unreliable quality , not readily available and usually very expensive especially to the small scale hatcheries. For advanced nursing, the local feed available in the market is not compatible to tanks due to low quality and high pollution effects which limit survival, and yet the imported feeds were expensive and not readily available. All these issues made adequate broodstock management larval/fingerling rearing almost impossible, with farmers resorting to short cuts that resulted into poor broodstock performance and larval survival. For example most hatchery operators only conditioned broodstock for only under 2 weeks in order to reduce on costs involved in conditioning them for longer periods. The outcome was very poor performance of the broodstock in terms of egg production, hatchability and larval survival.

The majority (67%) of the farmers had sufficient quantities of water but were limited by poor quality. Surface running water (streams and rivers diverted) contains a lot of silt while underground source is too cold and deficient of oxygen. In this case there was a general complaint of high expenditure on energy either for purification, aeration or thermoregulation of the culture water. A few cases reported shortage of water due to seasonal nature of their sources. Energy for pumping water, thermoregulation, lighting and running house hold equipment like feed mixer, refrigerator, aerator, degassing machine etc is limiting production. Majority (90%) of the operators reported unreliability of hydroelectric power and very expensive cost of all other types.

The source of broodstock was a pronounced factor in influencing the performance of broodstock. Hatchery operators who sought to replenish broodstock from ADRC – Kajjansi reported better performance compared to other sources. This may be because the research station uses a bigger genetic base to produce broodstocks as it often replaces its parent stock with a boost from the wild resources whereas the other hatcheries use the same parent stock over and over for long times [4].

Generally the hatchery operators seemed to know the right technologies for producing fish seed, but they intentionally avoid the elaborate procedures in order to cut down on costs involved. This resulted into poor performance both in terms of quality and quantity of fish seed produced. A little exposure and training of hatchery operators in best practices while cutting down on costs be carried out. A programme should be designed to target this technical level for better hatchery management and business skills. Hatchery operators should also be made aware of the advantages of good genetic resource management for the sustainability of the sector. Some of the issues highlighted in this paper are probably a result of lack of training for hatchery managers/ owners in genetic management of broodstock.

5. Conclusion

The survey findings paint a limping hatchery industry that unless it is overhauled the gap between fish seed supply and demand in the country and region at large will always increase. The technologies being used by most hatchery operators in the country though appropriate are inefficient. The findings bring out problems of poor breeding and management practices, high levels of inbreeding through use of small genetic base for long times, poor marketing of seed, employed of non-skilled personnel, high cost of broodstock management and larval/fingerling rearing, poor water quality, low larval survival rates, among others. Most of these problems are due to the fact that investment into the fish hatchery industry is very low compounded with poor business acumen. There is need for scientists to work on the inefficiencies on fish seed production technologies as applied in the country by designing interventions for improvement and working together with the hatchery operators/owners to implement them. Government should greatly subsidise the industry to allow its take off, for when it's up and running it can easily stand on its own [16].

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