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# ASSESSMENT OF BROODSTOCK MANAGEMENT PRACTICES IN NIGERIA

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## ABSTRACT

Genetic management of African catfish broodstock is important to ensure the quality of seed. This study was conducted to identify and critically evaluate current broodstock management practices in African catfish hatcheries in Nigeria. A questionnaire was presented in 44 hatcheries in three main aquaculture regions in Nigeria and 34 responded. The results indicated that more than 50% of hatcheries keep fewer than 40 broodfish, with a higher ratio of females than males. This causes the effective breeding number to be under the recommended minimum value in many hatcheries and can result in genetic drift or inbreeding depression. However, the common practice of optioning broodfish regularly from different sources may reduce the risk of inbreeding depression. Only 6% of the hatcheries use broodstock raised on their farms exclusively and this group is predisposed to problems due to poor genetic management. Most hatcheries use females that are 1-1.5 kg as broodfish. However, the results of the present study suggest that seed quality, quantity and survival could be increased significantly by using larger females. The results of the study were used to produce recommendations to improve broodstock management in Nigeria.

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# 1. INTRODUCTION

Aquaculture contributes significantly to the global fish supply (FAO, 2016) while natural stocks are fished at or over maximum capacity (Daw, Adger, Brown, & Badjeck, 2009). Sustainable growth of this sector is vital as the demand for fish increases with growing human population (Boyd, 2009). Fish account for about 17 percent of the global animal protein intake for humans (FAO, 2014). Due to the dynamic growth in the aquaculture sector in recent times, it now accounts for 73.8 million tonnes (44 percent) out of a total of about 167.2 million tonnes of world fish production (FAO, 2016). Aquaculture is currently the fastest growing food producing sector (FAO, 2016) and it is predicted that by 2030 it will supply 62% of world food fish (World bank, 2014) with the fastest growth likely in tilapia, carp, and catfish production (FAO, 2014).

Aquaculture production in Africa only contributes 2% of the world total aquaculture production. Nigeria is the second largest producer in Africa after Egypt (FAO, 2017). Other main aquaculture producing countries in Africa are Uganda, Ghana, Kenya, Zambia, Madagascar and South Africa. In the near future, aquaculture production in Africa is expected to increase substantially as income levels rise and the populations expand (World bank, 2013).

Natural conditions favour aquaculture production in Nigeria since the average temperature is high and the country has abundant water resources (Ukuedojor, 2013). The history of aquaculture in Nigeria can be traced back to 1951 when the pioneer aquaculture facility, Panyam fish farm, in the Plateau State was founded (Ajayi, 1971). Then, the practice of aquaculture was a government-driven venture, but in recent years, aquaculture in Nigeria is primarily a private venture affair (FAO, 2017) and most of the farms, fish feed industry, broodstock farms and hatcheries are owned by private organizations. Aquaculture fish species farmed in Nigeria, include catfish (*Clarias gariepinus*, *Heterobranchus longifilis*, and *H. bidorsalis*), tilapia (*Oreochromis* niloticus, *O. mossambicus*, *O. aureus*) and carp (*Cyprinus carpio*). However, African catfish constitutes more than 60 % and tilapia about 9 % of the total aquaculture production in Nigeria. The production system is primarily ponds (earthen or concrete) and tanks.

The fish supply in Nigeria comes both from domestic production and importation. The three domestic fish sources are; small scale captured fisheries, aquaculture, and industrial fishing (*Figure* 1). Fish from both domestic production and importation accounts for around 40% of the animal protein intake for the populace (Ozigbo, Anyadike, Adegbite, & Kolawole, 2014). Annual domestic fish supply from small scale and industrial fishing were about 710,500 Mt, while aquaculture supplied about 317,000 Mt in the year 2015 (Nigeria Bureau of Statistics., 2015).

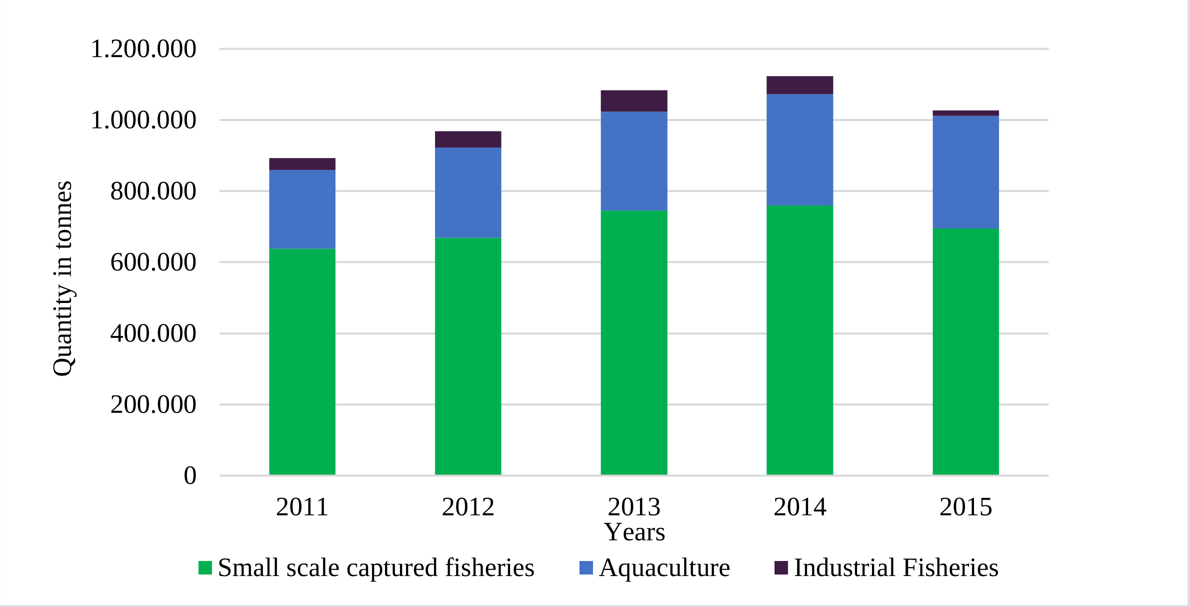


Figure 1: Nigeria's domestic fish production. (Nigeria Bureau of Statistics report 2017.)

In addition to the local production, it is estimated that over 700,000 tonnes of fish are imported (FDF, 2008) accounting for 41% of total fish supply. Therefore, Nigerian capture fisheries (both small scale and industrial captured fisheries) make up 41% of the fish supply, aquaculture accounts for 18% and imports for 41% of the fish supply in Nigeria. (Figure *2*).

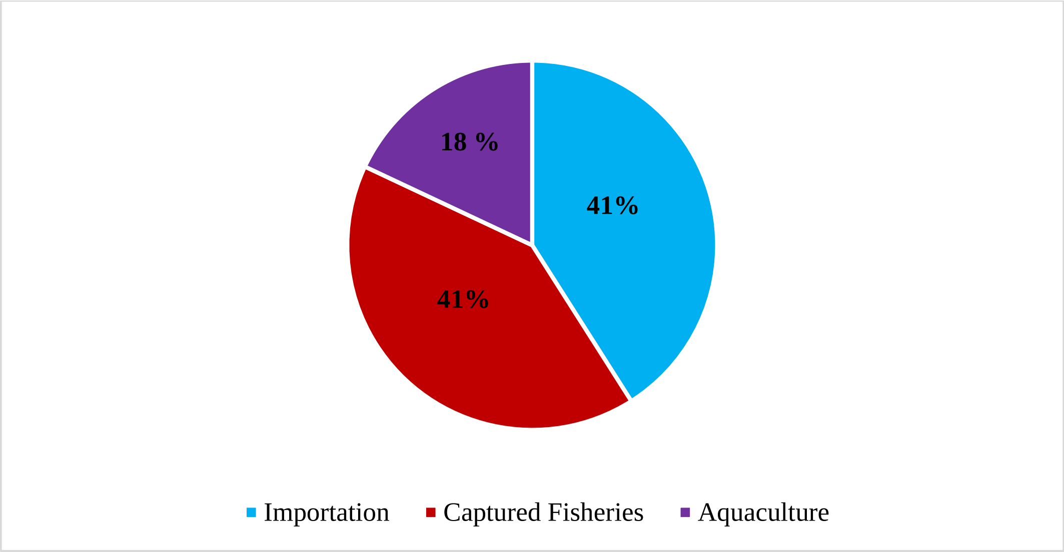


Figure 2: Sources of fish supply in Nigeria

Total fish demand for Nigeria based on the 2014 population estimate of 180 million people is 3.32 million Mt. (Nigeria Fishery Statistics, 2016) and much more than the current supply. This implies that the demand for aquaculture product in Nigeria is significant and increasing because of the growing population in the country. This creates good opportunities for aquaculture growth in Nigeria. Government policy has also favoured aquaculture in Nigeria. One of the strategies adopted by the Government of Nigeria to encourage the increase of domestic fish production was to reduce fish imports by 25% from 700,000 tonnes to 500,000 tonnes (USDA, 2014). The Federal Government also started a Growth Enhancement Support Scheme by distributing inputs such as catfish juveniles, fish feed, nets etc. at a subsidized price to fish farmers across the country. Furthermore, a brood stock production and seed multiplication project was recently initiated by the West Africa Agricultural Productivity Programme (WAAPP) in collaboration with Federal government research institutions and private hatcheries (WAAPP, 2017) to increase the quality of seed for aquaculture in the country.

In spite of all the strategies adopted to support the growth of aquaculture, the aquaculture industry is confronted with several lingering challenges such as the inadequate supply of good quality seed, poor management skills, the high cost of feed, lack of capital and faulty data collection (Adewumi & Olaleye, 2011). The poor management practices of brood stock include too little feeding, handling stress (Shourbela, Abd El-latif, & Abd El-Gawad, 2016) and lack of record keeping about the source, age and family line of the brood stock (Little, Satapornvanit, & Edward, 2002). These practices could in future lead to inbreeding and, as a result, poor-quality fish seed.

## 1.2. Rationale

Poor broodstock management practices may be a factor contributing to the low quality of fish seed in Nigeria. Access for fish growers to good quality seed is vital for sustainable and profitable fish farming and availability of good quality seed may be one of the constraints slowing the development of aquaculture in Nigeria (Adewumi & Olaleye, 2011). The problems with seed production may include inadequate technical knowledge and skills in the hatcheries (George, Olaoye, Akande, & Oghobase, 2010). This study was conducted to assess and evaluate broodstock management practices in Nigeria.

## 1.3. Objectives of the study

The aim of this study was to evaluate the methods used for broodstock management and suggest possible improvement practices that can enhance the quality of fish seed production. To achieve this objective, the following tasks were carried out:

- Current practices and challenges in broodstock management in Nigeria were identified.
- Current practices in broodstock management in Nigeria were critically evaluated.
- Recommendations to improve broodstock management in Nigeria were provided based on the results of the study.

# 2. LITERATURE REVIEW

## 2.1. Broodstock management

Good management of broodstock fish and proper control over the reproductive processes is essential for commercial aquaculture production (Mylonas, Fostier, & Zanuy, 2010). Broodstock management is a complex process which involves selection of appropriate fish for spawning, successful maturation of fish and good gamete quality, the spawning process and successful fertilization of eggs. Furthermore, production of good quality seed is affected by numerous factors such as feeding of both broodstock and juveniles, feeding routine, fish handling and fish health issues. Broadly, broodstock management and production of quality seed requires attention in two main areas – broodstock husbandry and the genetic management of the broodstock.

## 2.2. Broodstock husbandry

### *2.2.1. Broodstock feeding*

Broodstock nutrition is important for reproductive success because fecundity, gonadal maturation, and quality of both eggs and juveniles of fish are influenced by broodstock nutrition (Rodríguez-González, 2001) (Wouters, Molina, Lavens, & Calderón, 2001). Broodfish require high dietary protein which can affect the hatchability of African catfish eggs (Sotulu, 2010) (Sink, Lochmann, Pohlenz, Buentello, & Gatlin, 2010). The quality and quantity of nutrients deposited in the yolk determine the viability of eggs, fertilization, hatchability and consequently progeny survival (Constantine, et al., 2014).

### *2.2.2. The size of fish in broodstock*

The size of the broodstock fish is very important when selecting fish for spawning. Studies have indicated that egg size and fecundity are directly proportional to the size of fish (Bromage N. R and Roberts R. J., 1995). Eggs from larger broodfish have increased hatchability (i.e. the proportion of eggs that hatch) (Ataguba, Solomon, & Onwuka, 2012) and they tend to produce a larger number of eggs, bigger eggs, and better seed quality which in turn affects the growth and performance of juveniles (Jokthan, 2013).

### *2.2.3. Broodstock handling*

Proper handling affects reproductive attributes such has fertilization, hatching and early survival of larvae of the African catfishes (Shourbela, Abd El-latif, & Abd El-Gawad, 2016). In fact, it has been suggested that problems with seed production in many Nigerian hatcheries are due to poor handling of brood stock (Aiyelari, Adebayo, & Osiyemi, 2007). Poor handling can stress the fish and affect fish health which, in turn, is very important for the reproductive performance of fish (Muchlisin, Hashim, & Chong, 2006) (Aiyelari, Adebayo, & Osiyemi, 2007).

## 2.3. Genetic management of broodstock

The genetic management of broodstock entails both ensuring their genetic diversity and possibly also the genetic improvement through selective breeding. An important part of genetic management is good record keeping of pedigree and attention to the effective breeding number in the broodstock. Securing a large enough effective breeding number will guard against too high levels of inbreeding that can stunt growth and reduce survival. The effective breeding number is the total number of potential broodfish (male and female) that make up the hatchery broodfish population and produce viable offspring (Tave, 1999).

$$N_e = \frac{4\,(number\ of\ females)\,(number\ of\ males)}{(number\ of\ females) + (number\ of\ males)}$$

$N_e$ is determined by the number of males that leave viable offspring, the number of females that leave viable offspring, and by the sex ratio of the brood fish. This means that $N_e$ is maximized by increasing both the number of males and females that are spawned and by bringing the sex ratio as close to 1:1 as possible. Changes in $N_e$ over generations are also important. The average $N_e$ for a series of generations is determined by calculating the harmonic mean:

$$\frac{1}{N_e\ mean} = \frac{1}{t}\left(\frac{1}{N_e\,1} + \frac{1}{N_e\,2} + \cdots + \frac{1}{N_e\,t}\right)$$

where: $N_e$ mean is the mean effective breeding number over t generations; and $N_e1$, $N_e2$, and $N_e$ t are the effective breeding numbers in generations 1, 2, and t, respectively.

In large breeding farms, inbreeding can be avoided with good management and attention to the $N_e$. This will increase the chance that broodfish are mated with non-relatives in the following generation (Dupont-Nivet, Vandeputte, Haffray, & Chevassus, 2006). Furthermore, the fish breeder must keep good records to minimize the inbreeding over generations (Hallerman E. , 2003), (Tave, 1993).

The $N_e$ is inversely related to the level of inbreeding:

$$F = \frac{1}{2\,(N_e)}$$

where F is the amount of inbreeding produced (0-100%) in a single generation; F is the percent increase in homozygosity.

Assuming, $N_e$ = 150, the average inbreeding value for the fish in the population will be:

$$\mathrm{F} = \frac{1}{2(150)}$$

$$\mathrm{F} = 0.003$$

Also, if $N_e$ = 10, the average breeding number for the fish in the population will be:

$$\mathrm{F} = \frac{1}{2\,(10)}$$

$$\mathrm{F} = 0.025$$

This formula shows that as $N_e$ decreases, F increases. There is no general rule for the minimum $N_e$. However, a $N_e$ between 30 to 500 has been recommended (Dupont-Nivet, Vandeputte, Haffray, & Chevassus, 2006). The size of the $N_e$ depends also on the goal of the hatchery or fish farm (Dupont-Nivet, Vandeputte, Haffray, & Chevassus, 2006).

Inbreeding can contribute to loss in performance of aquaculture fish, fitness, and selective response (Evans, Matson, Brake, & Langdon., 2004) (Wang, Hard, & Utter, 2001). Production problems in aquaculture such as increased deformity, a decline in growth rate and yield can be indications of inbreeding. Inbreeding depression can cause reduction in growth rate, fry survival rate, feeding efficiency and increase in fry abnormalities (Gallardo & Neira, 2005), (Aulstad & Kittelsen, 1971), (Kincaid, 1979). Inbreeding depression also contributes to reduced embryo viability (Bickley, et al., 2013) as well as reduced fertilization rates and egg hatching success (Frommen, Mazzi, & Theo, 2008).The negative effects of inbreeding usually do not occur until after several generations. Inbreeding depression can also be minimized if the effective breeding population size is very large.

Genetic drift are random changes in gene frequency and it is more likely to happen when $N_e$ is low. The effects of genetic drift can lead to an irreversible alteration in gene frequencies and even elimination of alleles within a population. This can obstruct future selection of the population (Tave, 1999) for favourable traits such as increased growth rate (Teichert-Coddington & Smitherman, 1988). Furthermore, genetic drift can increase the number of fish with developmental disorders (Leary, Allendorf, & Knudsen, 1985).

It can be difficult to prevent genetic drift in hatcheries (Hallerman, Dunham, & Smitherman, 1986). The probability of genetic drift is inversely related to the $N_e$. This means that large $N_e$s produce small changes in gene frequency, while small $N_e$s produce large changes in gene frequency (Tave, 1999).

Proper management techniques can be employed to maximize $N_e$ and the minimize inbreeding over generations:

1. The number of fish that are spawned should be increased and a female to male sex ratio 1:1 be maintained. However, many hatcheries maintain more females than males to maximize egg production and minimize the production cost.
2. A pedigree mating system could be adopted (Tave, 1984) instead of random mating (the normal practice at most hatcheries). This will allow the breeder to avoid mating too closely related pairs.
3. It is important to ensure that the number of offspring from each mating is equal because unequal reproductive success and survival of eggs and larvae lowers $N_e$ of the offspring population (Fiumera *et al.*, 2004). This requires that each family is raised in a separate culture unit until family size can be made equal.
4. Stripping practices can be modified (Withler, 1988). If fish are stripped, milt should not be pooled or added in a sequential manner. These practices may result in gametic competition and the tendency that most of the eggs will be fertilized by one male, producing $N_e$ much smaller than expected.
5. Stretching the generations. A generation is the time interval for the replacement of parents with their offspring. Increasing the number of years for each generation makes it possible to use a smaller $N_e$ to achieve the desired goal.

6. Selection of parent stock from an open population. This involves using new brood fish that are imported or sourced from the wild (Bartley *et al.*, 1995) reported that if 10-25% new brood fish are imported in each generation, the amount of inbreeding that is produced can be drastically reduced.
7. Mating two unrelated populations and producing hybrids. Inbreeding has zero chances of occurring in a hybrid. If multiple unrelated lines are preserved, a rotational mating programme can be used to avert inbreeding for a number of generations (Kincaid, 1977).

### 2.4. Breeding programs

Breeding programs are a further step in the genetic management of broodstock. Selective breeding involves the planned mating of animals over several generations with the aim of improving factors such as the feed conversion efficiency, growth rate, adaptation to environmental conditions, product yield and other desirable attributes (Gjedrem, 2004). Selective breeding can reduce fish production cost, improve fish health and product quality should be prioritized. Setting up a breeding program requires facilities, technical skills and proper planning. They are expensive to set up and manage but in return they also provide significant returns through increased productivity and economic benefits for the farmer. Because of the high costs associated with selective breeding these operations should be centralised for each country or region. Thus, only one breeding program for catfish should be enough in Nigeria.

## 3. METHODOLOGY

This study was done to assess the status of broodstock management in Nigeria. The assessment was performed through a structured questionnaire (see Appendix) and interviews undertaken by fisheries officers. The questionnaire addressed important areas for brood stock management such as; fecundity, survival, hatchability, feeding routine, brood stock source and brood stock selection methods.

### 3.1 Study Area

The fisheries officers visited 34 African catfish broodstock farms and hatcheries and administered the questionnaire. Although about 44 hatcheries where initially contacted, only 34 responded. The hatcheries contacted had been in operation for a minimum of 5 years and they were selected randomly in the three main aquaculture regions in Nigeria: The North central zone, South west zone and South-East zone (Figure 3).

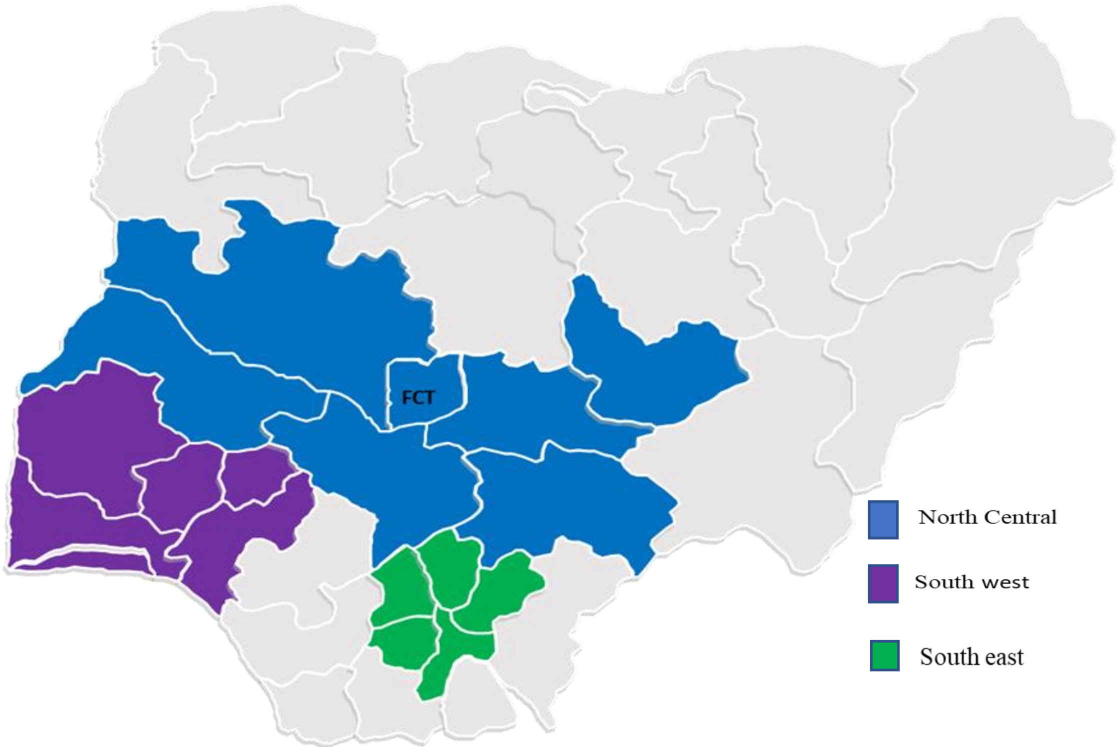


Figure 3: Map of Nigeria showing the study area.

**3.3 Implementation of Questionnaire**

The questionnaire was sent to fisheries officers who conducted the interviews with catfish hatchery owners or managers. The responses were recorded and entered into Google documents where they could be accessed. During the interviews, questions were asked about selection methods, the frequency of spawning female, fecundity, hatchability of eggs, survival rate, feed quality, feeding routine and other challenges faced by fish breeders.

**3.3 Analysis of the Questionnaire**

The questionnaire contained both open ended and closed questions. The open-ended questions were summarized while the responses to the closed questions were analysed using Ms excel 2016 with the Data analysis tool pack.

4. RESULTS

Information obtained from the respondents on the management practices of African catfish broodstock in Nigeria are summarised and illustrated below:

**4.1. Sources of broodstock**

Most catfish hatcheries, about 70%, source broodstock from other farms and several other sources and 21% obtain broodstock from the wild and from other sources (Figure 4). However, relatively few (6%) use only their own broodstock and this group is more disposed to inbreeding depression and genetic drift.

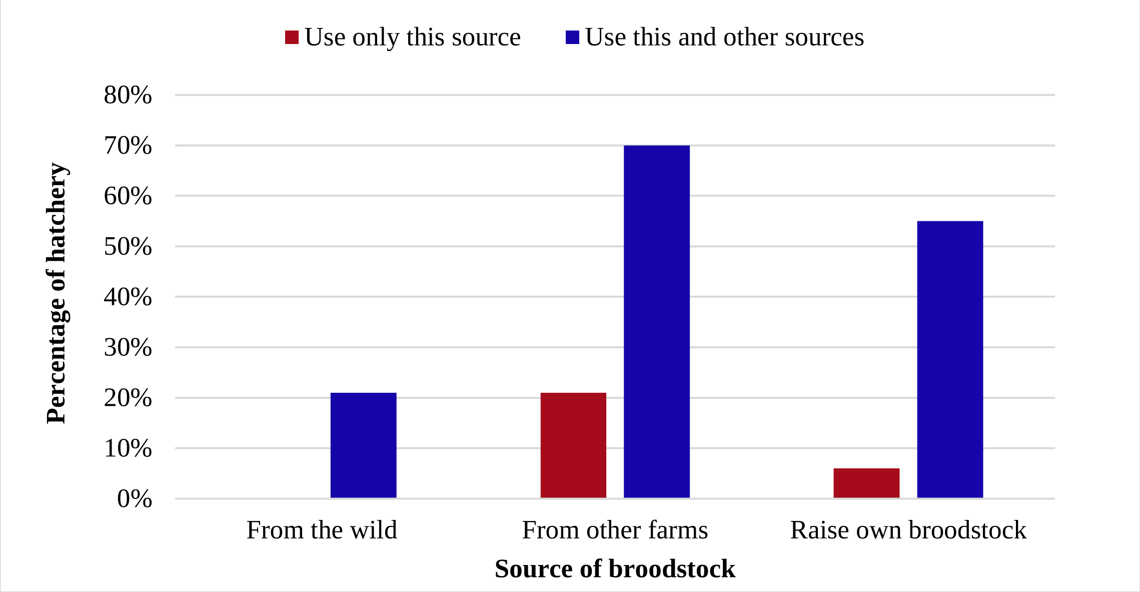


Figure 4: Sources of brood stock

## 4.2. Number of brood fish in the hatchery

Around 29% of the catfish hatcheries keep less than 20 broodfish in the hatcheries, 53% keep less than 40 broodfish and 71% keep less than 60 broodfish. In total, 24% of the farms keep 61-150 broodfish and only 6% keep above 200 broodfish (Figure 5).

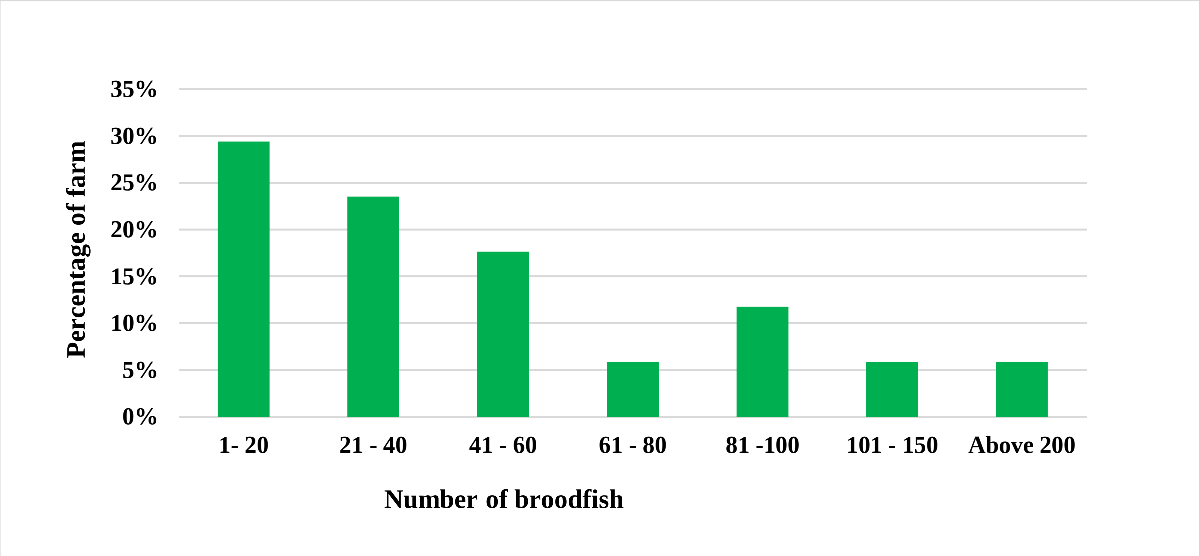


Figure 5: Number of brood fish in the hatcheries

### 4.3. Ratio of female to male brood fish

Most of the hatcheries (53%) keep a female to male ratio of 2:1, 23% keep a female to male ratio 3:1, about 6% keep a female ratio 4:1 and a further 6% keep the female to male sex in ratio 6:1 while 12% of the hatcheries keep equal female to male ratio (Figure 6).

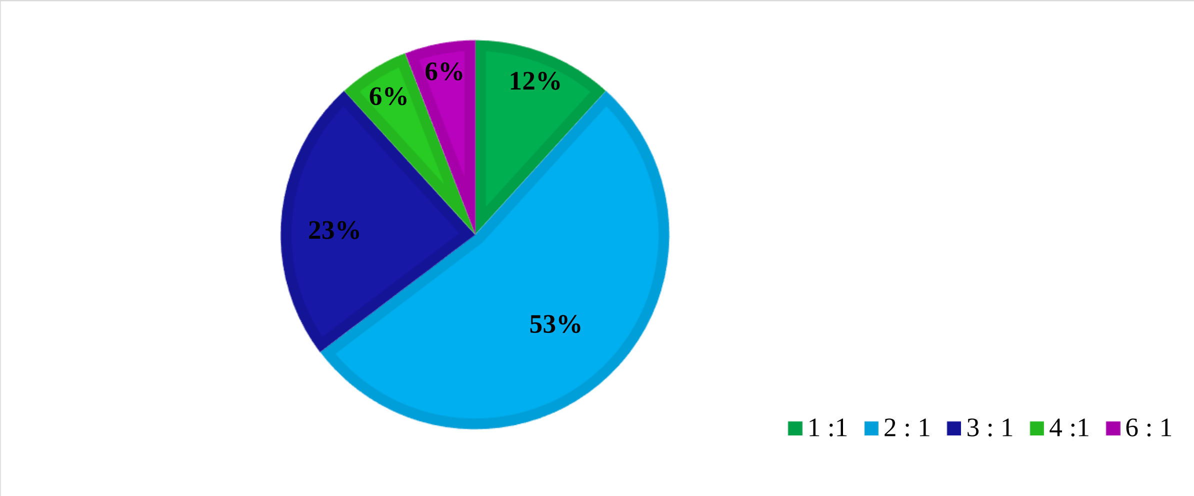


Figure 6: Ratio of female to male brood fish

### 4.4. Effective breeding number ($N_e$)

It was not possible to estimate the $N_e$ and the *F* in individual hatcheries based on the information provided in the questionnaire. However, the overall effective breeding number was estimated based on the number of fish in broodstock and the sex ratio (Figure 7). Based on the number of broodfish kept (Figure 7) and the female to male ratio, it is expected that the $N_e$ in more than half of the hatcheries is less than 40 and even as little as 20 in some.


Figure 7: Effective breeding number ($N_e$).

## 4.5. Weight of brood fish

The most common size of broodstock used for catfish fingerlings production was between 1.6 kg and 2 kg (59%) (Figure 8). About 18% use fish weighing less than 1.6 kg, while 24% use larger fish weighing above 2kg.

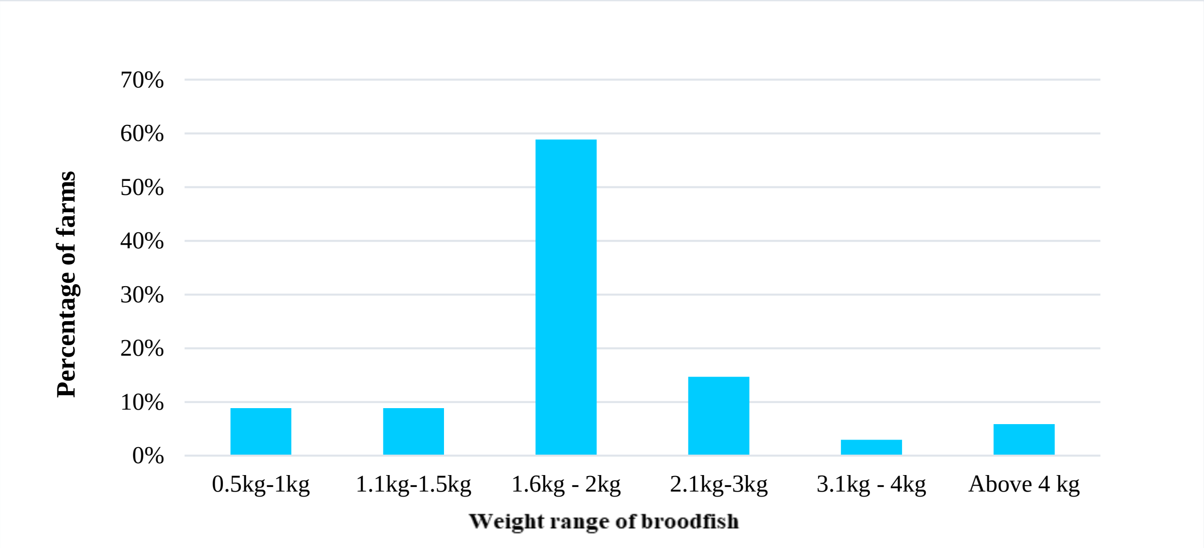


Figure 8: Weight range of brood fish

## 4.6. Weight of spawned eggs

About 44% of the hatcheries do not measure the weight of egg spawned. Of those that record egg weight, 18% reported that they obtain between 100 and 250 g of egg, while 26 % obtain about 251-500 g and just about 12% more than 500 g of eggs (
Figure 9).

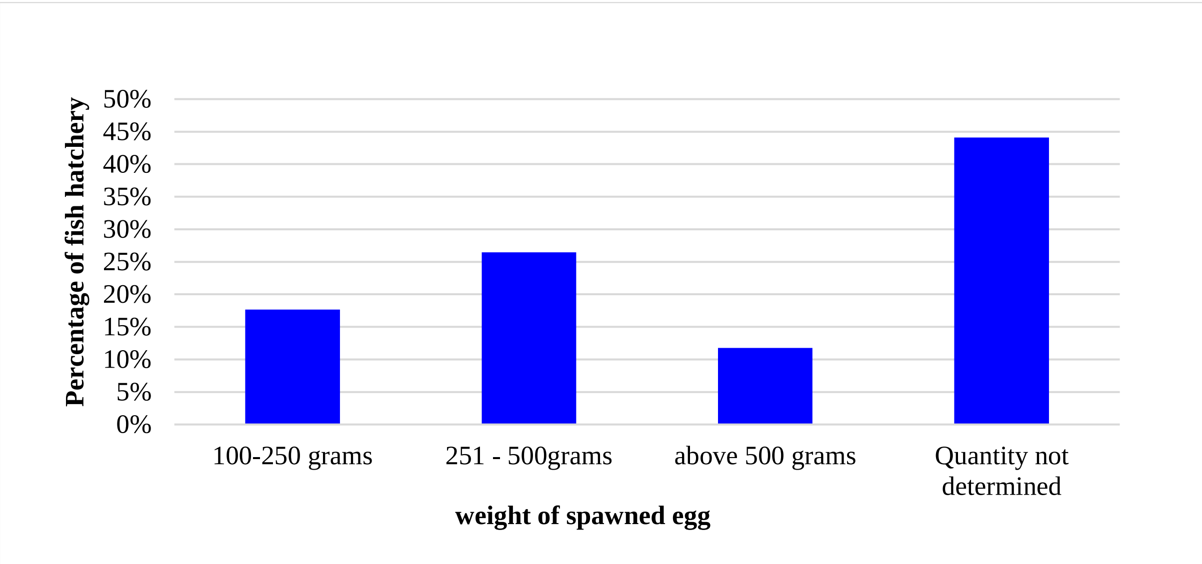


Figure 9: Total weight of spawned eggs

### 4.7. Survival rate of juveniles

The survival rate was estimated by subtracting the total number of juveniles from the total number of larvae from first feeding. The survival rate is usually determined at about 6 weeks from date of hatching. A survival rate of juveniles between 60-80% was reported in 46% of the hatcheries, 42% reported 40-60% survival rate while 13% reported above 80% survival rate from hatching to juveniles (Figure 10).

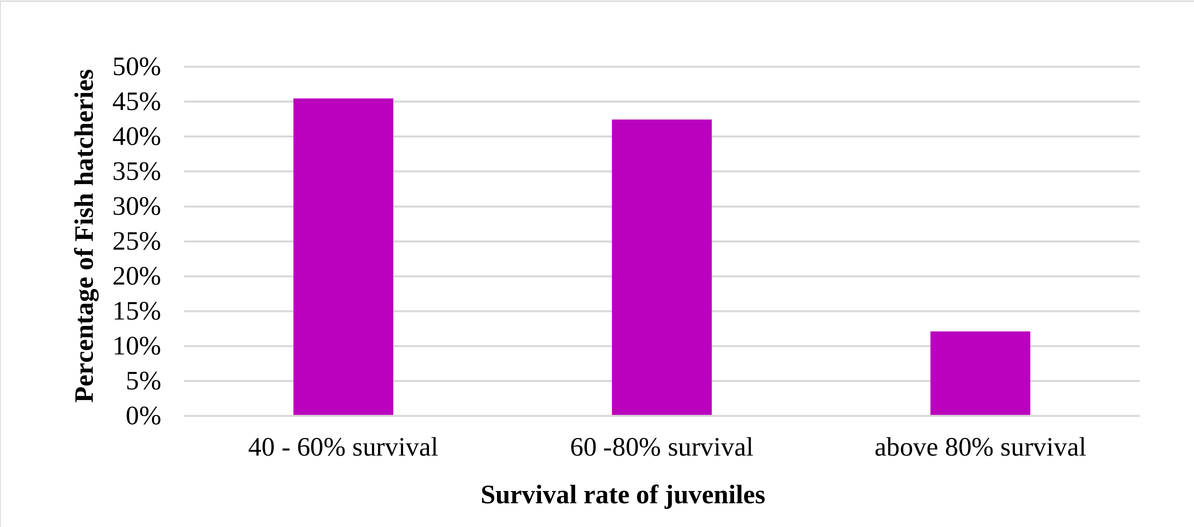


Figure 10: Survival rate of juveniles in fish hatcheries

### 4.8. Relationship between weight of female broodfish, weight of eggs and survival rate of juveniles

There was a significant linear relationship between the weight of eggs and weight of female broodfish, (
Figure 11) and the total weight of eggs increased with increasing weight of females ($p = 0.01$).

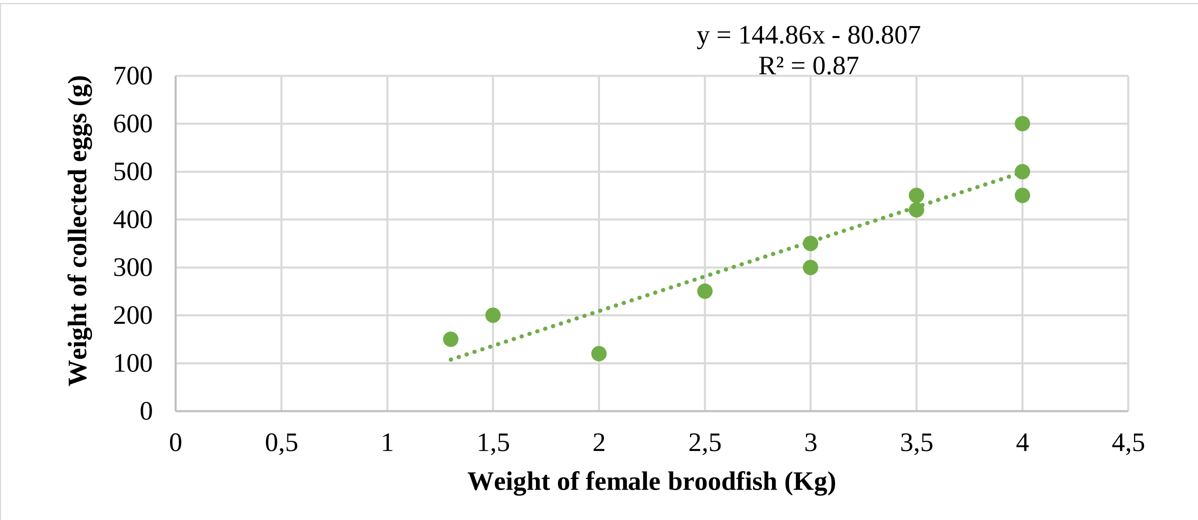


Figure 11: Relationship between weight of female broodfish and weight of collected eggs

There was also a significant relationship between survival rate of juveniles and total mass of eggs collected (p = 0.02), the survival rate of juveniles increases with an increase in the weight of eggs (Figure 12).

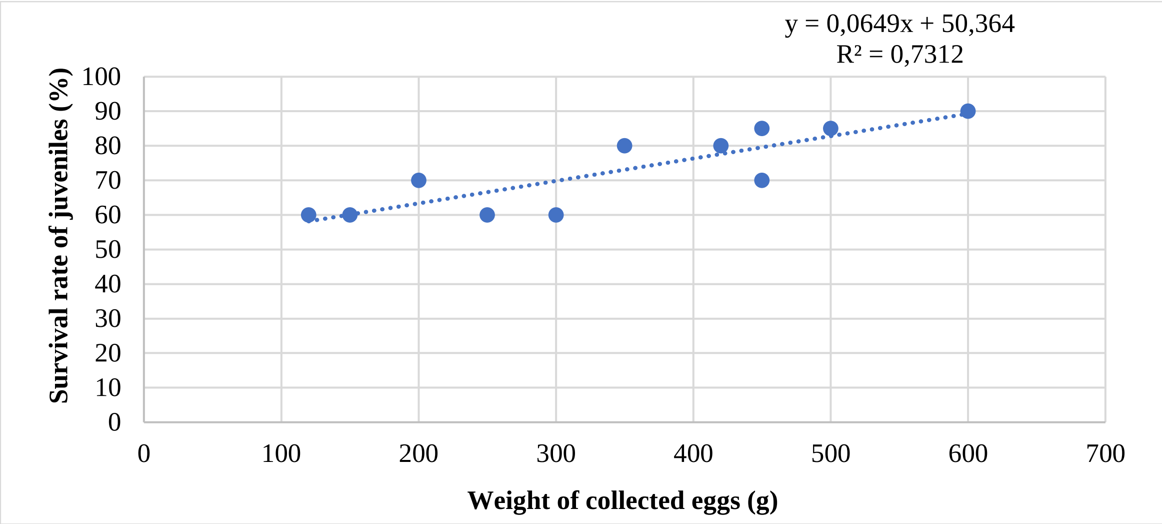


Figure 12: Relationship between survival rate of fingerlings and weight of the collected egg.

The survival rate of juveniles increased with increasing size of female broodfish (p = 0.001). The best survival (85-90%) was recorded when female broodfish were 4kg (Figure 13).

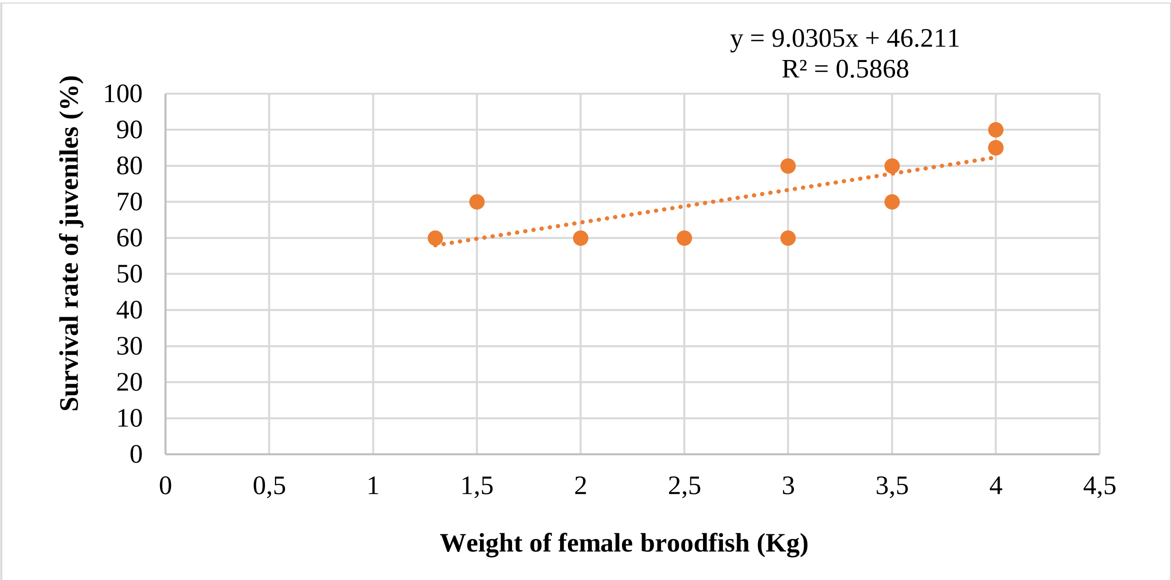


Figure 13: Relationship between weight of female broodfish and survival rate of juveniles

When the survival rate, the weight of broodfish and weight of eggs were analysed together. There appears to be auto correlation between survival rate, egg mass and the weight of females. This indicates that the weight of female broodfish affects egg mass and possibly also survival rate, possibly through larger eggs of larger females, although this was not measured.

### 4.9. Frequency of re-spawning eggs from female broodfish

Only 3% of the hatcheries collect eggs less than 3 months from the previous spawning. Most hatcheries (about 45%) collect eggs from the female broodfish again after about 3months, 42% collect eggs from female broodfish after 6 months and 9% collect eggs from the females 9 months after the previous spawning (Figure 14).

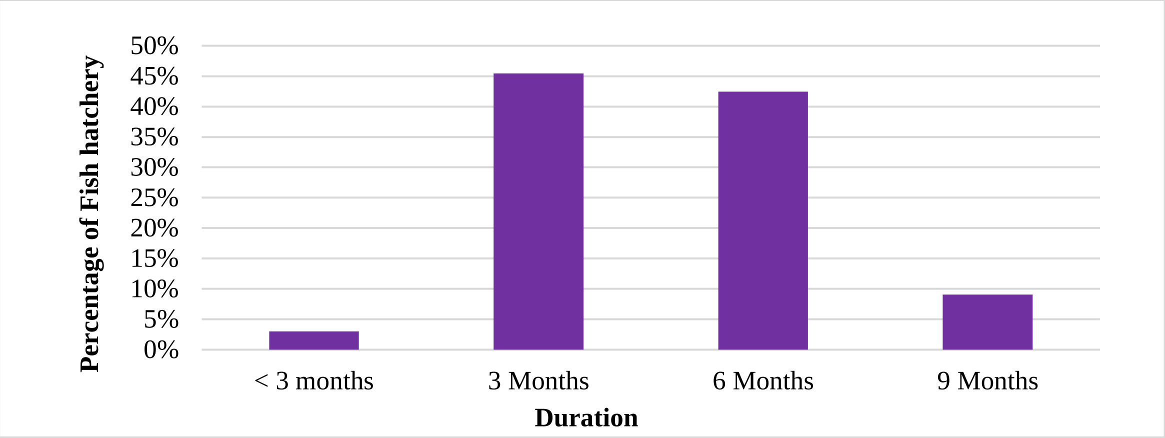


Figure 14: Duration between re-spawning of females

The frequency of re-spawning frequency had no significant effect (p= 0.75) on the weight of broodfish. Also, the re-spawning frequency had no significant effect (p= 0.47) on the weight of eggs collected.

### 4.10. Broodstock feeding frequency

More than half of the hatcheries (52%) feed the broodfishes every other day, 32% feed them once daily while only 12% feed twice daily (Figure 15).

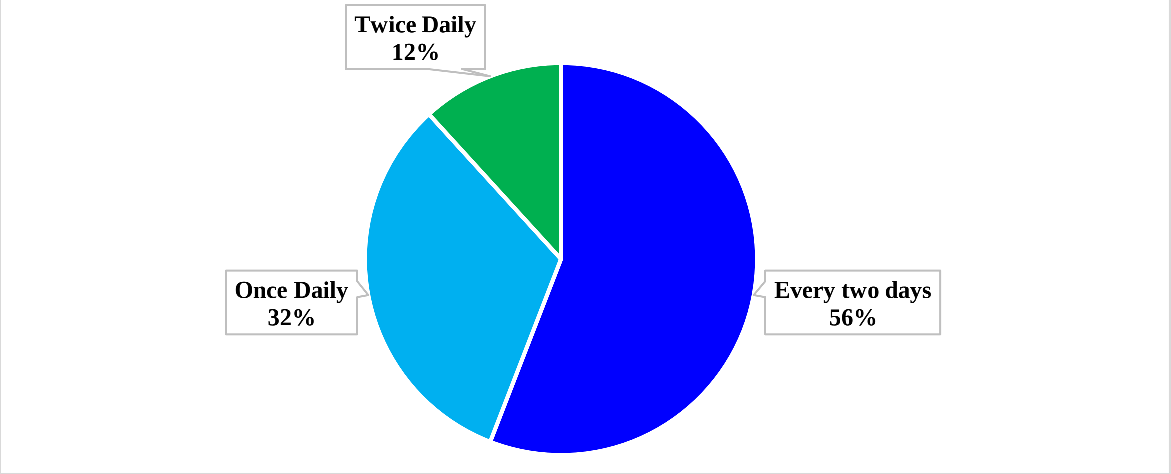


Figure 15: Feeding frequency for broodstock.

The feeding frequency had no significant effect (p= 0.77) on the weight of eggs collected. Also, the feeding frequency had no significant effect (p = 0.30) on the weight of broodfish.

### 4.11. Criteria for brood stock selection

In 62% of the hatcheries, broodstock fish are selected based on both the age and weight of the broodfish, while 23% select broodfish by the body weight alone (Figure 16). Also, 15 % of the hatcheries select the broodfish using the age of the fish has the selection criteria (Figure 16).

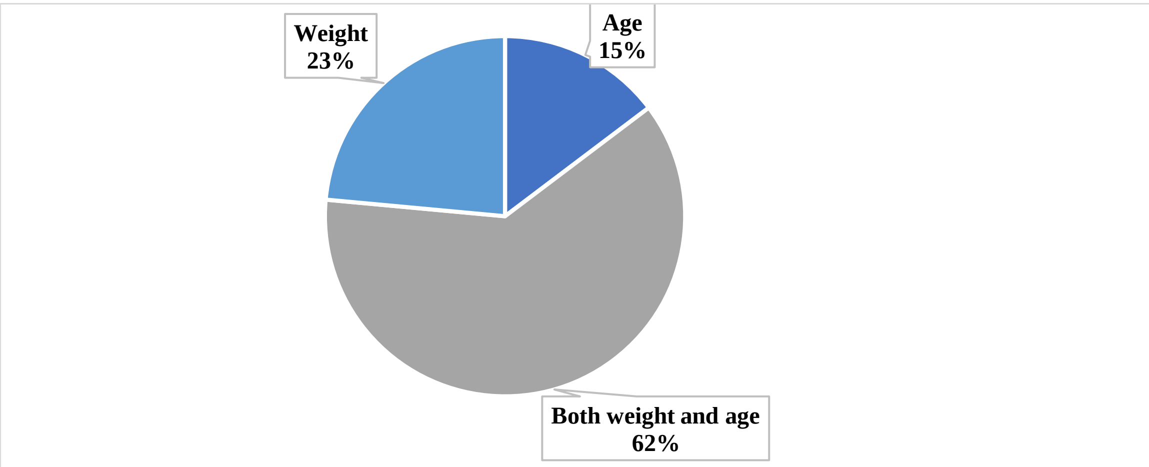


Figure 16: Criteria for brood stock selection

### 4.12. Percentage of shooter (rapidly growing) fish in a batch

Most hatcheries (65%) reported that the percentage of shooter fish in a batch is about 5%, and (32%) reported that the shooter fish obtained is between 6-10 %, while (3%) of the hatchery recorded between 11-15% of shooter fish per batch (Figure 17).

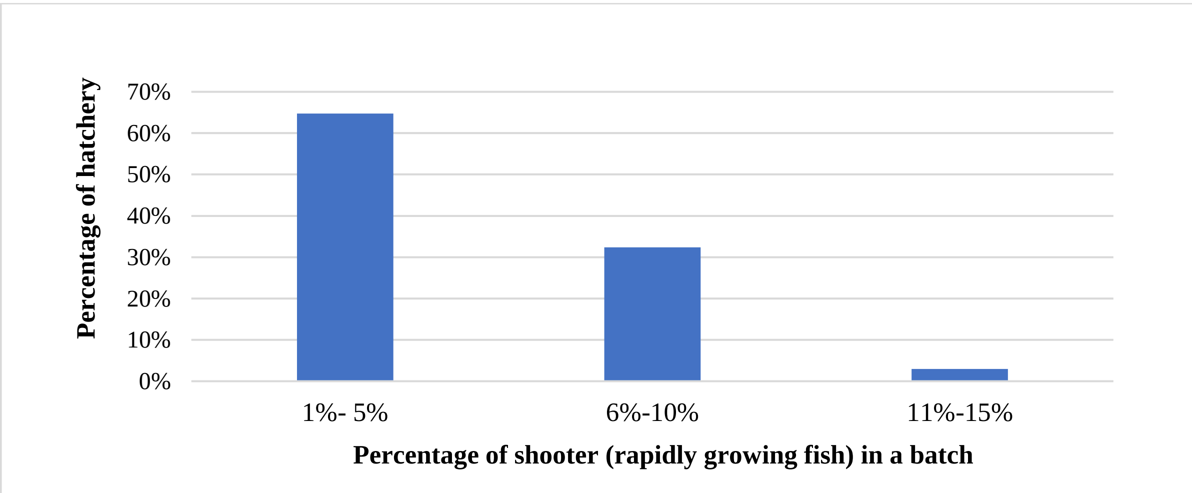


Figure 17: Percentage of shooter fish in a batch.

## 4.13. Further information on broodstock management practices in Nigeria

Further information collected on the broodstock management is summarised in Table 1. About 67% of the farms do not feed the broodfish to satiation, while 33% feed the broodstock fish to satiation (Table 1). Over half (52%) of the hatcheries do not keep records of broodstock age, while 44% keep records of the age of broodstock (Table 1). Most (59%) of the hatcheries reported that they estimate the growth rate of the fingerlings, while 41% do not estimate fingerlings growth rate. A high proportion (71%) of the hatcheries keep the shooter (fast-growing) fish and raise them for broodstock, while 29% do not keep the shooters as potential broodstock (Table 1). About 73% of the fish hatcheries are aware that inbreeding depression may occur due to the source of the broodfish. While only 27% have no knowledge about the effect of inbreeding depression on their fish stock (Table 1).

Table 1: Responses to other questions in the questionnaire

| | **Questions** | **Responses** | |
|---|---|---|---|
| I | Are broodstock fishes, fed to satiation, or not? | No<br>Yes | 67%<br>33% |
| II | Keep records of the ages of broodstock? | No<br>Yes | 56%<br>44% |
| III | Estimate the growth rate of fingerlings? | No<br>Yes | 59%<br>41% |
| IV | Keep the shooters (rapidly growing) fish and raise them for brood stock fish? | No<br>Yes | 29%<br>71% |
| V | Are the hatcheries aware that inbreeding depression may occur due to sources of the brood stock? | No<br>Yes | 27%<br>73% |

## 4.14. Challenges faced by brood stock farms and fish hatcheries in Nigeria

The hatchery owners and managers indicated numerous challenges in the interviews. The main issues brought up during the interviews are summarised below:

*A. Inadequate technical knowledge about genetic management of broodstock.*

Some hatchery operators complained that the number of untrained and uncertified breeders were increasing. This category of fish breeders has limited knowledge about the intricacies and proper procedures for a successful and sustainable genetic management of broodstock. Some of the uncertified breeders also sell broodstock of poor genetic quality with low survival and poor performance of juveniles.

*B. Scarcity of Quality Broodstock*

Fish hatcheries complained that they cannot be sure of the quality of the broodstock purchased. As farms selling broodstock do not disclose the source of broodstock, the age and other important information about the broodfish. A large number of hatchery operators reported that the common practice of sourcing broodstock from random farms makes it impossible for hatcheries to obtain information about the pedigree history of the broodstock they purchase.

Some hatcheries also reported that sometimes the broodfish sold to them has been previously spawned and may be culled fish from other farms.

*C. Water quality management*

Some hatcheries, particularly those in the south-eastern region of the country, have problems with water quality. They reported that the water chemistry such as water pH changes with seasons, creating poor water quality at certain times of the year. Fluctuations in water chemistry can affect the hatchability of eggs and survival rate of juveniles. Also, reproductive performance of broodfish is affected by temperature fluctuations particularly, during harmattan season (the season when cold, dry and dusty north-easterly trade wind from the Sahara Desert blows over West Africa into the Gulf of Guinea). This season is from the end of November to the middle of March and it’s characterised by high diurnal fluctuation temperature. During this season, the temperature can be low in the morning and suddenly rise in the afternoon, then the temperature drops again at night. This fluctuation in temperature affects hatchability of eggs, fish feeding patterns and fingerling survival rate. Making it difficult for most hatcheries to produce fingerlings during this season.

*D. High cost of quality feed*

Since most of the best quality feeds are imported, the price is quite high and not all hatcheries can afford it. As a means of reducing feeding cost, most farms feed their broodfish with local feed that is much cheaper but with a lower nutrient content. This may result in reduced egg quality and losses of juveniles after about 1-week post-hatching.

## 5. DISCUSSION

This is the first study to estimate hatchery management practices in Nigeria. The results suggest, in half of the hatcheries the number of broodfish and the $N_e$ are below the recommended levels of 50 or higher. In some of the hatcheries the $N_e$ could even be 20 or lower (Figure 7). This could cause problems with inbreeding and genetic drift. The main reason for small breeding populations are likely high feeding costs. Similarly, to save money, most of the farms do not keep a female to male sex ratio 1:1 which further reduces the effective breeding number (Figure 6). Small effective breeding number increases the probability of genetic drift or inbreeding depression (Tave, 1999). Therefore, too low $N_e$ may be a problem in some, but fortunately few (6%) hatcheries (Figure 4) which have a closed population.

The common practice of obtaining broodstock from different sources (Figure 4) can counteract the low number of broodstock in hatcheries. This introduces new fish into the broodstock and, as a result, the probability of inbreeding depression is reduced. The most common practice is to purchase large fish from farmers growing fish for food and keep the fish for some time to be used as broodstock. Unfortunately, the farmers cannot provide information on the pedigree of the fish. However, this may not be a problem if the fish are sourced from different farms, which reduces the likelihood of inbreeding. The questionnaire did not give information on how frequently the hatcheries bring in new broodfish from external sources but that would be an interesting study area.

The results of this study show that bigger broodfish spawn a larger egg mass (Figure 11). Furthermore, results of other studies suggest that the better survival of seed from larger females found in the present study could be due to larger yolk reserve in the eggs from bigger female broodstock (Springate & Bromage, 1985), (Marsh, 1986), (Hutching, 1991). As a result, eggs spawned from bigger females have better fertilization rate, better survival of juveniles and produce better quality seed. Hatcheries that use female broodfish of 4kg recorded about 38% better survival rate than hatcheries that use small female broodfish. This is in line with the results of (Jokthan, 2013) (Roff, 1992) who found that heavier females produced a better quantity of eggs and recorded higher fertilization rate and better survival than smaller females. The findings are also in accord with those of (Bichi, Isyaku, Danba, Kurawa, & Nayawo, 2014), which suggested that egg size determined most of the variation in final juvenile fitness and that larger eggs came from larger females which in turn produced larger juveniles.

The weight range of broodfish reported in the present study was between 1.6 to 2kg, although, some farms use larger broodfish weighing up to 4kg (Figure 8). As described above, the results of the present study suggest that heavier broodfish spawn more and better-quality eggs, which could increase the survival of the eggs and juveniles. These results are similar to those of (Jesse, 2008) (Jokthan, 2013) that suggested that females weighing between 1.8 and 3.6kg spawn eggs of better quality than smaller females and similar results were also reported by (Sule & Adikwu, 2004). Therefore, the quality of catfish eggs and seed in Nigeria could be increased significantly by using larger broodfish.

A large proportion of the hatcheries feed their broodfish every other day. Although some hatcheries feed the broodfish daily or even twice daily. No effects of feeding frequency were found on broodfish size or the survival rate. However, feeding frequency tends to affect the weight of female broodfish, the weight of egg spawned and survival rate as suggested by the results of (Cerda, Carrillo , Zanuy, Ramos, & de la Higuera, 1994) and (Shourbela, Abd El-latif, & Abd El-Gawad, 2016). Similarly, the practice of obtaining broodfish from different sources may have masked this effect. Furthermore, the weight of broodfish and eggs may also be affected by the frequent re-spawning in the hatcheries. Most of the hatcheries induce the female broodfish to re-spawn eggs after about 3 months (Figure 14), and this could also limit the weight of eggs collected and/or the weight of female broodfish.

Some of the hatcheries reported problems with water quality which could affect hatchability and survival rate of juveniles (Okanlawon, 2010). Also, seasonal ambient temperature fluctuation affects hatching success, fry survival and feeding habit of fish which is similar to what was reported by (Shourbela, Abd El-latif, & Abd El-Gawad, 2016). Other challenges currently faced by the catfish hatcheries are the lack of good quality broodstock, lack of information about the broodfish pedigree, inadequate technical knowledge of fish hatching practices, inadequate information about water quality management techniques and genetic management of broodfish has hindered an increase in aquaculture productivity in the country.

A future goal for Nigeria may be to set up a breeding program for African catfish. Breeding programs are expensive to set up and run. It also requires facilities and technical expertise that the hatcheries lack. However, the gains from selective breeding in terms of growth rate and survival could be very significant. The cost of running a breeding program precludes smaller hatcheries to be involved. Instead the government or larger private companies with the technical expertise and financial capacity could run such a program and only one central program should be set up in the country.

## 6. CONCLUSION

Even though too small breeding numbers may be a potential problem in catfish hatcheries in Nigeria, the common practice of obtaining broodfish from different sources can help to counteract the negative effects of inbreeding depression. Only relatively few hatcheries use only their own broodstock and they are predisposed to inbreeding depression. Secondly, the use of bigger female broodfish can improve the size, number and quality of eggs spawned, as well as hatching success, survival rate and quality of fish seed produced.

## 7. RECOMMENDATION

Under the present conditions, hatcheries in Nigeria should obtain their broodfish from different sources to reduce the risk of inbreeding depression and genetic drift.

Hatcheries are also encouraged to use larger females as broodfish to increase egg production and to improve the quality of fish seed.

It is recommended that fish hatchery managers and fish farmers adopt better record keeping on the pedigree of their broodfish so that this information can serve as a guide in the future selection of parent fish for breeding.

A breeding program should be set up to improve the performance of aquaculture catfish in terms of growth and survival. Broodstock from the breeding program can be produced and distributed among hatcheries across Nigeria. This is a task for the government or larger aquaculture companies.

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# 10. APPENDIX

**Questionnaire: Catfish Brood Stock Management Current Practices in Nigeria**

1. What are the potentials sources of their brood stock fish?
    a) Wild
    b) Importation
    c) Brood stock bank
    d) Raise the brood stock fish from fingerlings/juvenile
    e) Other farms

2. What are the criteria used in selecting Male and female brood stock fish?
    a) Weight
    b) Age
    c) Others, specify………………

3. What is the average weight of fish used as brood stock?
    a) 500g
    b) 500g- 1kg
    c) 1kg-1.5kg
    d) 2kg-3kg
    e) Above 3kg
    f) Others, Specify…………

4. What is the total number of male and female brood stock fishes kept by the hatcheries for breeding?

5. How do they recognise or estimate the gravid female to determine when they are ready for hormonal injection?

6. What is the average weight of egg obtained from female brood fish before fertilization.

7. How do they estimate Fertility and Fecundity?

8. How do they estimate or determine egg quality?

9. Do they mix eggs from different females together before fertilization?

10. Do they use sperm from one (1) male to fertilise eggs from more than one (1) female?

11. How do the hatcheries determine their hatching success per batch of fishes hatched?

12. What is the hatcheries estimated hatching and survival ratio?

13. What is the type of feed fed to brood stock fishes?

14. In what form is the feed given to the brood stock fish (floating pellet or sinking pellet)?

15. What is the feeding management plan for the brood stock fishes, are they fed to satiation, or not?

16. What is the average kilogram of feed consumed per day/weight/number of brood stock?

17. What is the feeding routine (How many times daily are the fish fed)?

    a) Once daily
    b) Twice daily
    c) Thrice daily
    d) Every other day

18. How frequent do they strip out eggs from the female again?
    a) Less than 3 months
    b) 3 months
    c) 6 months
    d) 9 months
    e) 1 year

19. Do the hatcheries keep records on the ages of brood stock?

20. Do they estimate the growth rate of fingerlings and juvenile?

21. What percentage of the fishes hatched are shooters in each batch?

22. Do they keep the shooter fish and raise them for brood stock fish?

23. Do the hatcheries put into consideration that inbreeding may occur due to sources of the brood stock?
    a) Yes
    b) No

24. What feedback do they receive from farmers who purchase fingerling or juvenile from these hatcheries?

25. What are the current challenges faced by the brood stock farm and hatcheries with respect to quality brood stock?

26. What are the possible solutions or measures to overcome these challenges?