



This breeding plan was developed as an outcome of several years of studies on the genetics of African catfish (*Clarias gariepinus*) in Nigeria. Breeding goals, mating design, selection strategy and the underlying factor responsible for the occurrence of shooters will be delved into.

## Breeding Plan for African Catfish in Nigeria

*Clarias gariepinus*, Burchell 1822

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## 1.0 Background

This breeding plan was developed as an outcome of several years of studies on the African catfish in Nigeria. As a requisite to setting up a breeding program for this aquaculture species, the following studies were carried out leading up to this breeding plan:

1. A review of the research on the African catfish genetics was carried out to establish a baseline and to identify gaps to be filled.
2. A survey of catfish hatcheries was carried out in 9 aquaculture producing states of Nigeria to understand the various practices, problems, prospects and areas needing intervention. Also, to assess the level of knowledge of the hatchery owners/managers on genetic management of stock and the implication of certain practices on inbreeding and fish seed quality.
3. A survey of catfish seed market was carried out to understand the fate of the fish seeds in the hands of business men, what sort of management practices they undertake, what biosecurity measures are in place, understanding the drivers of demand, source, sales and whether or not they are aware of implications of certain practices on the quality of the fish seeds.
4. Fin samples were collected from broodstock of 33 volunteering farms and 2 rivers (Rivers Niger and Benue). A total of 282 samples were sent to Australia (Diversity Arrays Technology Ltd.) for next - generation sequencing; to assess the levels of inbreeding and genetic variation within and between the different families, strains or populations.
5. Findings from the aforementioned studies led to the draft of a comprehensive best management practices guidelines for African catfish hatcheries – and this document was used to train a total 80 hatchery operators across the 9 states of the country. This is with a view of correcting certain practices that create bottlenecks in a breeding population.
6. A study on traits of interest was conducted to identify what traits are important to the hatchery operator, the on-grower, whole seller and the different kinds of processors, and consumers. This study was aimed at understanding what traits need to be selected for in our planned breeding programme, and how can these various traits be organized into a single genetic improvement program.

## 2.0 Introduction

The African catfish *Clarias gariepinus* is increasingly becoming an important aquaculture candidate in the sub-Saharan Africa, the most important species in Nigeria and an efficient feed converter, thus, its culture spans 4 continents of the world despite being native to Africa. This growth of the catfish industry in Nigeria is limited by inadequate supply of good quality fish seeds (fingerlings and juveniles) and good quality fish feeds. Given the right environment and management, the quality of fish seeds produced hinges largely on the genetics/quality of the broodstock used. While culture systems of *Clarias* has been researched in Belgium, The Netherlands, Central Africa, Ivory Coast and South Africa (Hecht *et al.*, 1996 and Miller and Atanda, 2011) with Nigeria benefiting a lot from the outcomes, the focus of current research has barely shifted from catfish nutrition, endocrinology, water quality and other management issues etc. Until recently, studies on the genetic management of African catfish stocks has been minimal, and very few studies have been documented, especially using modern molecular biology techniques as has been done with tilapia, salmon, carp, etc.

In order to understand and address some of the root causes of poor-quality fingerlings production, a study on hatchery practices in the *C. gariepinus* catfish industry was conducted. Results from the survey showed that only 3% of farmer exclusively sourced broodstock from the wild while 97% were all sourced from farms. Hatcheries produced different kinds of catfish seeds as only 54% of the respondent dealt exclusively on *Clarias gariepinus* while 46% produced *C. gariepinus*, *Heterobranchus longifilis*, *Heterobranchus bidorsalis*, and their respective hybrids with *C. gariepinus*. By implication, when a breeding programme is planned, attention needs to be paid the species produced by the hatcheries, why, and how a multispecies hatchery will perform against a mono-species hatchery. With 95% of respondents reusing their female broodstock, 67.57% of them reuse them up to three times in a year and only 3% of the respondents maintain a mating ratio of 1:1, the effective breeding number ( $N_e$ ) will rapidly decrease in an already inbred stock. This is further exacerbated by the fact that 94% of hatcheries select broodstock at grow-out stage, which are likely to be bred from a single mom and dad in commercial hatcheries. It is therefore important that the best management be adopted by every hatchery operator.

To understand the levels of inbreeding and genetic variation within and between farms, 282 fin samples were collected from broodstock of *C. gariepinus* in 35 locations (33 hatcheries and Rivers Niger and Benue). Next generation sequencing (DArTSeq) was used to develop SNP chips. From the results, 72,140 loci were identified from 280 samples (the remaining 2 samples failed). Following filtration, 6,797 loci and 276 individuals were called. An average observed heterozygosity of 0.082034 and an expected heterozygosity of 0.091318 were recorded. The very low heterozygosity values suggest that most of the farmed populations are inbred. It is noteworthy that 12 of the 33 farmed populations had negative  $F_{IS}$  values, suggesting no inbreeding within the populations sampled although the sample sizes in this study is low per hatchery, the overall performance of the broodstock in the industry suggests the need for an immediate intervention – a catfish genetics improvement programme.

A phylogenetic tree comprising all farms and locations was derived based on the SNPs discovered (**Figure 1**). Five major clades were observed with the wild stock from Rivers Benue and Niger aligning in the fifth clade closely with two commercial farms. The principal component analysis shows that the wild population were themselves distant from one another and also distant to some of the farmed stocks (**Figure 2**).

With 76% of respondents selecting shooters to raise as broodstock, and the fact that shooters are just a very few (usually less than 2% of the population) individuals in a cohort, produced from same families and raised together or separately to be used as broodstock, further increases the chances of inbreeding depression. The fact that new shooters emerge almost every week, hence needing sorting is also worth pondering upon. If they were actually genetically superior as widely proclaimed in the industry, why was the trait suppressed in the new shooters by the presence of the older shooter within the same cohort? Are they actually genetically superior or opportunistic cannibals that have gained size advantage and appetite for fish? This question needs to be addressed using a structured approach in a breeding programme.

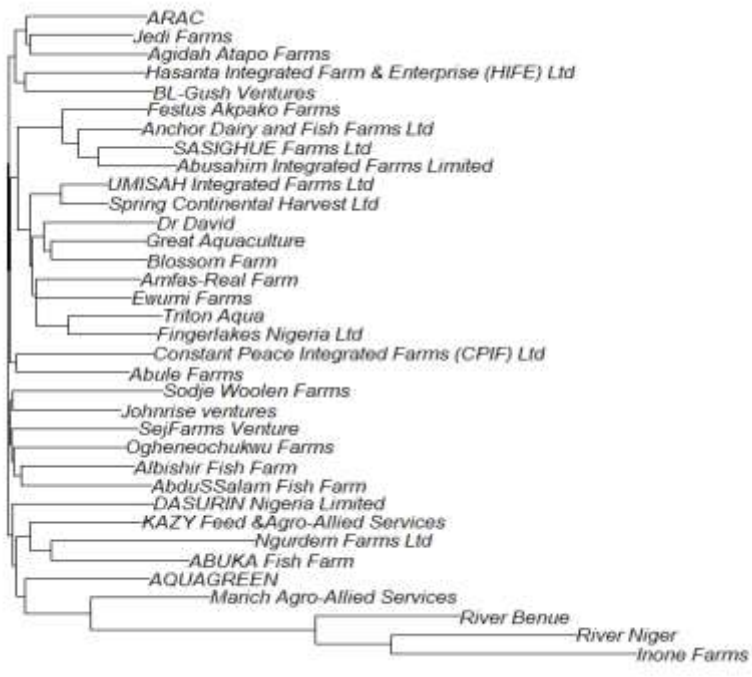


Figure 1. Phylogenetic tree

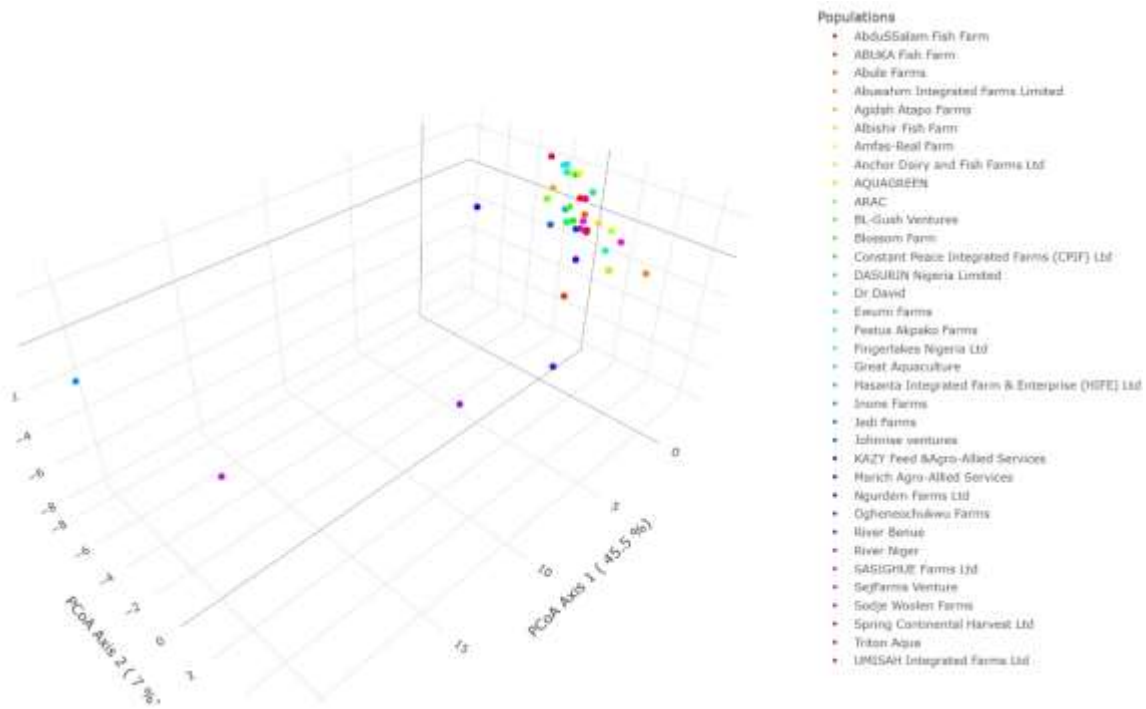


Figure 2. Principal component analysis, 3D

### 3.0 The Nigerian Market Demand

The Nigerian catfish aquaculture industry is comprised of many actors with both integrated markets and segregated products. In a recent study on traits assessment in the catfish aquaculture industry conducted by the WorldFish, it was reported that hatcheries require good quality broodstock for production of fish seed, and for the hatcheries. This implied healthy, highly gravid, mature, good sized (ideally 1.5 kg and above), active and non-deformed fish. Grow-out farms prefer fish seeds that are active, show good response to feed, grow fast, survive better, have good body length and are not gravid at time of sales. The middle-men and women prefer catfish that are well fed, healthy, good body length, good size (mostly 1kg – 4kg), less dense and less gravid. The processors, predominantly smokers, pepper-soup joints and fish roasters, have 2 sizes in mind. The melange usually ranging from 400 – 700g for folding round to smoke and 2 – 4 kg for cutting into chunks before smoking. In both cases, body length and less gravid fish are amongst the positive traits they look out for. Those smoking melange sizes do not worry about how gravid or not the fish are since they are yet to attain sexual maturity.

### 4.0 The Breeding Goals

Although less than 10% of the world's aquaculture production comes from genetically improved stocks (Gjedrem, 2012; Gjedrem *et al.*, 2012), the need for genetic management in *Clarias gariepinus* has been discussed at different levels (Ponzoni and Nguyen, 2008; Isa, *et al.*, 2019), in response to reports of suspected inbreeding depression, questionable mortalities, uneven growth, aggression and cannibalism-induced mortalities (van der Waal, 1978 and Hecht and Appelbaum, 1988; Hecht and Pienaar, 1993; Adeoye *et al.*, 2012; Igoni-Eqweke, 2018). It has become imperative therefore, to develop genetic management and improvement programme(s) for this species, and especially for the Nigerian catfish aquaculture industry. The question that beckons is, what type of improvement are we really embarking on?

There are different commercially important traits reported in the trait assessment study. Naturally, one will be considering integrating all the desired traits by the different stakeholders into a breeding goal. This is especially difficult as the hatchery operator for example, requires highly fecund fish as a trait to maximize his productivity amongst other traits, while every other actor in the value-chain dreads gravid fish. This is so because according to reports from the

same study on traits assessment by the author, weight loss in gravid and fatty fish on transit is considered higher than those of less gravid fish, during processing, the eggs are considered as disadvantage because the fish is weighed with the eggs at time of purchase, but the eggs have to be removed before processing, thus reducing the weight of the fish. It is unclear if high fecundity is linked to early maturity or not in the African catfish, as such, it is only wise to approach these traits independently or prioritize selection for late maturity over fecundity. Fecundity increases with increase in body size of fish, as such will not be considered here as a trait since we are already selecting for fast growth rate. Selection for late maturity will be a focal point because, if that happens, issues of too gravid fish during transit or processing will be resolved, and ultimately better harvest weights and sizes will be obtained as a result of more energy being directed into growth rather than gonad development.

Selection for growth (harvest weight and body length) is a primary objective for us based on findings from studies conducted on traits. Because aquaculture in Nigeria has increasingly become peri-urban, adaptation to different culture environment will form a key component of our breeding plan. As such a GxE will be incorporated to assess performance of the fish in different culture environment i.e. earthen ponds, concrete tanks and plastic tanks. Since we will be recording body weight and length, condition factor will be computed and correlations deduced.

Selection for FCR and disease resistance are quite complex to deal with at the onset of a breeding programme, we therefore are not deliberately incorporating in our primary objectives in the short run. However, performance will be evaluated as adequate data will be collected to enable us select for feed conversion efficiency and survival rate. Quality traits such as meat quality, reduced fat, dressed-out percentage, fillet yield, taste, firmness will be looked at as we get comfortable with the initial traits we are working on and as the industry evolves further.

Again, the lack of a genetic linkage map for this species make it difficult to recognize linked traits and antagonistic traits. We therefore are planning to focus on growth rate, FCE, late maturity, adaptation (GxE) and survival as our primary traits of interest in our breeding programme.

## 5.0 Current African Catfish Genetic Resources in Nigeria

In the industry, there are different strains of catfish that have been bred and interbred over a period of about 2 decades now. Some of them were from the Netherlands (the Dutch *Clarias*) while others are indigenous strains sourced from different water bodies and domesticated over a period of time. The Dutch domesticated catfish originally from West Africa and the Central African Republic was domesticated in The Netherlands in the 1970s and have over the years been bred in captivity. They are known to have good growth performance even though they have not undergone any form of science-based genetics improvement programme; rather “green fingered selection”. Presently, only few farms in Nigeria could trace the origin of their broodstock to the wild, as most of the farmed fish have been bred from the Dutch strain and a mix of the Dutch and the wild strains. The performance of these strains varies from one farm to another. While the husbandry system also varies, some farms have reported differences in performance of different batches of fish stocked on the same farm, and these fish were either sourced from different batches from the same hatchery or sourced from different hatcheries altogether; suggesting the need for evaluation. The performance of the Dutch strain was considered superior at the onset of introduction, however, with the level of improvement in husbandry systems in Nigeria today, it will be a valuable addition to evaluate the performance of the Dutch and a few other foreign strains in comparison to the local strains. Farmers have reported poor performance, deformities and mortalities which they themselves attribute to inbreeding depression. Deformities such as lordosis, missing pectoral fin(s), concave jaws etc. are commonly observed in the industry. While we have collected samples and analysed for genetic variation, it is still important to assess the different strains of catfish to correlate the levels of variation to growth performance, survival and well-being.

There are over a thousand water bodies in Nigeria comprising rivers, lakes, streams, dams and reservoirs. Majority of these water bodies house indigenous strains of the African catfish and thus constitute a wealth of resource for sourcing broodstock for genetic improvement programmes. Although the growth performance of the wild population is not as fast as the Dutch-domesticated and farmed strains in Nigeria, the levels of the genetic variation could be very high upon which selection can be based.

## **6.0 Current Resource Constraints**

Breeding programs require lots of resources and time to accomplish set goals. Ideally, the size and type of a breeding programme should determine the number of tanks/ponds to be used to keep the different families involved (as in the case of a pedigree breeding programme), the number of individuals per family also determines the size and or number of tanks to be used. Often, most commercial farms in Nigeria hardly make provision for research facilities especially when multiple tanks or ponds are required as is the case with a breeding programme. For example, a minimum of 125 tanks will be required to raise 125 families in a pedigree breeding programme. To extend the work into different environment (GXE) means additional 125 earthen ponds and 125 concrete tanks will be required. The government should have been in a better position to run a breeding program, however, the bureaucracy, inconsistency in funding, nonchalant attitude towards work and lack of continuity in the face of tenure change are some factors mitigating against domiciling a breeding program in an agency or ministry of the Nigerian government. A well-trained quantitative geneticist is required to man a breeding program. PIT tags, water quality monitoring kits, good quality feeds, good water volume and quality, stable electricity, reliable and competent support staff are some requirements that must be ensured to be in place prior to commencement of the breeding programme. A SNP chip will have to be developed and markers tested. They will be used for the parentage assignment and family identification. Work has already commenced on development of markers for diversity and population studies, this will need to be extended to the development on the SNP-chip.

## 7.0 Proposed approach

### 7.1 Strain and Population Testing

In order to develop effective genetic management programmes targeting improvement of different traits, it is important to evaluate the suitability of different strains and populations for aquaculture and evaluate the heritability of these traits. This is important because there is shortage of information about the genetics of different populations of *C. gariepinus* (both wild and farmed) (Volckaert and Agnès, 1995; Nguyen, 2008 and Isa et al., 2019), and the heritability of traits of commercial importance. This evaluation should be based on traits of interest for economic, conservation and sustainability purposes. Strain testing can be done either simply or using full or partial diallel crosses. Ideally, genetic materials are collected from multiple sources to ensure variation exist between the different sources. It is advisable to include wild strains in the breeding programme. This plan therefore will be based on 5 strains; 1 Dutch domesticated strain (from the Netherlands), 1 Thai domesticated strain (from Thailand), 1 farmed strain from Nigeria and 2 wild strains – 1 from Nigeria and the other from Zimbabwe.

### 7.2 Mating Design

The ease of artificial stripping of females in *Clarias gariepinus* makes it possible to have a wide range of mating designs. Males are dissected to collect the milt which can be extended and split into multiple parts also to facilitate production of full sibs and a wide number of half-sibs. Each population will comprise 5 males and 5 females and a partial diallel cross will be used to produce 125 families in a 5 by 5 factorial design as shown in **Table 1**. Each male will cross 5 females (one from each population) and the eggs from each female will be fertilized by sperm of 5 males (one from each population). This will produce 125 families from the 5 strains from where equal number of fry will be pulled together for early communal rearing, to eliminate environmental bias such as tank/pond effects, variation in stocking density or feeding regime, differences in light, shade or water quality. Such approach also minimizes the number of rearing facilities required to grow the fish, as they will be tagged when they get 50 g of weight, and grown on to harvest size (>1 kg) in six months of culture.

**Table 1: 5 by 5 Partial Diallel cross involving 50 broodstock**

F. Strain	A1	B1	C1	D1	E1	A2	B2	C2	D2	E2	A3	B3	C3	D3	E3	A4	B4	C4	D4	E4	A5	B5	C5	D5	E5	Crosses per male	
M. Strain	S/No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	
A1	1	AXA1	BXA1	CXA1	DXA1	EXA1																				ABCDE	
B1	2		BXB1	CXB1	DXB1	EXB1	AXB1																			BCDEA	
C1	3			CXC1	DXC1	EXC1	AXC1	BXC1																		CDEAB	
D1	4				DXD1	EXD1	AXD1	BXD1	CXD1																	DEABC	
E1	5					EXE1	AXE1	BXE1	CXE1	DXE1																EABCD	
A2	6						AXA2	BXA2	CXA2	DXA2	EXA2															ABCDE	
B2	7							BXB2	CXB2	DXB2	EXB2	AXB2														BCDEA	
C2	8								CXC2	DXC2	EXC2	AXC2	BXC2													CDEAB	
D2	9									DXD2	EXD2	AXD2	BXD2	CXD2												DEABC	
E2	10										EXE2	AXE2	BXE2	CXE2	DXE2											EABCD	
A3	11										AXA3	BXA3	CXA3	DXA3	EXA3											ABCDE	
B3	12											BXB3	CXB3	DXB3	EXB3	AXB3										BCDEA	
C3	13												CXC3	DXC3	EXC3	AXC3	BXC3									CDEAB	
D3	14													DXD3	EXD3	AXD3	BXD3	CXD3								DEABC	
E3	15														EXE3	AXE3	BXE3	CXE3	DXE3							EABCD	
A4	16															AXA4	BXA4	CXA4	DXA4	EXA4						ABCDE	
B4	17																BXB4	CXB4	DXB4	EXB4	AXB4					BCDEA	
C4	18																	CXC4	DXC4	EXC4	AXC4	BXC4				CDEAB	
D4	19																			DXD4	EXD4	AXD4	BXD4	CXD4		DEABC	
E4	20																				EXE4	AXE4	BXE4	CXE4	DXE4	EABCD	
A5	21																					AXA5	BXA5	CXA5	DXA5	EXA5	ABCDE
B5	22		AXB5																				BXB5	CXB5	DXB5	EXB5	ABCDE
C5	23		AXC5	BXC5																				CXC5	DXC5	EXC5	ABCDE
D5	24			AXD5	BXD5	CXD5																			DXD5	EXD5	ABCDE
E5	25				AXE5	BXE5	CXE5	DXE5																		EXE5	ABCDE
Crosses per female		ABCDE	ABCDE	ABCDE	ABCDE	ABCDE	BCDEA	CDEAB	DEABC	EABCD	ABCDE	BCDEA	CDEAB	DEABC	EABCD	ABCDE	BCDEA	CDEAB	DEABC	EABCD	ABCDE	BCDEA	CDEAB	DEABC	EABCD	ABCDE	
5x5 partial diallel cross involving 4 farmed strains (1 Dutch, 2 Thai and 1 Nigerian strain) and 1 wild strain (from a Nigerian river).																											
5 populations each comprising 5 males and 5 females i.e. a total of 50 broodstock, producing 125 half-sib families																											

### **7.3 Recording of Phenotypic and Genotypic Parameters**

A total of 50 broodstock will be producing 125 families of fish and all the broodstock will be tagged, phenotyped and genotyped at the onset of the project. Early communal rearing will be practiced, selecting 50 fry from each of the 125 families produced to create a cohort of 6,250 individuals. This will be replicated 10 times, i.e. creating 10 cohorts of 6,250 fish/cohort. Each cohort will be raised separately to 50 g, after which individuals in 1 cohort will be tagged. This tagged cohort will serve as our control where monthly growth data will be recorded and all individuals genotyped and assigned parentage. All ten cohorts will be raised to harvest size, culturing 3 cohorts in earthen ponds, 3 in plastic tanks, 3 in concrete tanks and the control will be raised in an indoor concrete tank. All fish raised in the three environments except the control will NOT be subjected to monthly sampling, rather, they will be weighed initially and at the end of the harvest point. Selection will be based on set thresholds of desired traits. All the selected fish will be genotyped and using SNP chip, assigned parentage and families. A synthetic base population will then be formed from the selected fish, upon which the breeding programme will be based. Despite the fact that some skeletal deformities are nutritionally based, all deformed fish will be culled out during selection. This breeding programme will then continue either as a pedigree breeding programme or using similar mass selection. Those from the three different environments will be subjected to the same threshold of selection for harvest weight, body length, late maturation, survival and feed conversion efficiency. This will then be followed by genotyping the selected individuals for family and strain ID. Daily record of water quality parameters, type and quantity of feed fed and mortality (if any) will be accurately kept.

### **7.4 Estimation of Breeding Values and Heritability**

Estimation of breeding values has become very possible owing to the type of crosses to be made. Each individual will be assessed on its merit. The average performance of the offspring from the 5 half-sib families produced is a better representation of the quality or value of each individual broodstock. The fact that parentage will be assigned after selection will enable identification of individuals, families and strains with the best performance in terms of traits of interests (harvest weight, body length, delayed maturity and survival). Individual selection will be employed for growth rate and FCE, while family selection will be applied for delayed maturity. Progeny testing will be employed, estimating the breeding values for all the aforementioned traits of interest before selection.

Heritability of these traits will also be assessed as a measure of what proportion of the phenotypic variation is due to genetic variation, and is expressed as  $h^2 = \sigma_A^2 / \sigma_P^2$ . In pedigreed populations, with data on phenotypes and genotypes, predicting or estimating heritability becomes possible. Heritability values differs between traits and populations and changes within a given population in response to changes in population size, environmental factors or changes in gene frequencies (Falconer and Mackay, 1996 and Oldenbroek and van der Waaij, 2015). All these factors will be taken into account.

Levels of heterozygosity will be assessed within strains and between strains to ensure inbreeding is kept on check. The wild populations therein are not only to contribute to the number of strains, but also to increase the levels of genetic variation in the eventual base population. A separate breeding programme can be set aside for the wild strains, from where they can be pulled to cross the farmed ones to increase variation.

### **7.5 Generation Time**

*C. gariepinus* attain sexual maturity at 7 – 9 months post hatch, i.e. 5 – 7 months in grow-out systems. From experience and reports of survey of hatchery practices in the Nigerian catfish aquaculture industry, broodstock perform better from a minimum of 12 months of age. In this project, we plan to have a generation time of 12 months, i.e. produce 5 generations in 5 years. This will also give time for proper genetic analysis before proceeding to the next generation, and provide ample time and opportunity for monitoring and evaluation, dissemination of broodstock and fish seeds, and generation of data on genetic gains from one generation to another.

## 8.0 Shooters as broodstock

Shooters are widely used as broodstock in the industry as reported in the introductory part of this document. Shooters will be removed from the 10 cohorts; they will be tagged, genotyped and assigned parentage. If majority of shooters come from a single family or group of families or even strain, there is an indication of a genetic link. Furthermore, if the shooters all came from the best performing families in the breeding program for fast growth rate, then it also gives an indication of a genetic link. However, if the shooters just occur randomly across the 125 families, it indicates a lack of genetic clue.

In an attempt to clear all doubts, we will take the experiment a step further by selecting 3 males and 3 females from the shooters and 3 males and 3 females from the non-shooters to set up a 2 x 3 partial diallel cross as shown in Table 2. These crosses will produce 12 families from where a second generation of shooters will be produced. Fries will be nursed and grown while shooters are selected, genotyped and assigned parentage. If all the shooters in the second generation all come from the shooters' family in the parental pair, then it confirms that there is a strong genetic factor responsible for shooters and not only the environment. If the shooters came from random families involving the non-shooters, then it strongly suggests that shooters are just opportunistic cannibals.

**Table 2: Partial diallel cross involving shooters and non-shooters**

	Females	A1	B1	A2	B2	A3	B3	Crosses/ male
Males		1	2	3	4	5	6	
A1	1	AxA1	BxA1					AB
B1	2		BxAB1	AxB1				BA
A2	3			AxA2	BxA2			AB
B2	4				BxB2	AxB2		BA
A3	5					AxA3	BxA3	AB
B3	6	AxB3					BxB3	AB
Crosses/female		AB	AB	BA	AB	BA	AB	
2 x 3 partial diallel cross involving shooters (denoted as A) and non-shooters (denoted as B)								
3 male and 3 females shooters and 3 males and 3 female non-shooters produce 12 families								

## References

- Falconer, D.S. and T.F.C. Mackay, 1996. Introduction to quantitative genetics, Fourth Edition, Longman Group Ltd, 464 pp.
- Gjedrem, T., 2005. Selection and Breeding Programs in Aquaculture. Springer Netherlands, 364 pp.
- Gjerde, B., 2005. Design of Breeding Programs. In: Gjedrem, T. (Ed.), Selection and Breeding Programs in Aquaculture. Springer Netherlands, pp. 173 – 195
- Hecht, T. and Pienaar, A. G. (1993) A review of cannibalism and its implications in fish larviculture. *Journal of the World Aquaculture Society*, 24 (2), pp. 246–261.
- Hecht, T., Oellermann, L. and Verheust, L. (1996) Perspectives on *clariid* catfish culture in Africa. *Aquatic Living Resources*, 9 (S1), pp. 197–206.
- Ibeun, M. O. (2006) Information for fisheries management in Nigeria: The role of libraries and networking. *Information for Responsible Fisheries: Libraries as Mediators*, proceedings of the 31st Annual Conference: Rome, Italy, October 10 – 14, 2005 Available: <https://darchive.mblwhoilibrary.org/bitstream/handle/1912/1562/proc05213.pdf> (Accessed: 13 September 2017).
- Oldenbroek, K. and van der Waaij, L. (2015) Textbook Animal Breeding and Genetics for BSc Students', *Centre for Genetic Resources The Netherlands and Animal Breeding and Genomics Centre*, p. 245. Available: <https://wiki.groenkennisnet.nl/display/TAB/Textbook+Animal+Breeding+and+Genetics> (Accessed: 20 November, 2018).
- Igoni-Egweke, Q.N. (2018). Analysis of value addition in commercial catfish (*Clarias Gariepinus Heterobranchus* Spp.) production in Rivers State, Nigeria. Thesis submitted to the Department of Agricultural Economics, Federal University of Technology, Owerri. Available <http://futospace.futo.edu.ng/xmlui/handle/123456789/1894> (Accessed: 02 January 2019).
- Miller, J. W. and Atanda, T. (2011) The rise of peri-urban aquaculture in Nigeria. *International Journal of Agricultural Sustainability*, 9 (1), pp. 274–281.
- van Der Waal, B. C. W. (1974) Observations on the breeding habits of *Clarias gariepinus* (Burchell 1822). *Journal of fish biology*, 6 (1), pp. 23–27.