



Assessment of Inbreeding Depression and Broodstock Management Practices in Catfish Farming in Lagos State, Nigeria

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ABSTRACT

This study assessed inbreeding depression and broodstock management practices among catfish farmers and hatchery owners in Lagos State, Nigeria. Structured questionnaires were administered to 265 respondents; data were analyzed using descriptive statistics, Chi-square tests, independent-samples t-tests, one-way ANOVA and Pearson correlation at $p < 0.05$. Most respondents (79.6%) sourced broodstock through purchase from other farms, 58.9% used multiple sources, and only 6.8% relied exclusively on own-farm stock. Nearly half (46.8%) used skewed sex ratios of four or more females per male. Effective population size (N_e) fell below the recommended threshold of 50 for most farms, with 67.2% recording an inbreeding rate above one percent per generation. Over 90% selected fast-growing "shooters" as breeding stock, while only 17.7% kept systematic breeding records. Farm scale, experience, education and record-keeping significantly predicted N_e category and management outcomes ($p < 0.05$). Mean N_e and the number of inbreeding-depression signs observed differed significantly by farm scale, shooter-selection practice, record-keeping status and education ($p < 0.001$). Broodstock holding size correlated positively with N_e ($r = 0.684$, $p < 0.001$), and N_e correlated negatively with the number of inbreeding-depression signs ($r = -0.412$, $p < 0.001$). Leading constraints were insufficient supply of genetically diverse catfish (74.7%) and lack of documentation (71.3%). The study concluded that broodstock management practices were significantly associated with inbreeding-depression risk, and recommended zonal broodstock banks, mandatory record-keeping and targeted extension services.

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INTRODUCTION

Catfish (*Clarias gariepinus*) aquaculture is among the most important livelihood and food-security activities in Nigeria, where Lagos State records the highest concentration of hatcheries and grow-out farms in the country. Nevertheless, hatchery managers across Nigeria have been reporting unpredictable hatching failures and unexplained fry and fingerling mortalities that have been linked to inbreeding resulting from undocumented exchange of broodstocks among farms and geopolitical zones and the lack of an effective zonal broodstock bank (Areola et al., 2024). Inbreeding depression, which is the reduction in fitness and other traits that occurs when organisms that are too closely related mate with each other, is a significant concern in small hatchery populations, especially where breeding is not well managed (Eknath & Doyle, 1990). For instance, inbreeding has been shown to cause the production of non-viable eggs or poor larvae survival in African catfish, especially when using closely related broodstocks of the same species (Tine et al., 2022). Similarly, a recent molecular assessment of genetic diversity of *C. gariepinus* in Nigeria showed that farmed populations had lower genetic diversity than their wild counterparts and that these domesticated populations had undergone severe reductions in effective population sizes,

with extensive admixture between unrelated stocks (Sanda et al., 2026). These findings point to the need for improved management of broodstocks in hatcheries to avoid inbreeding and the subsequent loss of genetic diversity in *C. gariepinus*. In addition to undocumented exchange of broodstocks among farms and zones, the use of shooters – the fastest-growing individuals in a given stock – as replacement broodstocks is another practice that has been associated with higher rates of inbreeding in aquaculture. A survey of hatchery operators in Uganda showed that over 90% of the respondents used shooters for breeding and that effective population sizes in their hatcheries were lower than expected (Kwikiriza et al., 2025). Similar observations have been made in Nigeria, where domesticated *C. gariepinus* populations have lower egg and sperm qualities than the wild populations from where they were originally sourced (Megbowon et al., 2014). Worse still, controlled breeding trials in Nigeria that involved crossing and stocking of *C. gariepinus* populations from different ecological zones showed that survival and growth rates varied significantly depending on the parent populations used (Kabir et al., 2026). These findings confirm that broodstock sourcing and breeding practices are significant contributors to inbreeding in catfish hatcheries. However, there are limited empirical studies on the use of broodstocks, effective

population sizes, and their associations with signs of inbreeding depression among catfish farmers and hatchery operators in Lagos State. This study sought to fill this research gap. Hence this study assessed the inbreeding depression and broodstock management practices in catfish farming in Lagos State, Nigeria

MATERIALS AND METHODS

The study was performed among catfish farmers and hatchery operators in Lagos State, Nigeria, engaged in hatchery, grow-out, or integrated activities. A cross-sectional survey design was used. A multi-stage sampling procedure was adopted. First, Lagos State Local Governments (LGAs) with catfish production were identified from the state fisheries department records. Within each LGA, respondents were selected using a combination of purposive (for hatchery operators, who are a smaller, specialized group) and simple random sampling (from farmer-association membership lists for grow-out and integrated operators). The sample size of 265 was selected using Krejcie and Morgan's (1970) table for a 95% confidence level, which was adequate given the estimated size of registered catfish farmers and hatchery operators in Lagos State. The questionnaire was pilot tested by 20 farmers not selected for the main study, and adjustments were made to improve clarity and reliability (Cronbach's $\alpha = 0.89$). Of the 280 questionnaires administered, 265 completed sets were collected, giving a 94% response rate.

An effective population size (N_e) was estimated for each respondent using the formula $N_e = 4N_mN_f/(N_m+N_f)$ (Eknath & Doyle, 1990). In this formula, N_m and N_f represent the numbers of male and female broodstock used for breeding in the next generation, which is actually a census of breeding animals adjusted by the respondent's contribution rate rather than the total number of breeding animals that they hold.

This adjustment was required because for most respondents, fewer than 50% of their broodstock (72.1%) are used for breeding in any given cycle. Therefore, using the total number of breeding animals would overestimate N_e . The rate of inbreeding was then calculated as $\Delta F = 1/2N_e$. The data were analysed using descriptive statistics (frequencies, percentages, means with standard deviation), association tests (Chi-square), comparison tests (independent-samples t-test, one-way ANOVA), and Pearson's correlation at a significance level of $p < 0.05$. Data analysis was performed using SPSS.

RESULTS AND DISCUSSION

Socio-Demographic and Enterprise Characteristics

Table 1 presents the socio-demographic and enterprise characteristics of the 265 respondents. Most respondents were male (84.2%), aged between 31 and 50 years (68.3% combined), and held tertiary education (47.5%). Just over two-fifths of respondents ran grow-out-only operations (35.8%), and more than half produced fewer than 100,000 seed annually (55.8%).

Table 1: Socio-demographic and Enterprise Characteristics of Respondents (N = 265)

Variable / Category	N	%	Mean $\pm$ SD
Sex Male	223	84.2	
Sex Female	42	15.8	
Age (years) ≤ 30	38	14.3	42.6 $\pm$ 9.8
Age 31–40	89	33.6	
Age 41–50	92	34.7	
Age > 50	46	17.4	
Education No formal/Primary	41	15.5	
Education Secondary	98	37.0	
Education Tertiary	126	47.5	
Experience < 5 years	67	25.3	9.4 $\pm$ 5.7
Experience 5–10 years	112	42.3	
Experience > 10 years	86	32.5	
Enterprise Hatchery only	78	29.4	
Enterprise Grow-out only	95	35.8	
Enterprise Integrated	92	34.7	
Seed output Small ($< 100,000$)	148	55.8	
Seed output Medium (100,000–500,000)	89	33.6	
Seed output Large ($> 500,000$)	28	10.6	
Ownership Sole proprietorship	198	74.7	
Ownership Partnership/Company	67	25.3	

Broodstock Sources, Holding Size, Sex Ratio and Effective Population Size

Table 2 shows that the majority of respondents sourced broodstock through purchase from other farms (79.6%) or from mixed sources (58.9%), while only 6.8% relied exclusively on their own farm and 17.7% used wild-caught stock. Nearly half of respondents (46.8%) maintained a

female-to-male sex ratio of four or more to one, and 72.1% reported that less than half of their held stock contributed to the next generation. Estimated N_e fell below the conventionally recommended threshold of 50 for 67.2% of respondents, corresponding to an estimated inbreeding rate above 1% per generation for 61.1% of the sample.

Table 2: Broodstock Sources, Holding Size, Sex Ratio and Effective Population Size Indicators (N = 265)

Variable / Category	n	%	Mean ± SD
Broodstock source Own farm exclusively	18	6.8	
Broodstock source Purchased from other farms	211	79.6	
Broodstock source Wild-caught	47	17.7	
Broodstock source Mixed sources	156	58.9	
Broodstock source Research institutes/government	22	8.3	
Broodstock held annually <20	76	28.7	68.4 ± 89.2
Broodstock held 20–40	68	25.7	
Broodstock held 41–60	45	17.0	
Broodstock held 61–150	52	19.6	
Broodstock held >150	24	9.1	
Sex ratio (♀:♂) 1:1	29	10.9	
Sex ratio 2–3:1	112	42.3	
Sex ratio ≥4:1	124	46.8	
Contribution to next generation <50%	191	72.1	
Contribution to next generation ≥50%	74	27.9	
Estimated Ne <50 (high risk)	178	67.2	41.3 ± 38.6
Estimated Ne 50–100	64	24.2	
Estimated Ne >100	23	8.7	
Inbreeding rate (ΔF) >1% per generation	162	61.1	
Inbreeding rate 0.5–1%	71	26.8	
Inbreeding rate <0.5%	32	12.1	

Note: Ne was calculated as $4N_mN_f/(N_m+N_f)$ using reported census numbers, contribution rates and sex ratios; ΔF was approximated as $1/2Ne$ following Eknath and Doyle (1990). Values of ΔF above 1% per generation indicate an elevated risk of inbreeding depression

Broodstock Selection, Replacement, Mating and Record-Keeping Practices

As shown in Table 3, the overwhelming majority of respondents (90.9%) selected shooters as future broodstock, consistent with patterns reported for hatchery operators elsewhere in the region (Kwikiriza et al., 2025). While 81.1%

reported having a formal replacement plan, replacement typically drew on a narrow genetic base: 75.8% used four or fewer families or batches for replacement, and only 17.7% kept systematic pedigree or mating-pair records. Active control of mating to avoid close relatives was practised by just 14.7% of respondents.

Table 3: Broodstock Selection, Replacement, Mating and Record-keeping Practices (N = 265)

Practice / Category	n	%
Selection of shooters as future broodstock Yes	241	90.9
Selection of shooters No	24	9.1
Formal broodstock replacement plan Yes	215	81.1
Formal broodstock replacement plan No/ad-hoc	50	18.9
Replacement frequency Biannual (n = 215)	88	40.9
Replacement frequency Annual	88	40.9
Replacement frequency ≥2 years	39	18.1
Families/batches used for replacement ≤4	201	75.8
Families/batches used for replacement >4	64	24.2
Systematic pedigree/mating-pair records Yes	47	17.7
Systematic pedigree/mating-pair records Partial/none	218	82.3
Active control of mating to avoid close relatives Yes	39	14.7
Active control of mating No	226	85.3
Female broodstock weight 0.5–1.0 kg	68	25.7
Female broodstock weight 1.0–1.5 kg	132	49.8
Female broodstock weight 1.6–2.5 kg	52	19.6
Female broodstock weight >2.5 kg	13	4.9
Broodstock feed Commercial broodstock feed	98	37.0
Broodstock feed Commercial grow-out feed	98	37.0
Broodstock feed Mixed commercial	34	12.8
Broodstock feed On-farm formulated	35	13.2

Awareness of Inbreeding Depression and Observed Phenotypic Signs

Table 4 shows that 72.8% of respondents were aware that small effective population size, sibling mating, or unknown parentage could cause inbreeding depression. Despite this awareness, 45.3% of respondents reported observing four or

more phenotypic signs consistent with inbreeding depression on their own farms, most commonly slow growth or extended time to market size (67.2%) and a high proportion of runts or uneven size at harvest (62.3%), echoing farmer accounts of unpredictable hatching and mass fry mortality reported elsewhere in Nigeria (Areola et al., 2024).

Table 4. Awareness of Inbreeding Depression and Observed Phenotypic Indicators (N = 265)

Item / Response	n	%
Awareness of inbreeding-depression causes Aware	193	72.8
Awareness Limited/unaware	72	27.2
Sign observed Slow growth/extended time to market size	178	67.2
Sign observed High proportion of runts/uneven size	165	62.3
Sign observed Reduced/unpredictable hatchability	142	53.6
Sign observed Low fry/fingerling survival	151	57.0
Sign observed Skeletal/morphological deformities	98	37.0
Sign observed Reduced disease resistance/elevated mortality	124	46.8
Sign observed Poor feed conversion ratio	109	41.1
Sign observed Reduced fecundity/loss of hybrid vigour	87	32.8
Number of signs per respondent 0–1	48	18.1
Number of signs 2–3	97	36.6
Number of signs ≥ 4	120	45.3

(Multiple responses permitted for signs)

Association Between Management Variables and Inbreeding-Risk Outcomes

Chi-square tests (Table 5) showed significant associations between educational level and awareness of inbreeding depression ($\chi^2 = 18.74$, $df = 2$, $p < 0.001$), years of experience and presence of a formal replacement plan ($\chi^2 = 14.92$, $df = 2$, $p = 0.001$), and farm scale and Ne category ($\chi^2 = 27.61$, $df =$

2, $p < 0.001$). Systematic record-keeping was very strongly associated with active mating control ($\chi^2 = 42.15$, $df = 1$, $p < 0.001$, Cramer's $V = 0.399$), the strongest association observed in the study. Exclusive reliance on own-farm broodstock and a skewed sex ratio ($\geq 4:1$) were both significantly associated with an Ne below 50.

Table 5: Chi-square Tests of Association between Selected Independent Variables and Key Inbreeding-risk or Management Outcomes

Independent variable	Dependent variable	χ^2	df	p	V
Educational level	Awareness of inbreeding depression	18.74	2	<0.001	0.266
Years of experience	Formal replacement plan	14.92	2	0.001	0.237
Farm scale (seed output)	Ne category (<50 vs ≥ 50)	27.61	2	<0.001	0.323
Selection of shooters	Observation of ≥ 3 inbreeding signs	11.38	1	0.001	0.207
Systematic record-keeping	Active mating control	42.15	1	<0.001	0.399
Exclusive own-farm source	Ne <50	6.84	1	0.009	0.161
Sex ratio ($\geq 4:1$ vs lower)	Ne <50	19.47	1	<0.001	0.271

Note: All associations remained significant after Bonferroni adjustment where applicable.

Table 6 compares mean Ne and mean number of observed inbreeding signs across grouping variables. Ne increased significantly with farm scale ($F = 31.42$, $p < 0.001$) and was significantly lower on farms that selected shooters as broodstock ($t = -3.91$, $p < 0.001$) and on farms without

systematic record-keeping ($t = 5.63$, $p < 0.001$, in favour of the systematic group). The number of observed inbreeding signs followed the inverse pattern in every comparison, decreasing with farm scale, systematic record-keeping and higher educational attainment ($p < 0.001$ in all cases).

Table 6. Comparison of Mean Effective Population Size (Ne) and Number of Observed Inbreeding Signs by Selected Categorical Variables, with Effect Sizes (N = 265)

Grouping variable	Category	Mean Ne SD	$\pm$ t/F	p	Effect size	Mean signs SD	$\pm$ t/F	p	Effect size
Farm scale	Small	28.4 $\pm$ 22.1	F=31.42	<0.001	$\eta^2 = 0.19$	3.9 $\pm$ 1.6	F=12.87	<0.001	$\eta^2 = 0.09$
	Medium	52.7 $\pm$ 35.8				3.1 $\pm$ 1.5			
	Large	89.6 $\pm$ 48.3				2.2 $\pm$ 1.3			
Shooter selection	Yes	38.9 $\pm$ 36.2	t=-3.91	<0.001	d = 0.62	3.6 $\pm$ 1.6	t=4.28	<0.001	d = 0.68
	No	68.4 $\pm$ 49.7				2.1 $\pm$ 1.2			
Record-keeping	Systematic	71.2 $\pm$ 51.4	t=5.63	<0.001	d = 0.79	2.0 $\pm$ 1.1	t=-6.14	<0.001	d = 0.86
	Partial/none	35.1 $\pm$ 32.7				3.7 $\pm$ 1.5			

Grouping variable	Category	Mean SD	Ne $\pm$ t/F	P	Effect size	Mean SD	signs $\pm$ t/F	p	Effect size
Education	Tertiary	51.8 $\pm$ 42.6	F=9.74	<0.001	$\eta^2 = 0.07$	2.9 $\pm$ 1.5	F=8.91	<0.001	$\eta^2 = 0.06$
	Secondary	36.2 $\pm$ 33.9				3.6 $\pm$ 1.5			
	Primary/none	27.5 $\pm$ 24.8				4.1 $\pm$ 1.6			

Note: Effect sizes are Cohen's d for t-tests and η^2 for one-way ANOVA. By conventional benchmarks, $d \approx 0.2/0.5/0.8$ and $\eta^2 \approx 0.01/0.06/0.14$ correspond to small/medium/large effects the record-keeping and shooter-selection comparisons show medium-to-large effects, while the education comparisons are medium.

Pearson correlation (Table 7) confirmed that years of experience, broodstock holding size and female broodstock weight were all significantly, positively correlated with estimated Ne, while the number of observed inbreeding signs was significantly negatively correlated with all the other

three. The strongest relationship in the matrix was between broodstock holding size and estimated Ne ($r = 0.684$, $p < 0.001$), and Ne itself showed the strongest negative correlation with the number of observed signs ($r = -0.412$, $p < 0.001$).

Table 7: Pearson Correlation Matrix among Continuous Variables Related to Inbreeding Risk and Management (N = 265)

Variable	1	2	3	4	5
Years of experience	1				
Number of broodstock held	0.312***	1			
Estimated Ne	0.287***	0.684***	1		
Number of observed signs	-0.241***	-0.356***	-0.412***	1	
Female broodstock weight (kg)	0.198**	0.163*	0.221***	-0.187**	1

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$. rep. the varying level of significant

Constraints to Effective Broodstock Management

Table 8 ranks the constraints respondents identified as limiting effective broodstock management. Scarcity of genetically diverse, quality broodstock was the most frequently cited constraint (74.7%), followed closely by the lack of systematic pedigree and source documentation

(71.3%) and inadequate technical knowledge of genetic management and Ne (66.4%). The absence of functional zonal or national broodstock banks was cited by more than half of respondents (58.1%), directly corroborating the intervention recommended by farmers surveyed elsewhere in Nigeria (Areola et al., 2024).

Table 8: Major Constraints to Effective Broodstock Management and Prevention of Inbreeding Depression

Constraint	n	%	Rank
Scarcity of genetically diverse/quality broodstock	198	74.7	1
Lack of systematic pedigree and source documentation	189	71.3	2
Inadequate technical knowledge of genetic management and Ne	176	66.4	3
High cost of specialised broodstock feed and inputs	165	62.3	4
Absence of functional zonal or national broodstock banks	154	58.1	5
Water-quality problems affecting broodstock performance	112	42.3	6
Limited access to improved/imported strains	98	37.0	7

Discussion

The finding that nearly four-fifths of respondents purchased broodstock from other farms, often in combination with other sources, while barely a fifth maintained pedigree records on a systematic basis, suggests that broodstock exchange in the study area is common, but not systematically documented. The same observation is typical of Nigerian hatchery operators at large, who freely exchange catfish broodstock between hatcheries and across geopolitical zones, with little or no knowledge of the filial relationships between the animals they purchase (Areola et al., 2024). In line with similar findings, the Ne estimates obtained in this study indicate that two-thirds of respondents used effective population sizes below the universally accepted threshold of 50, implying an inbreeding accumulation rate of over 1% per generation for most participants.

The observed near-universal preference (90.9%) for shooters as breeding stock is entirely in line with reports on the use of similar heuristics by Ugandan catfish hatchery operators (Kwikiriza et al., 2025). As shown by the Chi-square and t-test analyses, this selection criterion was strongly associated

with the manifestation of three or more signs of inbreeding depression, as well as lower mean Ne estimates compared to non-shooter-selecting farms. In particular, the association between shooting and decreased genetic diversity appears to be a potentially modifiable risk factor for inbreeding among hatchery-bred catfish in Nigeria, although the study's cross-sectional design precludes establishing a causal relationship. The observed positive association between the scale of broodstock holdings and the corresponding Ne estimates, as well as the negative association between Ne and the number of signs of inbreeding depression, are entirely consistent with the established understanding of the impact of effective population size on the rate of inbreeding (Eknath & Doyle, 1990). The finding reflects the fact that the majority of farms (62.5%) selected effective sizes below 50 and, consequently, experience a rapid loss of genetic diversity. This phenomenon is further compounded by reports of extensive undocumented admixture among hatchery stocks in Nigeria (Sanda et al., 2026). In line with the findings of this study, the main signs of inbreeding depression identified by Nigerian catfish farmers are slow growth rates, irregular sizes at harvest, and

unpredictable hatchability. Indeed, the three phenomena have been previously reported in connection with Nigeria's catfish hatcheries, either as signs of mass fry mortality following unexplained hatching failures (Areola et al., 2024) or as reduced hatching rates and fry survival capacities common to many farms using genetically similar broodstocks (Tine et al., 2022).

The extremely strong association between systematic record-keeping and active control of mating pairs to prevent interrelations between related broodstocks (Cramer's $V = 0.399$), which emerges as the strongest in the study, suggests that record-keeping may be used as a proxy for the active management of genetic diversity by the respondent hatcheries. This assumption is supported by the findings of Kabir et al. (2026), who report that careful control of mating pairs in Nigerian *C. gariepinus* hatcheries could improve survival and growth rates of fry through the manipulation of relevant breeding values. In this regard, note that the study's finding on the strong association between record-keeping and the reduction of signs of inbreeding depression might be leveraged to shift the focus of intervention efforts on processes directly affecting genetic diversity, given the relative ease of improving record-keeping practices in the short term. Nevertheless, it is important to note, in the context of Nigeria's catfish hatcheries, that the inbreeding coefficients traditionally used to assess the impact of hatchery practices on target populations often prove to be inadequate (Christie et al., 2012). In other words, while the signs of inbreeding depression identified by Nigerian farmers are consistent with existing literature, the use of an extended set of genetic coefficients may yield more nuanced results for the analysis of Nigeria's hatchery stocks.

In terms of Nigeria's farmers' recommendations, the identified constraints, as reflected in the constraints ranking, were largely focused on the general shortage of genetically diverse broodstocks, the lack of documentation as a source of genetic diversity information, and the absence of a system of zonal broodstock banks. These three factors emerge as the most pressing challenges in Nigeria's catfish aquaculture, with the last of the three directly ranking from the surveyed farmers (Areola et al., 2024).

CONCLUSION

This study found that catfish hatcheries in Lagos State, Nigeria, predominantly operate with effective population sizes below the established threshold, a factor associated with the use of shooter fish as breeding stock, skewed sex ratios, and the absence of systematic record-keeping. In turn, farm size, years of experience, educational status, and systematic recordkeeping were identified as factors associated with lower risks of inbreeding and better management practices among hatchery operators. It is recommended that state

governments and farmer associations establish zonal broodstock banks for documented stock exchange, that extension services promote simplified pedigree and mating-pair recordkeeping tools alongside targeted training to address the shooter selection heuristic.

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