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Intraspecific hybridization of native and exotic strains of *Clarias gariepinus* and growth performance of hybrid fry in South Western, Cameroon

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Abstract

Increase in global population has resulted in a drastic rise in demand of fish and fisheries products hence increased aquaculture production is clearly needed to meet this demand. Intraspecific hybridization was carried out between a Native Cameroon (NS), an Exotic Hybrid (EH) strain of *Clarias gariepinus* and their reciprocal hybrids with the aim of producing high per formant and resistant seed with improved hatchability, survival, and growth performance under indoor conditions in order to increase fish seed production. The effect of hybridization on growth performance and survival of 3000 *Clarias gariepinus* fry fed shell-free *artemia* was evaluated under indoor conditions for 14 days. Fertilization rate was highest in the NS♀ x EH♂ hybrid (45.50%) ($P<0.05$). Hatchability was higher in the pure parent crosses (41.10% and 36.82%, respectively) ($P=0.05$). Hatchability also differed significantly ($P<0.05$) between the EH♀ x NS♂ (20.60%) and the NS♀ x EH♂ (08.73%) hybrids. Percentage survival was significantly higher in the pure EH cross (75.87%) than in the pure NS cross (50.93%). Percentage survival was higher in the NS♀ x EH♂ hybrid than in the EH♀ x NS♂, although not significantly ($P>0.05$). Weight gain was highest in the pure NS (22.85mg), followed by pure EH (11.51mg), NS♀ × EH♂ (10.47mg) and EH♀ x♂ NS (9.53mg) ($P<0.05$). There was no significant difference across the treatments in length increase ($P>0.05$). Based on the significantly higher values of fertilization and survival rates, the hybrid crosses are more desirable for use in aquaculture than the native parent cross.

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Introduction

Global population expansion has resulted in a persistent and drastic rise in demand of aqua-foods hence increased aquaculture production is clearly needed to meet this demand (Mair *et al.*, 2018). Capture fisheries are at capacity or showing precipitous declines due to over fishing (Pauly and Zeller, 2017). The estimated minimum daily crude protein requirements of an adult ranging from about 65g and 85g to be obtained from animal sources (Scholtens, 2019). Encouraging fish production through aquaculture and improvement of culture species by hybridization and selective propagation will take advantage of the prolificacy, development and fast growing hybrids produced thereby shortening culture time (Oloyede, 2005; Oben *et al.*, 2015). Hybridization is the mating of genetically differentiated individuals or groups of individuals and may involve crossbreeding within a species (strain crossing) or crosses between separate species [Rahman *et al.*, 2013]. The process is precipitated by a rapid demand for high quality protein especially from aquatic sources (Adene *et al.,* 2017).

The scarcity of genetically improved fish seed is one of the major constraints to the rapid development of the aquaculture industry and stock management (Yisa *et al.*, 2018) in Cameroon. The production of improved and environmentally stable fish seed will in no doubt increase aquaculture productivity and hence increase accessibility to aqua-protein to meet the minimum daily crude protein intake requirements (Oloyede, 2005). A good supply of high quality fish seed is essential for successful aquaculture production and this can be produced through the union of gametes from two different species strains to produce a new organism of desirable character traits with the aim of improving the genetic quality of the offspring compared to the parents (Adene *et al.*, 2017). This involves mating combinations between genetically isolated populations.

To combat the problem of the introduction of non-native species, selective breeding programs in which researchers chooses the next generations broodstock based on predetermined criteria ranging from weight, resistance to disease, environmental variability, survival, increase fecundity, fry survival and ability to withstand adverse environmental conditions from domesticated native stocks (Palmer *et al.*, 2007; Abualreesh, 2020), are ongoing. This work therefore investigated the hatchability and survival rate of Native and Exotic hybrid *Clarias gariepinus* strains and their reciprocal crosses and compared their growth performance with two pure strains of *Clarias gariepinus*.

Materials and methods

Study site

This research was carried out at an experimental site setup the Limbe Nautical Arts and Fisheries Institute (LINAFI), the OKF fish hatchery complex, Limbe and the University of Buea CORAF/WECARD Fisheries laboratory in the Department of Fisheries and Aquatic Resources Management University of Buea mount Cameroon Region. Broodstock selection, and hormone injection and all laboratory procedures were done as described by Slembrouck *et al.* (2003), Sutton, (2006) and Ogunsina, (2014).

Experimental Crosses

The following genetic crosses of the two *Clarias gariepinus* strains (exotic hybrid *C. gariepinus* strain and native strain) were carried out.

Females		Males
Exotic hybrid (EH)	X	Exotic hybrid (EH)
Exotic hybrid (EH)	X	Native strain (NS)
Native strain (NS)	X	Exotic hybrid (EH)
Native strain (NS)	X	Native strain (NS)

Each of the four crosses was then incubated in separate 1000L capacity breeding recirculatory aquaculture system where hatching took place. Three 1L capacity flow through translucent hatching bowls were cleaned and disinfected mosquito netting material (for egg collection) of appropriate size were placed in them and also in the recircurlatory tanks. Each cross had three replicates making a total of 12 bowls. The fertilized eggs were spread on the netting material and the temperature maintained at 28^{o}C with thermostatic heaters in each hatching bowl. The egg diameter of 100 eggs from each female was measured to the nearest 0.01mm.

After hatching, all the dead eggs, dead and live hatchlings were counted in each of the triplicate flow-through bowls. Percentage hatchability calculated using the formula:

$$\%\ Hatchability = \frac{total\ №\ hatched\ of\ eggs}{total\ №ferilized\ of\ eggs} x100$$

The fertilization rate was check at 10 hours from the time of incubation and the percentage hatchability at 10 hours was calculated as

$$Fertization\ rate = \frac{total\ №\ ferlized\ of\ eggs}{total\ №\ incubated\ of\ eggs} x100$$

Setting of indoor Experiment and daily survival of hatchlings

Each treatment was in triplicates. Two hundred and fifty (250) hatchlings after taking the pool weight were place in a 50x30x26 cm3 plastic container filled with 30L of water complete with aeration each. The survival of fry in each container was taken daily for 14 days while the length and weight of the fry was taken every 72 hour. Weights of 20 hatchlings and individual lengths were taken with a sensitive hooded electronic weighing balance and a Vernier Caliper to the nearest 0.01g and 0.01mm respectively.

Feeding of Larvae and Water quality monitoring

Three days post hatching, the larvae were transferred into 12 indoor tanks. After all the yolk were thought to have been completely absorbed, the fry were feed shell free artemia nauplii for 14 days at 3 times a day. During this period, measurements such as lengths and weight were taken on a 72 hours basis and on the 14th day.

The growth parameters record during this study include

- Mean length gained (cm) = (L2 – L1)
- Mean weight gained (mg) = (W2 - W1)
- Growth rate DGR (mg/day)

DGR = (W2-W1)/(t2-t1)

- Specific growth rate SGR (%/day)

SGR = (lnW2-lnW1)/(t2-t1)*100

Where W1 is initial weight (mg)

W2 is final weight (mg)

L1 is initial length (cm)

L2 is final length (cm)

t2-t1 is duration between W2 and W1 (days)

- Heterosis (H)

$$H = \frac{F1 - 0.5(P1 + P2)}{0.5(P1 + P2)}$$

Where F1, P1, and P2 are the averages of the performance of the first generation of hybrids, Parent 1 and Parent 2, respectively.

The essential water quality parameters such as dissolved oxygen, pH and temperature were monitored thrice daily while ammonia content was measured in the hatchery tanks and once weekly in the indoor rearing tanks using a HANNA Ammonia Medium Range meter (portable spectrophotometer HI96715) with reagents HI93715-01A and HI93715-1B.

Statistical Analysis

The data collected during the experiment were subjected to analysis of variance and the mean separated with Duncan multiple range tests for testing treatment means using the statistical package for social sciences (SPSS) version-21. Polynomial regression was performed on increase in fish lengths with time for each cross to predict trends and reveal hidden dynamics in fish growth.

Results

A comparison of the reproductive characters of female spawners from the native strain and the exotic strain of *C. gariepinus* showed that the female of the exotic hybrid (EH) strain were significantly ($P<0.05$) larger and produced more eggs than the native Cameroon strain (NS), but NS produced significantly larger and heavier eggs than EH ($P=0.05$). Both NS and EH were however in comparable (not statistical significance) physical condition as shown in Table 1.

Table 2 shows the breeding characteristics: fertilization rate, hatchability, survival and heterosis of NS, EH and their reciprocal hybrids. The fertilization rate of the pure NS (28.5%) and EH (28.1%) cross were significantly lower ($P<0.05$) compared to their reciprocal hybrids (32.9% and 45.5%), while the hatchability of the two pure cross

NSxNS (36.82%) and EHxEH (41.14%) was significantly higher at P<0.05, compared to the hybrid crosses (20.6% and 8.73%). However, the hatchlings of the pure NS (75.87%) cross showed a significantly higher survival at P<0.05, while the pure EH (50.93%) cross showed a significantly lower survival at P<0.05 relative to the reciprocal hybrids (64.27% and 65.33%).

The pure EH and NS recorded comparable length gain (48mm and 56mm respectively) to their hybrids (48mm and 55mm) at P<0.05 the growth parameters of initial weight, final weight and weight gain. Results of all the mating combinations showed that NS had a significantly better performance for final weight (28.33mg) and weight gained (22.85mg). The intraspecific mating combination were comparable with EH for both parameters as shown in Table 4.

Table 1. Reproductive characteristic of female spawners of Native Cameroon *Clarias gariepinus* strain (NS) and Exotic hybrid strain (EH).

Parameter	NS	EH	P-value
K-factor	2.25	2.30	--
Fecundity	15152±330^{a}	82408±4604^{b}	0.000
Egg diameter (mm)	1.64±0.22^{a}	1.56±0.19^{b}	0.002
Egg weight (mg)	2.92±0.23^{a}	2.44±0.29^{b}	0.000

Means in the same row with the same superscript are no significantly different (P≤0.05).

Table 2. Breeding parameters and heterosis (H) of pure and reciprocal crosses of native Cameroon strain (NS) and exotic hybrid strain (EH) of *Clarias gariepinus*.

Parameter	♀NS × ♂NS	♀EH × ♂NS	♀NS × ♂EH	♀EH × ♂EH	P-Value
Fertilization (%)	28.10±0.36^{a}	32.90±0.33^{a}	45.50±0.69^{b}	28.50±0.49^{a}	0.001
Hatchability (%)	41.14±1.22^{a}	20.60±1.23^{b}	08.73±0.50^{c}	36.82±1.53^{a}	0.000
H for Hatchability (%)	-	-0.472	-0.152	-	-
Survival (%)	50.93±1.22^{b}	64.27±1.22^{a}	65.33±1.22^{a}	75.87±1.22^{c}	0.000
H for Survival (%)	-	0.013722	1.032986	-	-

Means in the same row with different superscript differ significantly (P≤0.05).

Table 3. Growth parameters and heterosis (H) of pure and reciprocal crosses of *Clarias gariepinus* strains reared for 14-days under indoor hatchery conditions.

Parameter	♀NS × ♂NS	♀EH × ♂NS	♀NS × ♂EH	♀EH × ♂EH	P-Value
Length (cm)	0.0739±0.017	0.0729±0.02	0.0729±0.017	0.0739±0.017	0.25
Final length (cm)	0.121±0.17	0.117±0.23	0.123±0.20	0.127±0.20	0.11
Length gain (cm)	0.048±0.10	0.048±0.29	0.055±0.08	0.056±0.08	0.093
Weight (mg)	5.48±0.117	5.47±0.115	5.53±0.113	5.49±0.116	0.370
Final Weight (mg)	28.33±0.33	15.00±0.63^{a}	16.00±0.27^{ab}	17.00±0.52^{b}	0.000
Weight gain (mg)	22.85±3.10	9.53±1.99^{a}	10.47±1.33^{a}	11.51±1.33^{a}	0.005
H for growth (%)	-	0.014	1.033	-	-
Growth rate (mg day-1)	1.6±0.03	0.68±0.02	0.75±0.19	0.82±0.19	0.150
Specific growth rate	10.20±0.58	3.97±0.39^{a}	4.56±1.03^{a}	5.29±1.03^{a}	0.000

Means in the same row with different superscript differ significantly (P≤0.05)

In the indoor experimental units, water temperature ranged from 28.99±0.16 to 29.19±0.15 ^{o}C, pH (8.33±-0.02 to 8.40±0.02), and dissolved oxygen (6.44±0.11 to 6.73±0.097 mg/l), (Table 4). The spatial variations in temperatures in the indoor rearing space ranged from 23.99^{o}C in the morning 6-9am to –31.5 ^{o}C afternoon during the study period November–December in Limbe, Cameroon.

Table 4. Mean water quality parameter recorded in the experimental unit during the 14-day study period.

Parameter	♀NS × ♂NS	♀EH × ♂NS	♀NS × ♂EH	♀EH × ♂EH	P-Value
Temperature ^{o}C	29.04±0.15	29.01±0.15	28.99±0.16	29.01±0.15	0.995
DO (mgL^{-1})	6.73±0.097	6.54±0.11	6.49±0.11	6.44±0.11	0.098
pH	8.40±0.02^{a}	8.37±0.02^{ab}	8.33±0.02^{b}	8.33±0.02^{b}	0.033

Mean in the same row with different superscript differs significantly (P≤0.05)

There was a general increase in fry length and weight throughout the experimental period and through all the individual crosses as shown in table 5 and 6 for lengths and weights respectively. The length increase from an initial length of 0.0173cm to a final length ranging from 0.1174±0.023 for ♀EH × ♂NS to 0.127±0.020 for ♀EH × ♂EH (Table 5). Similarly, the fry also gained weight from an initial of about 5.48mg to a final weight ranging from 15.0±0.63mg for ♀EH × ♂NS to 28.33±0.26mg for ♀NS × ♂NS.

Table 5. Growth Performance (length changes in cm) of the fry/fingerlings of pure Native Cameroon strain (NS), pure Exotic hybrid strain (EH) of *Clarias gariepinus*, and their reciprocal crosses, at the aquaculture experimental unit of LINAFI Limbe, Cameroon.

		♀EH × ♂NS	♀NS × ♂EH	♀EH × ♂EH	P-Value
Initial	0.074±0.017	0.073±0.017	0.073±0.017	0.074±0.017	0.025
Day 3	0.073±0.017	0.0712±0.015	0.068±0.015	0.071±0.018	0.01448
Day 6	0.075±0.014	0.0697±0.019	0.082±0.016	0.078±0.018	0.24
Day9	0.0941±0.014	0.0933±0.014	0.102±0.015	0.105±0.008	0.31
Day12	0.103±0.014	0.102±0.017	0.1102±0.013	0.113±0.018	0.28
Day14	0.121±0.017	0.1174±0.023	0.123±0.020	0.127±0.020	0.11

Mean in the same row with different superscript differs significantly (P≤0.05)

Table 6. Growth Performance (weight changes in mg) of the fry/fingerlings of pure Native Cameroon strain.

	♀NS × ♂NS	♀EH × ♂NS	♀NS × ♂EH	♀EH × ♂EH	P-Value
Initial	5.48±0.117	5.47±0.115	5.53±0.113	5.49±0.116	0.125
Day 3	8.17±0.61	8.17±0.61	8.17±0.61	8.17±0.61	0.370
Day 6	7.50±0.35^{a}	6.00±0.22	7.17±0.73^{a}	7.23±0.15 ^{a}	0.002
Day9	8.50±0.43^{a}	7.67±0.15^{a}	9.67±0.25	13.00±0.22	0.000
Day12	11.17±0.34	9.0±0.28	13.67±0.21^{a}	13.24±0.35^{a}	0.000
Day14	28.33±0.26	15.0±0.63^{a}	16.0±0.27^{ab}	17.0±0.52^{b}	0.000

Mean in the same row with different superscript differs significantly (P≤0.05)

Predictive polynomial functions of lenght increase with time in the various crosses

The relationship between length and time in the various crosses along with their respective polynomial growth models (of degree 2) are shown in Fig.s 1, 2, 3 and 4. The goodness-of-fit representation of the data was good in all the crosses, ranging from 95.47% (♀EH × ♂NS) to 97.66% (♀NS × ♂NS).

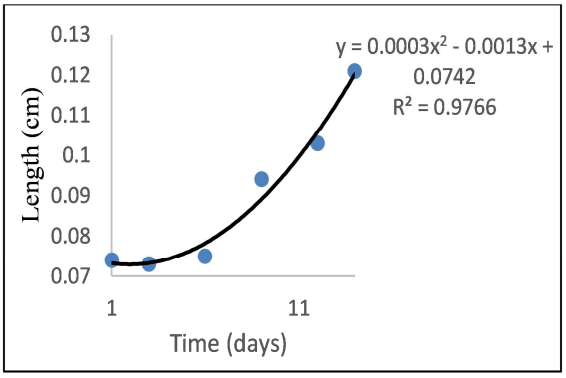

Fig. 1. Growth model for increase in fish length with time for ♀NS × ♂NS.

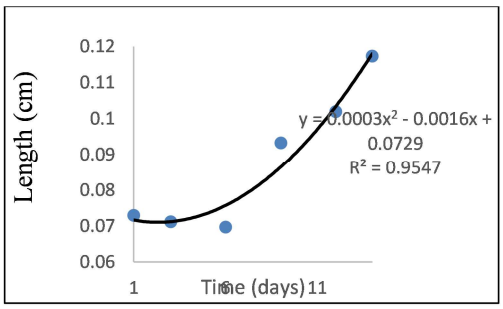

Fig. 2. Growth model for increase in fish length with time for ♀EH × ♂NS.

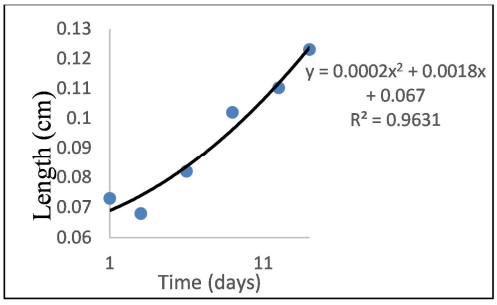

Fig. 3. Growth model for increase in fish length with time for ♀NS × ♂EH.

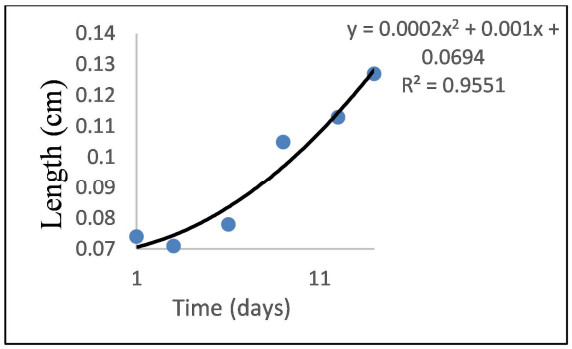

Fig. 4. Growth model for increase in fish length with time for ♀EH × ♂EH.

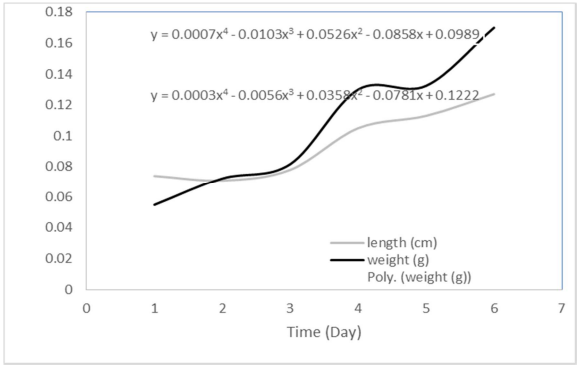

Fig. 5. Growth model for increase in fish length and weight with time showing a general increase within the exprimental period.

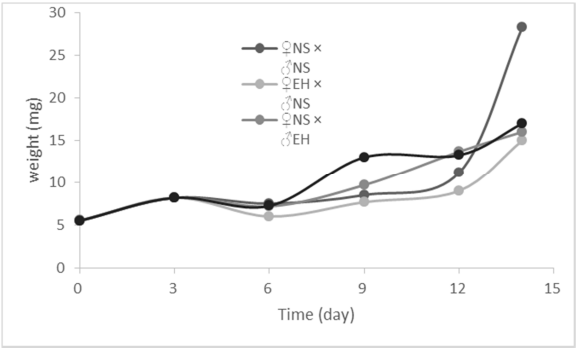

Fig. 6. Growth model for increase in fish weight with time showing changes in weight of Fish for the different experimental crosses.

Discussion

The intraspecific crosses of NS and EH showed that the highest percentage hatchability of 41.10% was recorded by ♀NS × ♂NS which is contrary to the results reported by Adene *et al.* (2017) who hybridized a native African catfish strain in Nigeria with improved "hollandaise" strain, but is similar to the result obtained in an interspecific hybridization by Tiogue *et al.* (2020). This was followed by the cross between ♂NS x ♀EH with 36.82% and the least was 8.73% for ♀NS × ♂EH. There was a significant difference in percentage hatchability between the pure strains and their reciprocal cross. Although there has been limited research work on this area, but the high percentage hatchability recorded in EH might be due to generic improvement through selective breeding. Tine *et al.* (2021), reported in the average of 4.76% and 95% percentage hatchability and mortality respectively wish is significantly lower that obtained in this work at 33.75% Hatchability and 35.95% mortality respectively *Clarias gariepinus* crosses with the highest indoor percentage survival of 75.87% recorded for the parental exotic hybrid and the least of 50.93% recorded for parental native strain of *Clarias gariepinus* which could be due to the lack of adaptation of the native strain to indoor culture conditions. The highest survival recorded for the parental Exotic hybrid cross might be due to its hardness and adaptation to the indoor rearing environment results from selective breeding for resistance while the native strain which are less adapted to indoor rearing conditions recorded the least survival. Olufeagba *et al.* (2000) recorded a high indoor percentage survival of (72.5%) for *Clarias angularis* as an introduced species in aquaculture.

The indoor growth performance showed that there were no significant differences ($P<0.05$) in the crosses but the exotic hybrid *Clarias gariepinus* performed better in length gain (1.21cm) while the native strain performed better in weight gain at 28.33mg. This might also be attributed to genetic improvement, on the exotic strain and the hardiness and adaptability of the native strain to its environment. The cross ♀NS × ♂EH performed significantly better ($P<0.05$) for all parameters when compared to the cross ♀EH × ♂NS with 10.47mg in weight and 0.73cm, length increase and weight increase respectively.

All through the experimental period, the growth curve of experimental fish was in the lag and log phase as show by the growth models in Figs 2-6 of the growth models. Body weights and body length increased

among the experimental crosses with a significant difference ($p>0.05$) though the curves for length increase showed minimal variation in shape from one experimental cross to the other. Similarly, the change in weight was also in the increasing phase of growth and had a significant difference from one cross to the other ($p>0.05$) among treatments as from the 4th day of the trial till the end of the trial period.

Conclusion

The combination with the best hatchability, survival rate and growth performance was ♀NS × ♂EH. This hybrid had a comparablely high survival rate, percentage hatchability and increase in length close to the pure parental breed and the percentage growth rate was also close to that of the exotic parental cross. All four crosses however showed promising performance under indoor experimental conditions. All the fry produced for the experiments were eliminated to avoid contamination of the local water bodies which is a concern as expressed by Vitule *et al.* (2006) on the introduction of a potential invasive species (the African catfish) into Brazilian freshwater aquaculture which caused detrimental effects on the local aquatic biodiversity.

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References

Abualreesh M. 2020. Cryopreservation of blue catfish stem cells for conserving genetic resources and xenogeneic transplantation.

Adene IC, Adedeji OA, Bakry HO. 2017. Intraspecific Hybridization of *Clarias anguilaris* and Exotic Hollandis *Clarias gariepinus*. International Journal of Sciences **6(08),** 15-20.

Bartley DM, Rana K, Immink AJ. 2001. The use of inter-specific hybrids in aquaculture and fisheries. Reviews in Fish Biology and Fisheries **10(3),** 325-337.

De Graaf GJ, Galemoni F, Banzoussi B. 1995. Artificial reproduction and fingerling production of the African catfish, *Clarias gariepinus* (Burchell 1822), in protected and unprotected ponds. Aquaculture Research **26(4),** 233-242.

De Silva SS, Nguyen TT, Turchini GM, Amarasinghe US, Abery NW. 2009. Alien species in aquaculture and biodiversity: a paradox in food production. Ambio 24-28p.

Fermon Y. 2013. Subsistence fish farming in Africa: a technical manual. ACF International.

Ghose B. 2014. Fisheries and aquaculture in Bangladesh: Challenges and opportunities. Annals of Aquaculture and Research **1(1),** 1-5.

Gollasch S, Cowx IG, Nunn AD. 2008. Environmental impacts of alien species in aquaculture. Progetto Impasse, Relazione Delmarzo 150.

Graham M, Devin B, Daniela L, Matthias H. 2019. The state of the world's aquatic genetic resources and the need for a global information system. *Fisheries and Aquaculture Policy and Resources Division Food and* Agriculture Organization of the United Nations Viale Delle Terme di Caracalla-00153, Rome, Italy.

Jentoft S, Eide A, eds. 2011. Poverty mosaics: realities and prospects in small-scale fisheries. Springer Science and Business Media.

Louis NN. 2010. Markets and Market Chain Analysis for Eru (*Gnetum* spp.) in South West and littoral regions of Cameroon (Doctoral dissertation, Department of Geology and Environmental Science, University of Buea) 2-20p

Mair GC, Bartley DM, Stankus A, Beveridge M, Funge-Smith S, Garcia-Gomez R. 2018. The state of the world's aquatic genetic resources. *ISGAPG10*.

Moffitt CM, Cajas-Cano L. 2014. Blue growth: the 2014 FAO state of world fisheries and aquaculture. Fisheries **39(11),** 552-553.

Nkongho GO, Oben BO, Sanni MT, Agbebi OT, Obie AE, Makombu JG, Narika AF, Arrey MA, Oben PM. 2019. Morphological and Molecular Characterization of Some Wild and Cultured *Clarias* (Clariidae, Siluriformes) Fish Species from Cameroon. International Journal of Research Studies in Biosciences **7(3),** 16-26.

Oben PM, Oben BO, Akoachere R, Joseph E. 2015. Induced spawning, survival and growth of African catfish hybrid (female *Clarias gariepinus* and male *Clarias anguillaris*) fingerlings relative to their parental species in the mount Cameroon region. Tropical Freshwater Biology **24,** 63-88

Ogunsina L. 2014. 19 Steps to efficient African catfish breeding. The fish site. https:// thefishsite. com/ articles/19-steps-to-efficient-african-catfish-breedingj

Olenin S, Didžiulis V, Ovcarenko I, Olenina I, Nunn AD, Cowx IG. 2008. Environmental impacts of alien species in aquaculture. Sustainable management of Europe's natural resources D, 1.

Oloyede HOB. 2005. All for the love of nutrients. The seventy eight inaugural lecture, Library and publication Committee, University of Ilorin.

Palmer PJ, Burke MJ, Palmer CJ, Burke JB. 2007. Developments in controlled green-water larval culture technologies for estuarine fishes in Queensland, Australia and elsewhere. Aquaculture **272(1-4),** 1-21.

Pauly D, Zeller D. 2017. Comments on FAOs state of world fisheries and aquaculture (SOFIA 2016). Marine Policy **77,** 176-181.

Pouomogne V. 2008. Capture-based aquaculture of *Clarias* catfish: case study of the Santchou fishers in western Cameroon. **In Lovatelli A, Holthus PF,** (Eds). Capture-based aquaculture. Global overview. FAO Fisheries Technical Paper. No. 508. Rome, FAO. 93-108p.

Rahman MA, Arshad A, Marimuthu K, Ara R, Amin SMN. 2013. Inter-specific hybridization and its potential for aquaculture of fin fishes. Asian journal of Animal and veterinary Advances **8(2),** 139-153.

Ranjan R. 2018. Protecting endemic species from African Catfish invasion when community behavioral responses get in the way. PloS one **13(12),** p.e0209009.

Scholtens E. 2019. The Intake and Composition of Intermittent Fasting, the 5: 2 Method (Doctoral dissertation, University of Otago).

Slembrouck J, Subagja J, Day D, Legendre M. 2003. Induced spawning. Institut de recherche pour le développement. Wisma Anugraha, Jl. Taman Kemang Selatan No. 32B, 12730 Jakarta, Indonesia

Sunarma A, Carman O, Zairin M, Alimuddin A. 2016. Inter-population crossbreeding of farmed and wild African catfish *Clarias gariepinus* (Burchell 1822) in Indonesia at the nursing stage. Aquatic Living Resources **29(3),** 303, 1-8.

Sutton K. 2006. Understanding catfish spawning. Game and Fish

Thorstad EB, Fleming IA, McGinnity P, Soto D, Wennevik V, Whoriskey F. 2008. Incidence and impacts of escaped farmed Atlantic salmon *Salmo salar* in nature. *NINA* special report **36(6).**

Tine M, Ngom A, Senghor S. 2021. Enhancing the supply and self-sufficiency of animal protein for local population through artificial propagation of African sharptooth catfish *Clarias gariepinus* (Burchell, 1822). Journal of Aquaculture and Marine Biology **10(1),** 13-24.

Tiogué CT, Nyadjeu p, Mouokeu SR, Tekou G, Tchoupou H. 2020. Evaluation of hybridization in two African Catfishes (Siluriformes, Clariidae): Exotic (*Clarias gariepinus* Burchell, 1822) and Native (*Clarias jaensis* Boulenger, 1909) species under controlled hatchery conditions in Cameroon. Advances in Aquaculture-**2020,** 1-11 https://doi.org /10.1155/2020/8985424

Varney RL, Wilbur AE. 2020. Analysis of genetic variation and inbreeding among three lines of hatchery-reared *Crassostrea virginica* broodstock. Aquaculture **527**, 735452.

Vendrami DL, Houston RD, Gharbi K, Telesca L, Gutierrez AP, Gurney-Smith H, Hasegawa N, Boudry P, Hoffman JI. 2019. Detailed insights into pan-European population structure and inbreeding in wild and hatchery Pacific oysters (*Crassostrea gigas*) revealed by genome-wide SNP data. Evolutionary Applications **12(3),** 519-534.

Vitule JR, Umbria SC, Aranha JMR. 2006. Introduction of the African catfish *Clarias gariepinus* (BURCHELL, 1822) into Southern Brazil. Biological Invasions **8(4),** 677-681.

Yisa M, Olufeagba SO, Iwalewa M, Gabriel SS, Olowosegun OM, Goni MI, Nwangwu DC. 2017. Improving growth performance of fingerlings of *Clarias anguillaris* through intraspecific hybridization. Agronomie Africaine **29(1),** 83-89.