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Hatchability, Post yolksac Development and Survival of *Clarias gariepinus* (Burchell, 1822) in Simulated Brackish Conditions.

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ABSTRACT
The African catfish (*Clarias gariepinus*) is a widely cultured freshwater species valued for its adaptability and rapid growth. However, with increasing interest in aquaculture expansion into brackish water zones, understanding the species' tolerance to salinity during early developmental stages is crucial for hatchery success. In a study to determine the hatchability and survival of *Clarias gariepinus* larvae under brackish water conditions, the following were assessed: the effect of salinity (0–10 ppt) on egg hatchability, larval development and survival across different salinity levels, water quality parameters and their influence on larval performance. Mature eggs were stripped from 2 induced female brood Catfish, fertilized with milt obtained from the sacrificed male brood-fish, and the fertilized eggs spread in incubation tanks with saline spawning water varying in salinity from 0ppt (control) to 10 ppt. Percentage hatch was recorded, and larvae samples were collected daily from day 1 to 4, and subsequently on days 9, 12, 15, and 18. Growth parameters were observed using an Olympus light microscope, Sony 20.1-megapixel digital camera, and measured using an ocular micrometer. Post-yolk-sac larvae, fry, and advanced fry stages were monitored for survival and growth, by evaluating the mean hatchability of the embryo, and the: mean body length, mean weight, and mean decrease in yolk-sac size of the post-hatching larvae. Dissolved oxygen, pH, temperature, conductivity, Ammonium, Ammonia, Nitrate and Nitrite were evaluateed with the aid of a salinometer, sera test kit, and multiparameter pen-type water quality tester. Results revealed the highest hatchability in the control (0 ppt) and 2 ppt salinity groups, with significant differences ($P \leq 0.05$) between the control, 4%, and 6% salinity treatments. Larval growth showed a steady decrease in yolk-sac size as length and weight increased, with reduced development rates at higher salinities. Optimal growth occurred within in saline concentrations of 0ppt–4ppt salinity, with tolerable survival up to 6ppt. Mean survival rates showed significant differences ($P \leq 0.05$) between the control and 4% salinity from day 14 post-hatching. Water quality parameters varied across treatments, with both significant and insignificant differences observed between the control and the various treatments. Consequently, *Clarias gariepinus* larvae can be successfully reared in brackish water conditions up to 4 ppt for at least two weeks post-hatching. This finding supports the feasibility of establishing specialized hatcheries using brackish water sources for seed culture of *C. gariepinus.*

Keywords: Post-hatching, Larvae, Salinity, Development, Survival, Water quality.

INTRODUCTION
Being one of the most commercial food commodities around the world, Fish possesses a rich essential amino acids, minerals, vitamins content, and possesses low fat with lower levels of cholesterol (FAO, 2016). For a rapidly increasing human population,

providing sufficient food is one of the greatest challenges today in the world. Seafood bases play a significant part in filling the nutritional needs of humans, world over (FAO, 2014). Cheaper than most protein sources, Fish contributes substantially to abating poverty via small scale household farming of aquatic organisms for income and consumption (Babatunde et al., 2021). In addition to the provision of high-quality protein sources, fisheries and aquaculture avails economic-value through the production, trade, and marketing of wild and farmed fish (Cai et al., 2019).

Small-scale fisheries and aquaculture makes critical contributions to development in the areas of employment, with over 41 million people worldwide, the vast majority of whom live in developing countries, working in fish production; food security and nutrition, with fish constituting an important source of nutrients for the poor and often being the cheapest form of animal protein; and trade, with a third of fishery commodity production in developing countries destined for export (Finegold, 2009).

Africa's fast-growing human populace outstrips the growth in fish supply, and most of the continent's wild fish populations are fully exploited (Yimin, 2024). Aquaculture production must therefore more than double by 2050 to satisfy the projected fish demand, according to Cai et al., 2017. African aquaculture, which has grown much more slowly than in other regions, faces numerous challenges, including resource conflicts and difficulties in accessing credit, quality seed and feed, and information (Finegold, 2009).

On average, fish accounts for about 50 percent of total protein intake in Nigeria (NBS Nigeria 2018). Its supply in Nigeria, originates from both local production and imports. The local production stems from: artisan fisheries, (comprised of coastal, brackish waters, inland lakes, dams and rivers), industrial marine fishing, and aquaculture (FAO, 2018). Aquaculture is defined by The Food and Agricultural organization (2016), as such interventions as management, disease prevention and control, and improvement of production quality and quantity in the culture of aquatic organisms. With few species, notably: catfish, mackerel, tilapia, and crayfish dominating consumption, many Nigerian households consume a wide-range of fish species, such as freshwater and saltwater sardines, bonga, croakers, and codfish in various processed forms (Subasinghe et al., 2021).

Clarias gariepinus (Burchell, 1822), commonly known as the African sharp-tooth catfish, is a *Clariidae* of high economic importance, that contributes to annual fish production of the world. Known for its hardiness and dodged resistance to disease, this predatory, omnivorous and cannibalistic specie is a rich protein source; easy to culture, and offers high yield potentials (Olaniyi, 2013); availing it as desirable for controlled production. Catfishes are able to live in very turbid waters and can tolerate temperatures as low and high as 8°C and 35°C respectively. However, their optimal temperature for growth is between 28°C and 30°C (Arnold et. al., 2012). They are bottom dwellers and feeders, obligatory air breathers, capable of living in very poorly oxygenated (Obirikorang, 2025). They are also able to secrete mucus to prevent drying and is able to burrow in the muddy substrate of a drying body of water (Skelton, 1993; Obirikorang, 2025). The larval stages of *C. gariepinus* are very sensitive to

environmental disturbances as light and salinity. There however remains, a knowledge gap on the breeding of the post-hatching stages of this specie in a brackish/marine environment, and to what tolerable extent.

Optimal water quality varies for different organisms at various developmental stages, and must be monitored to maximize productivity (Kolawole et al., 2011). The quality and quantity of the water source, with reference to fish culture, plays a key role in the success of any aquaculture enterprise. Physical and chemical water quality parameters including: dissolved oxygen, temperature, salinity, hardness, alkalinity, ammonia, nitrite, nitrate and pH, which affects the survival, growth and reproduction of the cultured species, must be monitored to ensure maximized productivity (Ayoola, 2017).

Aquaculture development is needed for sustainable food fish production in order to supplement capture fisheries by reducing the pressure on its activities and the needed animal protein by the mass propagation of fish seeds. A major prerequisite for the success of fish farming enterprise is a reliable and consistent source of fish seed, especially the commercially important species as Catfish. Its production in Nigeria accounts for 70% of the fish production from aquaculture (Williams et al., 2008). The popularity of the culture of Catfish culture, has birthed a demand for its seed, culminating into a rapid increase in catfish hatcheries in Nigeria (Oyebola et al., 2014). However, protein of animal sources is still in short supply due to the rapid increase in human; population annually and as well as the decrease in livestock population due to several factors including diseases, drought, high feed cost, poor water quality, scarcity of fish seed e.t.c (Akankali et al., 2011). This has given rise to an increase in the demand for fish to supplement the needed animal protein intake (Akankali et al., 2011). As at 2014, the demand for fish in Nigeria still surpassed the local production as reported by Ozigbo, 2014. Although aquaculture production as reported by Ozigbo (2014) had steadily increased to about 316,700 tonnes in 2015, from 21,700 tonnes in 1999, the production rate, however, as at 2022, stands at 300,000 tonnes, showing a decline in the supply of fish through aquaculture (World bank, 2022; FAO, 2022).

Fish seed availability, with the aid of specialized hatcheries can be used to meet this increasing fish demand. Efforts have been made by researchers to solve aquaculture related problems, ranging from hybrid or cross-breed fish-seeds, low cost but high nutrient fish feed using local ingredients, effects of tank volumes in relation to growth performance of fish, effects of important water quality parameters in relation to growth performance, survival and deformities, effects of culture sections on growth performance of fish, e.t.c, (Akinwole and Faturoti, 2007) but adequate information on the post-hatching larval development is also essential for successful seed production (in relation to salinity tolerance), in view to extend its possible culture beyond the freshwater environment, whilst taking advantage of the brackish water environment ((Akinwole and Faturoti, 2007); Nwanna, 2010). Artificial reproduction by induced breeding through hormone treatment, artificial fertilization, incubation of the fertilized eggs and the subsequent rearing of larvae to fingerling size has several advantages (F.A.O., 2019; Nwachi and Nwuba,2015) including: better rates of fertilization, protection against enemies and unfavourable conditions, better

conditions for growth and survival, etc. (Ataguba et. Al., 2010)

The culture of *C. gariepinus* in Nigeria is limited by problems of high mortality in the early developmental stages and the resulting seed scarcity, which makes production of seed for grow-out of the marketable product, a prerequisite for domestication and establishment of a sustainable aquaculture industry (Mylonas et al., 2010). Most fish farmers have also been observed to be seasonal producers, which puts them at the receiving end of natural mishaps such as the adverse effects of climate-change e.g extreme temperatures, drought, heat waves, flooding, wide fluctuations in water quality parameters (salinity inclusive); resulting to a huge loss of fish and funds.

Hence the need to channel efforts towards achieving higher production intensities whilst taking advantage of the varieties of water bodies in Nigeria. More-so, there exists a knowledge gap on the effects of salinity on the early development of *Clarias gariepinus*, except fewer studies on its hematological characteristics, nutritional or feeding characteristics, salinity tolerance of juveniles and adult stages, digestive enzymes profile, parasite fauna and induced spawning (Fagbenro et al. 1991, 1993; Adebayo and Fagbenro 2004). Post-hatching larval studies of this species are essential for improvement on its breeding and aquaculture potentials to meet the fish demand and supply, and biodiversity in Nigeria. Anatomical and physiological characteristic of *Clarias gariepinus* (Burchell, 1822) have been observed to exhibit some degree of salinity tolerance of >12% and >15% in the juvenile and adult stages respectively (Clay, 1977), but the possibility of its production using a brackish/ marine water source has not been fully explored in Nigeria with our numerous coastal systems and enormous potentials for aquaculture (Ezenwa et al.,1994).

- Furthermore, the major aim of the Nigerian National Aquaculture Strategy is to achieve increased domestic fish production from all sources on a sustainable and renewable basis to the level of self-sufficiency, and fish export in the to long term. The Federal Ministry of Agriculture and Rural Development (FMARD) has identified insufficient fish seed hatcheries, as one of the key issues prevalent in Nigerian aquaculture. The ministry also identified Inadequate supply and high cost of fish seed as one of the challenges facing aquaculture. This study was designed contribute to achieving the first three objectives under its aquaculture policy.

This study therefore investigated the post-hatching developmental stages of *Clarias gariepinus*, exposed to a simulated brackish water environment, in a bid to better understand the salinity tolerance capacity of *C. gariepinus*, and in view to maximize the use of most/all aquatic environments for its possible culture. It is also essential for improvement on its breeding, provide a means of livelihood for fish farmers in settlements around brackish water eenvirons through the possible production of catfish-seed, and strengthen aquaculture's potential to meet fish demand and supply in Nigeria.

MATERIALS AND METHODS

Study Area

The study was conducted at the Department of Aquaculture and Fisheries Management, University of Ibadan (Laboratory-A), South-western Nigeria, **Latitude:** 7° 23' 28.19" N and

Longitude: 3° 54' 59.99" E (Latitude, 2024). The mean maximum and minimum temperatures are 26.46^{0}C and 21.42^{0}C respectively and the relative humidity is 74.55% (Demographia, 2015). All source of direct sunlight was sealed off to regulate light intensity and temperature within the experimental area, to ensure the endogenous rhythm of embryo and welfare of larva.

Preparation of Culture tanks
Rectangular tanks were used, each 35 litres in capacity, and in triplicates for each treatment. The tanks were washed, and rinsed with freshwater. Six circular plastic tanks, 50litres each, used to supply spawning water of 0,2,4,6,8,and 10ppt saline concentration to the various incubation tanks, were mounted above the incubation tanks (Olaniyi and Omitoyin, 2016).

Preparation of saline spawning water
The saline media was prepared by completely dissolving 2,4,6,8, and 10g of common (NaCl) respectively, in every litre of water in the supply tanks, as well as the start-up spawning water in the various culture tanks, while checking the salinity at intervals with the aid of a salinometer. Each treatment tanks were filled to 70% capacity and respective portions of NaCl was added per litre of water (IITA, 2021).

Plate 1: Experimental set-up

Stripping, collection of milt, fertilization, and incubation
The induced female brood-stock were stripped of matured eggs by gentle and careful application of pressure to the abdomen, to press out the eggs. This was done into a clean bowl, after a 15hrs latency period in temporary holding troughs at room temperature (27^{o}C), as described by Davies *et al.*, (2006). The male was sacrificed, and its milt collected into a petri-dish containing 25ml of saline solution, to fertilize the eggs, as described by Potangkan and Miller, (2016). Fertilization was achieved by spreading the milt over the eggs and mixing it with a plastic spoon, and adding clean water of equal volume. The mixture was then spread on each incubation net of 2mm mesh size in the culture tanks for the various treatments, as described by Okunsebor *et al.*, (2015).

Determining water quality
Salinity, dissolved oxygen, pH, ammonia, nitrite, conductivity and temperature, were monitored daily for all 18 incubation troughs, from the first day of spawning. One third of the water in each tank was siphoned daily, using a rubber hose (covered with a net), and

refilled with clean water of varying salinity respectively, in order to maintain the tank's water quality (Okunsebor *et al.*, 2015). Physio-chemical parameters were checked using standard procedures, before and after every change of water, to ensure optimal water quality

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Determining Hatchability:

Hatching rates were determined by the procedures and formulae as described by El-gamal, (2009) and Naeem *et al.*, (2011).

Microscopy, photo-micrography and ocular micro-measurement:

The optical transparency of the hatchling enables us to see its distinctive features, such as the yolk-sac and pictorially characterize its development while subjected to saline treatments. Post hatching larval development was investigated and described with the aid of an Olympus light microscope at 10x magnification, a Sonny 20.1 mega-pixel digital camera and a PC (personal computer), as described by (Wasiu and Omitogun, 2013), daily, from 0-minute after fertilization till the advanced fry stage was attained (Wasiu and Omitogun, 2013). The samples were killed/anesthetized using 4% formalin, to prevent damaging of tissues for few hours. Samples were randomly collected and viewed under an Olympus light microscope. The morphological development of the larval stages was documented and recorded pictorially. Increase in length was taken with the aid of a micrometer, calibrated in (mm). The mean weight gain of the post-yolk-sac larvae was also determined (Wasiu and Omitogun, 2013).

Data collection and analysis technique:

Random sampling technique was used to collect samples from the various culture tanks. The observed data was analyzed using descriptive statistics, One way ANOVA, and the statistical variance between means was tested at 95% confidence level (Okusenbor et al., 2015).

RESULTS

The highest **mean hatchability** of 88.46% and 84.60% was observed in fertilized eggs incubated in 0ppt and 2ppt salinity respectively, as shown in Table-1. Proportions of hatched larvae reduced progressively as the salt concentration increased. This result showed that, hatching of *Clarias gariepinus larva* is optimally possible under brackish water conditions between 2-4% and can be tolerated up to 6% of NaCl.

Table 1: Mean percentage hatchability of embryos for control and all salinity treatments.

	Salinity Treatment			
Replicates	0(ppt)	2(ppt)	4(ppt)	6(ppt)
1	88.43	83.44	84.69	70.41
2	87.19	84.48	84.74	70.96
3	89.75	85.67	83.49	70.7
Mean (%)	88.46	84.60	84.31	70.69
StDev (±)	1.28	1.12	0.71	0.28

The mean body lengths of yolk-sac larvae showed significant difference between the control and the 6% treatment, and no significant difference ($P \geq 0.05$) between the control, 2% and 4% salinity treatments. This result suggests that, with increasing salinity, the rate of increase in body length would decrease.

The optimal salinity suitable for development in terms of increase in length, ranges fro 0-4%, but tolerable up to 6%.

Table 2: Mean increase body length of post-hatching larvae.

	Increase in Length per salinity			
Days	0(ppt)	2(ppt)	4(ppt)	6(ppt)
1	1.1	0.9	1.1	0.8
2	0.6	0.8	0.5	0.1
3	1.1	1.1	0.5	0
4	0.9	0.8	0.3	0.1
Mn(mm)	0.925	0.9	0.6	0.25
StDev(±)	0.24	0.14	0.35	0.37

Table 3 represents the results of the mean weight of yolk-sac larvae showed significant difference between the control and the 6% treatment, and no significant difference (P≥0.05) between the control, 2% and 4% salinity treatments. This results suggests that, with increasing salinity, the rate of increase in weight of the fish would decrease. Also it reveals that for the yolk-sac larvae, the optimal salinity suitable for development in terms of increase in weight, ranges from 0 to 4%, but tolerable up to 6%.

Table 3: Mean increase in weight of post-hatching larvae.

	Increase in Weight per salinity			
Days	0(ppt)	2(ppt)	4(ppt)	6(ppt)
1	1.4	1.5	1.7	0.5
2	0.9	0.7	0.1	0.1
3	0.6	0.7	0.4	0.4
4	0.7	0.6	0.7	0.2
Mn(mg)	0.9	0.875	0.725	0.3
StDev(±)	0.36	0.42	0.70	0.18

Statistical analysis revealed a significant difference (P≤0.05) in yolk-size decrease rate between the control and the 6% treatment, and no significant difference (P≥0.05) in the daily yolk absorption rates between the control, 2% and 4% salinity treatments, as represented in Table 4 below. This results suggests that, with increasing salinity, the rate of yolk-sac absorption would decrease. Also, it shows that for the yolk-sac larvae, the optimal salinity range for development lies between 0-4%, and tolerable up to 6%.

Table 4: Mean decrease in yolk-sac size of post-hatching larvae .

	Decrease in Yolk-sac per salinity			
Days	0(ppt)	2(ppt)	4(ppt)	6(ppt)
1	0.5	0.2	0.2	0.1
2	0.4	0.2	0.4	0.1
3	0.4	0.3	0.2	0
4	0.2	0.2	0.2	0.1
Mn(mm)	0.375	0.225	0.25	0.075
StDev(±)	0.13	0.05	0.1	0.05

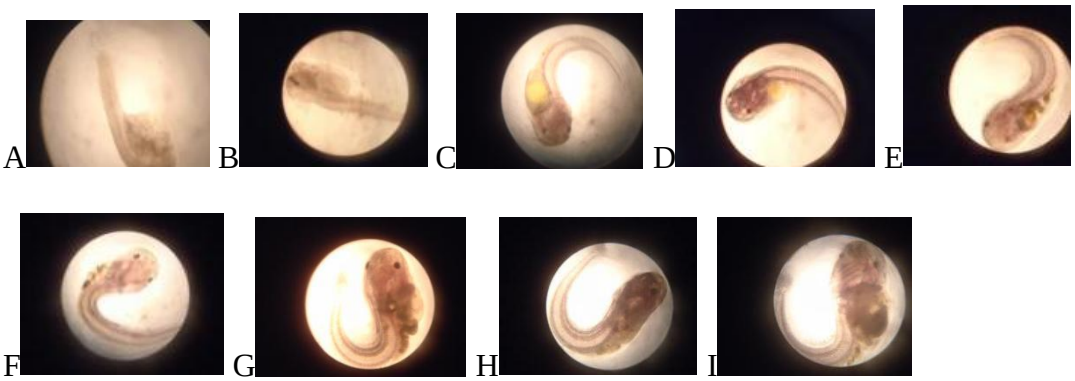

Plate 1 (A-I): Post hatching larval development (0% salinity).
Magnification: x10

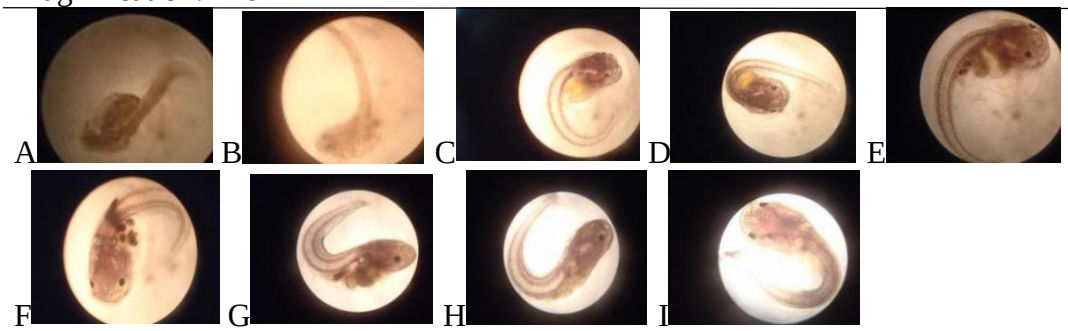

Plate 2 (A-I): Post hatching larval development (2% salinity).
Magnification: x10

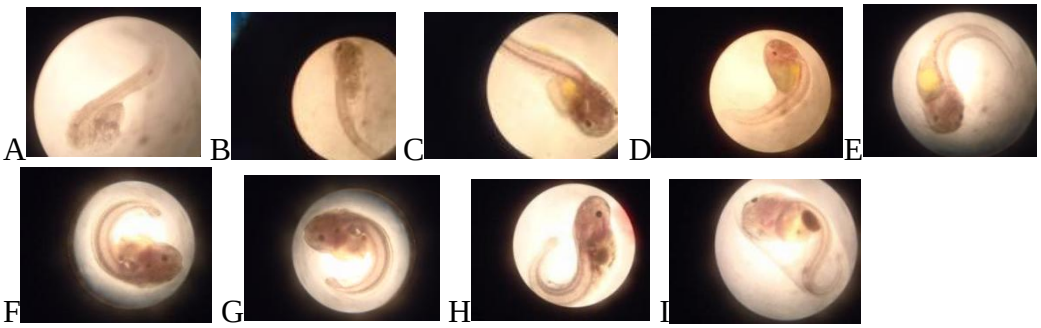

Plate 3 (A-I): Post hatching larval development (4% salinity).
Magnification: x10

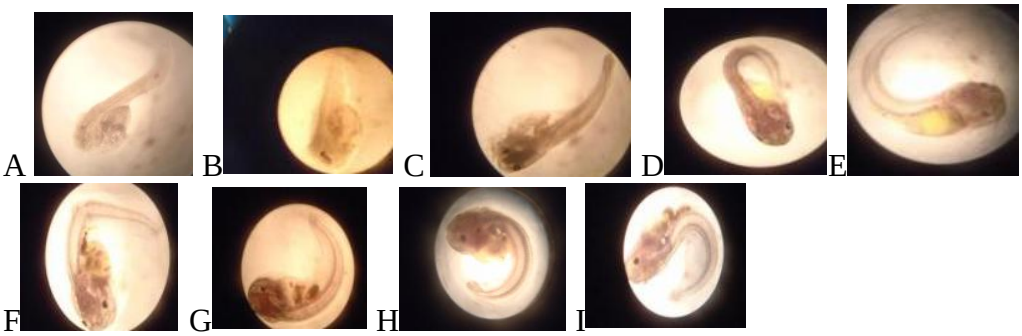

Plate 4 (A-I): Post hatching larval development (6% salinity).
Magnification: x10

Tables 5-8 shows that the survival rate of the larvae, from the 4th day till the 18th day (end of experiment), reduced progressively as the salt concentration increased. A sharp drop at 6% salinity on the 4th day (Table-5), and a steep

decline at 4% salinity from the 9th day, to the end of the experiment (Tables-6,7and 8), suggests that hatched larvae can survive optimally in brackish conditions between 2-4% salinity and tolerable up to 6%, up until the 4th day; while its survival from the 9th day till advanced fry stage, the optimal salinity is 2% and tolerable up to 4%. This result shows that the hatched larvae of *C. gariepinus*, can be spawn and hatched in a brackish environment of 2%-4% salinity for a period of two weeks after the completion of yolk-sac absorption. However, the rate of survival steadily drops within this period.

Table 5: Mean percentage survival of hatchlings at the end of day-4.

	Salinity Treatments			
Replicates	0(ppt)	2(ppt)	4(ppt)	6(ppt)
1	84.17	81.59	82.32	39.26
2	84.82	80.85	78.43	36.13
3	82.13	78.87	82.00	34.67
Mean(%)	83.71	80.44	80.92	36.69
StDev(±)	1.40	1.41	2.16	2.35

Table 6: Mean percentage survival of post yolk-sac larvae at the end of day-9

	Salinity Treatments		
Replicates	0(ppt)	2(ppt)	4(ppt)
1	67.95	64.63	54.71
2	65.17	62.15	54.69
3	69.14	66.02	25.86
Mn(%)	67.42	64.27	45.09
StDev(±)	2.04	1.96	16.65

Table 7: Mean percentage survival of fry at the end of day-14.

	Salinity Treatment		
Replicates	0(ppt)	2(ppt)	4(ppt)
1	53.29	51.44	31.61
2	55.36	49.16	28.05
3	52.00	52.15	29.91
Mn(%)	53.55	50.92	29.86
StDev(±)	1.70	1.56	1.78

Table 8: Mean percentage survival of advanced fry at the end of day 18.

	Salinity Treatment		
Replicates	0(ppt)	2(ppt)	4(ppt)
1	42.86	41.91	29.75
2	39.57	39.91	28.28
3	42.06	38.31	25.10
Mn(%)	41.50	40.43	27.87
StDev(±)	1.72	1.80	2.45

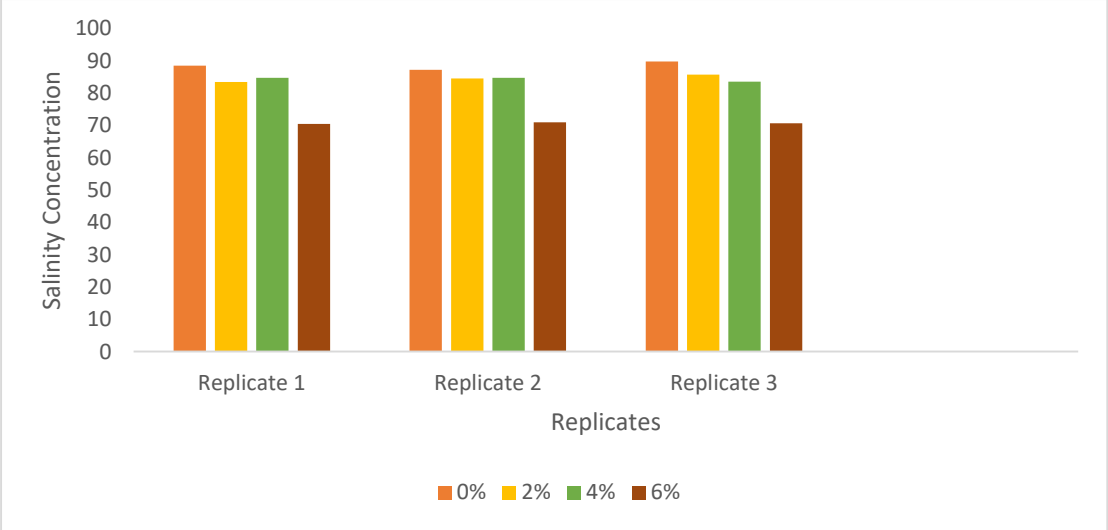

Chart 1: Mean percentage hatchability of embryos across salinity treatments.

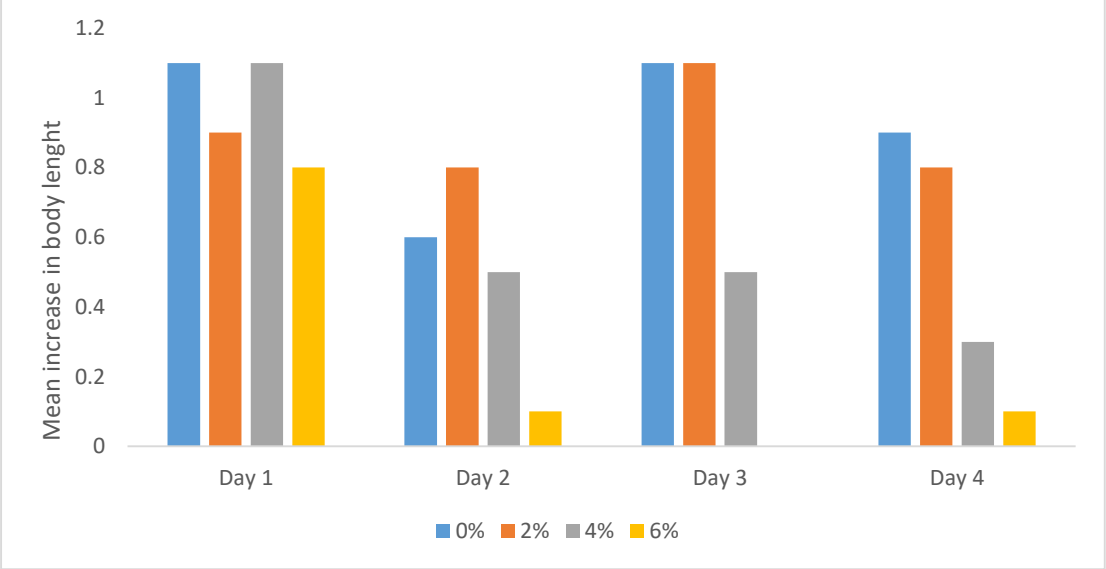

Chart 2: Mean increase body length of post-hatching larvae.

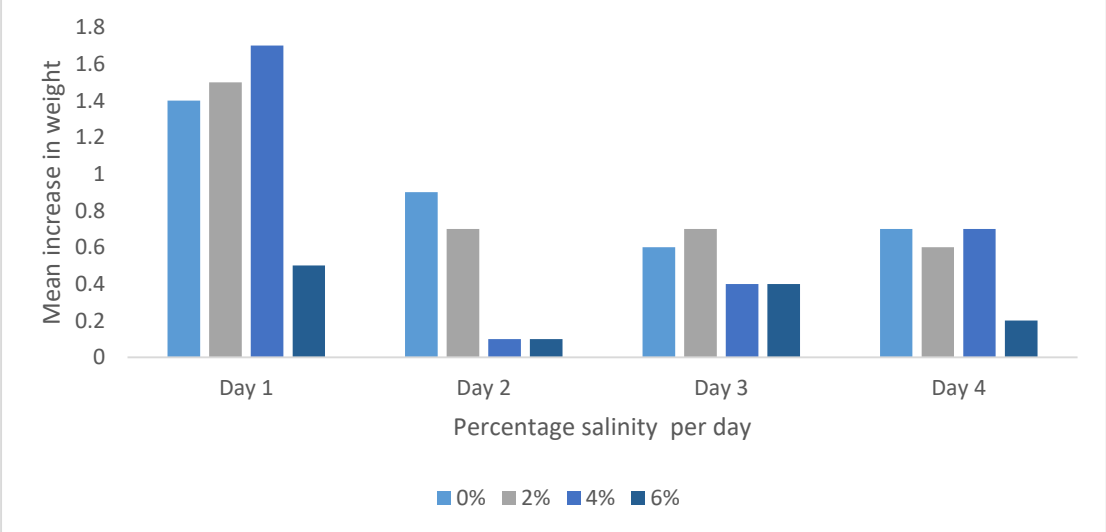

Chart 3: Mean increase in weight of post-hatching larvae.

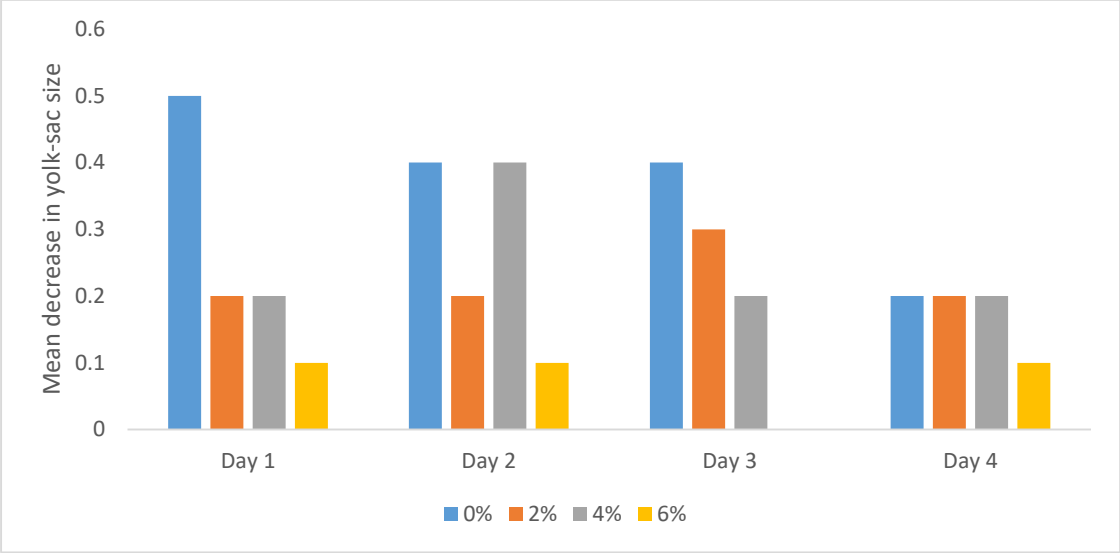

Chart 4: Mean decrease in yolk-sac size of post-hatching larvae .

Table 9: Water quality parameters measured for Control (0% Salinity).

Salinity (%)	Days	Temp (0C)	pH	DO (mg/l)	Cond. (uS)	NH3 (mg/l)	NH4 (mg/1)	NO2 (mg/1)	NO3 (mg/1)
0%	1	26.80	7.06	6.6	520	0	0	0	0
	2	26.51	6.86	6.58	587	0	0	0	0
	3	27.20	7.04	4.47	724	0.5	0.5	0	0
	4	27.20	7.04	5.26	1240	0	0	0	0
	9	26.92	6.80	6.35	3948	0	0	0	0
	12	26.78	6.77	6.33	6964	0.5	0.5	0.25	0.25
	15	26.78	6.77	6.49	9237	0.25	0.25	0	0
	18	27.10	6.77	6.40	****	0.25	0.25	0	0
Mn		26.91	6.89	6.06	3317.14	0.19	0.19	0.03	0.03
StDev		±0.24	±0.13	±0.77	±3536.92	±0.22	±0.22	±0.09	±0.09
2%	1	26.80	7.05	6.60	3650	0	0	0	0
	2	26.80	6.84	6.58	3998	0	0	0	0
	3	27.18	7.04	4.47	3976	0.25	0.25	0	0
	4	27.20	7.04	5.26	7470	0	0	0	0
	9	26.90	6.76	6.35	9386	0.25	0.25	0	0
	12	26.67	6.76	6.37	****	0.5	0.5	0.25	0.25
	15	26.68	6.75	6.39	****	0.25	0.25	0	0
	18	27.05	6.85	6.42	****	0.25	0.25	0	0
Mn		26.91	6.89	6.06	5696	0.19	0.19	0.03	0.03
StDev		±0.21	±0.14	±0.77	±2587.99	±0.18	±0.18	±0.09	±0.09
4%	1	26.78	7.05	6.6	6967	0	0	0	0
	2	26.79	6.82	6.58	7410	0	0	0	0
	3	27.15	7.00	4.47	9475	0	0	0	0
	4	27.17	6.90	5.26	****	0.25	0.25	0	0
	9	26.90	6.32	6.26	****	0.5	0.5	0	0
	12	26.67	6.41	5.87	****	0.25	0.25	0	0
	15	26.67	6.48	6.00	****	0.5	0.5	0.25	0.25
	18	27.03	6.25	6.32	****	0.1	0.1	0.25	0.25
Mn		26.90	6.65	5.92	7950.67	0.2	0.2	0.06	0.06
StDev		±0.20	±0.32	±0.73	±1338.57	±0.21	±0.21	±0.11	±0.12

6%	1	26.74	7.03	6.56	9165	0	0	0	0
	2	26.78	6.80	6.59	****	0	0	0	0
	3	27.13	6.98	4.36	****	0	0	0	0
	4	27.05	7.00	4.18	****	0.1	0.1	0	0
Mn		26.93	6.96	5.42	9165	0.03	0.03	0	0
StDev		±0.20	±0.10	±1.33	±0.00	±0.05	±0.05	±0.00	±0.00
8%	1	26.74	6.97	6.60	****	0	0	0	0
10%	1	26.78	7.05	6.25	****	0	0	0	0

DISCUSSION

The results showed that the African catfish larvae within the first four days, can grow optimally in saline media between 2-4%, and tolerable up to 6% salinity. The growth and development rate of *C. gariepinus* was observed to decline with increasing saline concentration. This agrees with the findings of Ujagwung et al., 2021, who exposed fourteen day-old fry to 0 – 6 ppt, and had 90%, 87.5% and 10% survival at the end of the 96 hour test period. Those subjected to 8 ppt and 10 ppt had 100% dead within 48 and 12 hours, respectively. It is also in line with the results of Kawamura et al.,2017, who recommend that hatchery rearing of African catfish be done at the optimum low salinity of 4–6 ppt rather than in full fresh water , for up to a least of 21 days. This rearing method, they reported, fosters larval welfare and improves hatchery production.

Table-1 revealed the highest numerical hatchability of 88.46% and 84.60% was observed in fertilized eggs incubated in 0ppt and 2ppt salinity respectively. Proportion of hatched larvae reduced progressively as the salt concentration increased, as also reported by Borode and Oyintoke (2004). This result showed that, hatching and rearing of *Clarias gariepinus larve* is optimally possible under brackish water conditions between 2-4% and can be tolerated up to 6% of NaCl.

Statistical analysis as shown in **Table-2** uncovers a significant difference ($P \leq 0.05$) in yolk-size decrease rate between the control and the 6% treatment, and no significant difference ($P \geq 0.05$) in the daily yolk absorption rates between the control, 2% and 4% salinity treatments. This results suggests that, with increasing salinity, the rate of yolk-sac absorption would decrease. Also, it showed that for the yolk-sac larvae, the optimal salinity range for development lies between 0-4%, and tolerable up to 6%. This has been correlated with the fact that *Clarias gariepinus* is stenohaline and possesses only a limited ability to withstand an increase in the ambient salinity as a result of its limited ability for regulatory mechanisms.

Table-3, which is the mean body lengths of yolk-sac larvae showed significant difference between the control and the 6% treatment, and no significant difference ($P \geq 0.05$) between the control, 2% and 4% salinity treatments. This results suggests that, with increasing salinity, the rate of increase in body length would decrease. The optimal salinity suitable for development in terms of increase in length, ranges fro 0-4%, but tolerable up to 6%. This has been attributed to the organism channeling more energy to maintaining its regulatory functions, thereby making growth a secondary task.

Results of mean weight of yolk-sac larvae **(Table-4)** showed significant difference between the control and the 6% treatment, and no significant difference (P≥0.05) between the control, 2% and 4% salinity treatments. This results suggests that, with increasing salinity, the rate of increase in weight of the fish would decrease. Also it reveals that for the yolk-sac larvae, the optimal salinity suitable for development in terms of increase in weight, ranges from 0 to 4%, but tolerable up to 6%. This has also been attributed to the fact that *Clarias gariepinus* is stenohaline and possesses only a limited ability to withstand an increase in the ambient salinity resulting from the limited ability of its regulatory mechanisms, hence the decrease in body length, as the organism regulatory functions takes priority, thereby making growth secondary. The findings agrees with the work of Ujagwung *et al.*, 2021.

The survival rate of the larvae, from the 4th day till the 18th day **(Tables 5-8)**, reduced progressively as the salt concentration increased. A sharp drop at 6% salinity on the 4th day, and a steep decline at 4% salinity from the 9th day, to the end of the experiment, suggests that hatched larvae can survive optimally in brackish conditions between 2-4% salinity and tolerable up to 6%, up until the 4th day; while its survival from the 9th day till advanced fry stage, the optimal salinity is 2% and tolerable up to 4%. This result shows that the hatched larvae of *C. gariepinus*, can be spawn and hatched in a brackish environment of 2%-4% salinity for a period of two weeks after the completion of yolk-sac absorption. However, the rate of survival steadily drops within this period. This result agrees with the report of Fashina-Bombata and Busari (2003), who reported the mean lethal salinity (MLS) of the post yolk-sac larvae of *H. logifilis*, a stenohaline specie, as 4.35.

Results from this study **(Table-9)**, also agrees with the findings of Borode et. al., (2002), who opined that, the optimal salinity range for the African Catfish larvae is between 0 and 2ppt, and acceptable up to 6ppt. The temperature range for this experiment, fell within the ranges of 22-35^{0}C as recommended by Akinyemi (1998), for the African catfish. Dissolved oxygen concentrations ranged between 4.47mg/l-6.6mg/l, which lies within the optimal range of 3-8mg/l as recommended by the FAO (2003); Bhatnagar and Devi (2013), and the pH ranged from 6.86-7.05, within the recommended values of 6.5-8.5 reported by FAO (2003); Bhatnagar and Devi (2013). A sharp drop in water quality (particularly ammonium and ammonia) was observed on the third day, which was due to the introduction of mixed feeding, as a result of almost completely absorbed yolk-sac, as well as fecal wastes from the fish.

CONCLUSION

This study reveals that increasing salinity (NaCl) slows growth and development of the *Clarias gariepinus* (African catfish) post-hatching larvae. Yolk-sac absorption rate was significantly faster in the control and 2% salt concentrations and slower in 4% and 6% salt concentrations. Mean increase in length and weight decreases with increasing salinity also, however, contrary to some reports on hatchability and post-hatching larval development, this study recorded no hatching at 8% salinity. The results of this study showed that the optimal range for the culture of the African catfish larvae is between 0% -2%, and is tolerable up to 4%, till the advanced fry stage is attained, in about 14-18days, as also reported by Borode et. al., (2002). This species is therefore suitable for seed-culture under brackish water

environment up to 18days. Considering the availability of brackish/ saline water bodies in rural localities, which is a major natural resource for the achievement of sustainable and renewable fish-seed farming, and with the results obtained from this study, it is suggested that specialized fish-seed hatcheries should be set up around brackish water sources, as well as the effective use of the coastal wetlands, to maximize the production of fish seeds, which is a major requirement for sustainability of the aquaculture venture in Nigeria. This will contribute to also to achieving the second objective of the National aquaculture strategy, through fish-hatchery establishment/management; and will contribute to the achieving the sustainable development goals (SDGs).

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REFERENCES

Addisu D., & Asmelash T. (2016) .A review on water quality and its impact on Fish health. *International Journal of Fauna and Biological Studies* **3(1**),21-31

Akankali, J. A., Seiyaboh, E. I., & Abowei J. F. N. (2011). Fish hatchery management in Nigeria. *Advanced Journal of Food Science and Technology* **3**(**2**), 144-156.

Akinyemi , O. (1988). Effect of different culture tank selection on production of African Catfish juveniles. *MSc. Project.* Department of Fisheries and Wildlife. Federal University of Technology, Akure, Nigeria.

Ajayi, O.; Akinrinlola, A.; Usman, A.; Muhammed, A.; & Van der Knaap, M. (2022). Aquaculture Development in Nigeria and FAO's Role. *In FAO Aquaculture News—International Year of Artisanal Fisheries and Aquaculture 2022*; Special Issue; FAO: Rome, Italy, pp. 21–24.

Alabi K. I. & Ocholi O. S., (2019). Studies on the hatchability, growth performance and survival of African catfish (Clarias gariepinus) in different aquaculture production systems. *International Journal of Fisheries and Aquatic Studies* 2019; **7**(**5**): 34-38

Allen, P. J. & Steeby, J. A. (2011) Aqu aculture: Challenges and Promise. *Nature Education Knowledge* **3(10)**:12

Ameer, M.W., Jabeen, F., Asad, M. et al.(2021). Comparative efficacy of Ovaprim and hMG (menotropin) to induce breeding in African catfish (Clarias gariepinus). *Fish Physiology and Biochem* 47, 1559–1564. https://doi.org/10.1007/s10695-021- 01003-x

Amoah, K., Adu-Asiamah, P., Dong, Xh. et. al. (2020). A comparative study on the hatchability and survival rate of African catfish, Clarias gariepinus (Burchell, 1822), induced with catfish's pituitary gland hormone from farmed and wild sources. *Aquaculture International* **(28)**, 2221–2234 .

Amachree, D., Akinrotimi, O. A., & Dabor, P. O. (2018). Effects of different physiological saline concentrations on the reproductive performance of *Clarias gariepinus* (Burchell, 1822). *Journal of Fisheries Sciences* ***12***(**4**), 4–8.

Amusa, T. A., Agbo, F. U. & Offor, E. I. (2018). Economic assessment of backyard catfish (Clarias gariepinus) production in Abia State, Nigeria. *African Journal of Agriculture Technology and Environment* Vol. **7**(**2**): 1-13, December 2018.

Anpe, J.A., Absalom K.V. , Igoche, L.E., Ofojekwu, P.C., & Audu, B.S.. (2017), The embryonic development of Clarias gariepinus fertilized eggs subjected to different water temperature interval in an indoor hatchery in Jos. *International Journal of Fisheries and Aquatic Studies* 2017; **5**(**3**): 39-44

Ayodele, I. A. & Ajani E. K. (1995). Essentials of fish farming (Aquaculture). Oduduwa Press, Ibadan. 46p.

Babatunde, A.,Deborah, R.A., Gan, M. & Simon, T. A. (2021) Quantitative SWOT analyses of key aquaculture players in Africa. *Aquaculture International* **(29)**, 1753–1770.

Borode, A. O., Balogun, A. M. & Omoyeni, B. A. (2002). Effect of Salinity on embryonic development, hatchability and growth of African catfish, C. gariepinus, eggs and larvae. *Journal of Applied Aquaculture* **12**(**4**): 89-93.

Boyd E. (2017). General relationship between water quality and aquaculture performance on ponds. In: *Fish diseases*. Elsevier, pp 147-166.

Boyd E. & Licthkoppler A. (1979). Water quality managemnt on fish pond culture. *Journal of Auban University, Alabama* **5**: 28-45.

Britz, P. J. & Hecht, T. 1989. (2002). Effect of Salinity on Growth and Survival of African sharptooth catfish (Clarias gariepinus) larvae. *Journal of Applied Ichthyology* **5**:1994–2002.

Bromage, N. R. & Roberts, R. J. (1995). Brood-stock Management and Egg and Larval Quality. Blackwell Science: Iowa State University Press, USA 6–24p,76–93p.

Cai J, Leung PS. Short Term Projection of Global Fish Demand and Supply Gaps; FAO Fisheries and Aquaculture Technical Paper No. 607; FAO: Rome, Italy, 2017.

Cai J, Huang H, Leung PS. Understanding the Contribution of Aquaculture and Fisheries to GDP; FAO Fisheries and Aquaculture Technical Paper No. 606; FAO: Rome, Italy, 2019, 80.

Cassou, E., (2018). Aquaculture (English). Agricultural Pollution Washington, D.C.: WorldBankGroup.http://documents.worldbank.org/curated/en/346531521207655964/Aquaculture

Clay, D. (1977). Preliminary Observation on Salinity Tolerance of Clarias gariepinus from Israel. *Israeli Journal of Aquaculture* **29**: 102-109.

Dauda, B. (2005): Tackling Africa's deficit. Proceedings from: New Partnership for Africa's Development-Fish for All summit: August 25, 2005 Abuja Nigeria. Aquaculture 31p.

Dedi F. P. , Dedy A., Adli W. P., Iko I. A., & Kavinta M., (2022). The Effect of Different Salinity Concentrations on the Embryogenesis Development of the Freshwater African Catfish, *Clarias gariepinus*, Burchell 1822. *Egyptian Journal of Aquatic Biology & Fisheries.* Zoology Department, Faculty of Science, Ain Shams University, Cairo, Egypt. ISSN 1110 – 6131 Vol. **26**(**6**): 1329 – 1347 (2022)

Edwards, P. (1999). Towards Increased Impact of Rural Aquaculture. A

Discussion Paper prepared for the First Meeting of the APFIC Ad -Hoc Working Group of Experts on Rural Aquaculture 20-22 October 1999. FAO Regional Office for Asia and the Pacific (RAP) Bangkok, Thailand. 86-89.

Ezenwa, B. I., & Ayinla, O. A. (1994). Conservation strategies for endangered fish in Breeding and Nursery grounds within the coastal wetlands of Nigeria. Aquatic Conservation in Marine and Freshwater Ecosystems 4: 125-133.

Falaye A. E., (2013). Status of Aquaculture in Nigeria. African Union-International Animal Resources. Expert Planning meeting on Aquaculture Development in Africa Mangochi, Malawi 8-9 March 2013. 44p

Falaye A. E., (2013). Fish: A Jewel in Land and Sea Environment. An Inaugural Lecture 2012/2013, University of Ibadan Publication. 1: 5-6.

Fashina-Bombata, H. A., & Busari, A. N. (2003). Influence of salinity on the developmental stages of African catfish Heterobranchus longifilis (Valenciennes, 1840). *Aquaculture* 224: 213-222.

Federal Ministry of Agricultural and Rural Ddevelopment, (2011). Agricultural Transformation Agenda: We Will Grow Nigeria's Agricultural Sector. Draft for Discussion; Federal Ministry of Agriculture and Rural Development: Abuja, Nigeria, 2011.

Federal Ministry of Agriculture and Rural Development, (2017). Nigerian National. Aquaculture Strategy. Handbook on the Nigerian National Aquaculture strategy 2017. www.fmard.gov.ng. Retrieved 2-5-2019.

Food and Agriculture Organisation, (2012). The State of World Fisheries and Aquaculture 2012. The Food and Agriculture Organization of the United Nations, Rome. www.fao.org/nigeria. Retrieved 2-5-2019.

Food and Agriculture Organisation, (2016). Food and agriculture-Keys to achievable Development 2014-2030. The Food and Agriculture Organization of the United Nations, Rome. www.fao.org/nigeria. Retrieved 2- 5-2019.

Food and Agricultural Organisation, (2019). Fisheries and Aquaculture-Cultured Aquatic Species Information Programme. Clarias gariepinus (Burchell, 1822). www.fao.org/nigeria. Retrieved 2-5-2019.

Food and Agricultural Organisation, (2022). Aquaculture Growth Potential in Nigeria: WAPI Factsheet; FAO: Rome, Italy, 2022.

Gabriel, U. U., & Deekae, S. U. (2020). Hatchability and larval survival of African catfish under different salinity regimes. *Journal of Aquaculture Research & Development*, **11(2)**, 45–53.

Gbulubo, A., & Erondu, E. (1998). Salinity influence on the early stages of the African catfish. *Aquaculture International* **6**, 369–379

Hogendoorn, H. & Vismans, M. M. (1980). Controlled propagation of the African catfish, Clarias lazera. II. Artificial reproduction. *Aquaculture* **21**: 39–53.

Huisman, E. A. & Richter, C. J. J. (1987). Reproduction, Growth, Health control and Aquacultural potential of the African catfish, Clarias gariepinus (Burchell, 1822). *Aquaculture* **63**: 1–14.

Imam, T. S., Abdullahi, Z. D. & Sani, A.,(2019). Effect of Different Water Qualities On Clarias gariepinus Growth And Survival. *Journal of Veterinary and Biomedical Sciences.* Vol. **I** (**2**). PP 78 - 84, February, 2019 ISSN:2635-3067

Isaiah, A. (2019). Studies on the hatchability, growth performance and survival of African catfish (Clarias gariepinus) in different aquaculture production systems.

Kawamura, G., Bagarinao, T., Yong, A. S. K., Sao, P. W., Lim, L. S., & Senoo, S. (2017). Optimum low salinity to reduce cannibalism and improve survival of African catfish larvae. Fisheries Science, **83(4)**, 597–605.

Konings, A., Freyhof, J., FishBase team RMCA, & Geelhand, D. (2019) [amended version of 2018 assessment]. "Clarias gariepinus". IUCN Red List of Threatened Species.2019:e.T166023A155051767. doi:10.2305/IUCN.UK.2018-2.RLTS.T166023A155051767.en. Retrieved 3 April 2024.

Kolawole, A. E., Olusegun, A. A., & Ibukunoluwa A., A. (2011). Fundamentals of fish farming in Nigeria. Walecrown Ventures.

Kosemani, S.E., Obayemi, O.E., Ayodeji, O. et al (2024). Impacts of fish pond effluent on the water quality of an afrotropical stream: a comprehensive evaluation using the water quality index. *Discover Water* **4**(**67**). https://doi.org/10.1007/s43832-024-00122-9

Mbagwu C. B., Keke I. R., & Okorie P. U., (2022). Water quality and carcass proximate composition of Clarias gariepinus (Burchell 1822) juveniles fed blood meal graded diets. *International Journal of Fisheries and Aquatic Studies* **10**(**6**): 56-61

Munguti, J., & Odeke Iteba, J. (2022). Advances in African Catfish (Clarias Gariepinus) Seed-Production Techniques in Kenya. IntechOpen. doi:10.5772/intechopen.105665

Nwadukwe, F. O., & Nana, I. G. (2000). Effects of rearing periods on the production of hybrid-Catfish (Clarias gariepinus x Heterobanchus longifilis) fingerling. *Journal of Aquatic Sciences* **(15)**: 23-26.

Okomoda, V.T., Isah, S., Solomon, S.G., & Mhd I., (2024). Salinity tolerance in Clarias gariepinus (Burchell, 1822): insight on blood parameter variations and gill histological changes. Fish Physiology and Biochemistry **(50)**, 605–616. https://doi.org/10.1007/s10695-023-01293-3

Olaniyi, Wasiu & Omitogun, Ofelia. (2013). Stages in the early and larval development of the African catfish Clarias gariepinus (Teleostei, Clariidae). Zygote(Cambridge,England). **22** 1-17. 10.1017/S0967199413000063.

Olaniyi, W.A., & Omitogun, O.G. (2014). Embryonic and larval developmental stages of African giant catfish Heterobranchus bidorsalis (Geoffroy Saint Hilaire, 1809) (Teleostei, Clariidae). *SpringerPlus* **(3)**, 677. https://doi.org/10.1186/2193-1801-3-677

Olaniyi, C. O., & Omitoyin, B. O. (2016). Effects of salinity on fertilization and hatching of African catfish (Clarias gariepinus) eggs. *International Journal of Fisheries and Aquatic Studies*, 4(6), 01–05.

Opiyo, M., (2017). Fecundity, growth parameters and survival rate of three African Catfish (Clarias gariepinus) strains under hatchery conditions. *Journal of Aquaculture Engineering and Fisheries Research*.**3**(**2**):75- 81 (2017)

Oyebola, O. O., & Awodiran, M. O. (2014). Effects of Spawning Methods on Fertilization, Hatchability and Fry size Variation in Clarias gariepinus. Department of Aquaculture and Fisheries Management, University of Ibadan, Ibadan, Nigeria, *Ife Journal of Science* **17**(**2**)15-20.

Ozigbo, E.,Anyadike C., Adegbite O., & Kolawole P. (2014). Review of Aquaculture Production and Management in Nigeria. *American Journal of Experimental Agriculture* **4**(**10**): 1137-1151.

Pasch, J., & Palm, H. W. (2021). Economic Analysis and Improvement Opportunities of African Catfish (Clarias gariepinus) Aquaculture in Northern Germany. *Sustainability*, **13**(**24**), 13569. https://doi.org/10.3390/su132413569

Reuben, L., Michael, O., & Stephen, M. (2024). Induced Breeding in Clarias gariepinus: A Systematic Review and Meta-Analysis of Overprim and It's Saline Dilution Doses. *Journal of Multidisciplinary Science*: MIKAILALSYS, **3**(**1**), 45-60.

Subasinghe R, Siriwardena SN, Byrd K, Chan CY, Dizyee K, Shikuku K, Tran N, Adegoke A, Adeleke M, Anastasiou K, Beveridge M, Bogard J, Chu L, Fregene BT, Ene-Obong H, Cheong KC, Nukpezah J, Olagunju O, Powell A, Steensma J, Williams G, Shelley C, and Phillips M. (2021). Nigeria fish futures. Aquaculture in Nigeria: Increasing Income, Diversifying Diets and Empowering Women. Report of the scoping study. Penang, Malaysia: WorldFish. Program Report: 2021-16.

Teugels, G.G. (1986). A systematic revision of the African species of the genus Clarias (Pisces: Clariidae). Annal. Musee Royal de l'Afrique Centr. 247, 1–199.

Ujagwung, U., Awotongha, J., & Deekae, S. (2021). Salinity tolerance of African catfish larvae under varying concentrations. *Animal Research International*, **18(3)**, 352-360

Wasiu A. O., & Omitogun O. G. (2013): Stages in the early and larval development of the African catfish Clarias gariepinus (Teleostei, Clariidae). Dept of Animal Sciences, Obafemi Awolowo University, Ile-Ife, 220005, Osun State, Nigeria. Cambrige University Press 10. 10:17.

Williams, S. B; Olaosebikan, B. D; Adeleke, O. A. & Fagbenro, O. A. (2008). Status of African catfish farming in Nigeria. In: Proceeding of workshop on the Development of a Genetic Improvement Program for African Catfish Clarias gariepinus. Ponzoni, R.W. and N. H. Nguyen .Eds. 2008. World Fish 56p.

WorldFish Center, (2009). Climate; Research to Meet the Challenges Facing Fisheries and Aquaculture ISSUES Brief 1915, Penang, Malaysia. www.worldfishcenter.org. Retrieved 22-5-2019.

WorldFish Center (2018). WorldFish Nigeria Strategy: 2018-2022. Penang, Malaysia: World Fish Strategy: 2018-09. www.worldfishcenter.org