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Precision Farming Model for Optimum Catfish Production

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Abstract Fish farming has been identified as a great source of animal protein for the large percentage of the world population and Nigeria, a country with over 170million population is not left behind. The level of productivity of catfish farm is determined by production knowledge and skills, suboptimal stocking and overstocking, poor fish population control methods, low feeding rate, water temperature, water quality, and health status of the fishes under culture. Combination of these factors influence the ability to maintain ethically sound, productive, and environmental friendly production of fish. In other to achieve optimum production of catfish, a solution through the use of wireless sensors was deployed to address some of the problems of low yield. The approach used to track optimum temperature through the deployed wireless sensor and administer feed to the fish at that particular temperature of the day. The study shows that the deployed system helped the farmers to design a feeding pattern that supports optimum growth of fish under culture by achieving a lower Feed Conversion Ratio (FCR) of 0.62 in the experimental pond as against 0.67 in the control pond, the solution provide a platform through which farmers can have access to the status of the pond from anywhere in the world.

Keywords: *precision farming, wireless sensor networks, catfish, android application*

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1. Introduction

Nigeria is the largest producer of catfish in Africa, which is the dominant fish cultured in the country because it is found all over, it is eaten by most tribes, resistant to harsh environmental conditions, commands a reasonable price, tasty, and can be kept alive for days during marketing. Estimates put the current production output of *Clarias gariepinus* in the Country at over 155,323 metric tonnes as of 2017 [1]. With these rates of production, new market, and value addition to catfish will be exploited to absorb total production in the future.

1.1. Precision Fish Farming (PFF)

Precision Farming (PF) for Fish production is targeted at applying engineering ethics to the production of fish, thus improving the farmer's skill to control, monitor closely, and document biological processes in fish farms. By adopting some core principles from PF and given an account of the boundary conditions and prospects that are peculiar to farming operations in the aquatic environment [2]. To help in defining PFF, it is useful to picture fish farming as several cyclical operational practices realized in four phases where bio-responses in the cage are noticed (Observe phase) and interpreted (Interpret phase), leading to a foundation for decision making (Decide phase) on which actions to enforce (Act phase) that in turn stimulate a bio-response in the fish [2].

1.2. Justification

Fish is the cheapest source of animal protein and is generally cherished as one of the healthiest sources of protein. Production of Fish in aquaculture is now on the rise due to the high demand for fish as a result of an increase in population and over-exploitation of fishes. In optimizing fish production, stocking density, feeding rate, water quality, fish nutrition, or physiological stage of the fish, the type of production system, size, and the type of the rearing tanks must be considered [3]. Feed quality, frequency of feeding, water quality, water temperature, and fish health status is the most important contributing factors for the optimum production of fish [4]. This report seeks to achieve optimum production of catfish using recommended conditions and emerging technologies to monitor the status of the fish in other to increase productivity, improve population monitoring, growth rate, and welfare of the fish.

2. Literature Review

African catfish, also known as *Clarias gariepinus*, is an important aquaculture species that are cultured in several regions in the world. The top-most producing country in Africa is Nigeria, followed by Kenya, South African, Cameroon, and Mali [5]. The aggregate production of African catfish is 246,476 tonnes in 2017. The 2015 data by FAO put the total African catfish production in Nigeria at 160,295. Data from 2016 and 2017 by FAO showed 159,911 and 155,325, respectively, as displayed in Figure 1 show a decline in the production of African catfish in Nigeria [1].

2.1. Factors Affecting Catfish Production

Generally, factors hindering the production of fish in freshwater systems can be categorized as biochemical, physical, or combination. Water physical properties that are vital to fish production and growth include turbidity, temperature, and the concentrations of suspended and settle-able solids; important chemical parameters include pH, dissolved oxygen, electrical conductivity, alkalinity, hardness, and metals [6]. Other factors affecting fish productivity in the farm are fish pond, feed, and feeding practice, feed quality, feeding rate, size of fish to stock, number of fish seed to be stocked [7].

2.2. Precision Farming

Precision farming (PF) involves the application of technology and principles in proper monitoring and controlling of farming activities. Quite several precision agriculture systems have been employed in crop cultivation, an advanced GSM-based harvesting and irrigation system was designed, this system efficiently utilizes the irrigation water for the farm's crops by tracking the field's soil moisture, atmosphere's temperature, and humidity status [8]. Also, an automated water irrigation system using Arduino Uno and Raspberry Pi with the Android interface. The use of correct soil moisture sensors was presented, which helps to relieve the discomfort in monitoring and keeping records about soil moisture variation [9].

2.3. Overview of Wireless Sensor Networks (WSNs)

Wireless Sensor Networks can be described as a self-configured network to observe environmental conditions, such as vibration, motion, temperature, sound, pressure, or contaminants, and to obligingly pass their data through the network to the central location or sink where the data can be observed and analyzed.

2.4. Application of Wireless Sensor Networks (WSNs)

Wireless sensor networks have gained immense popularity due to their flexibility in solving problems in different application domains and have the potential to change our way of living in different ways. WSNs have been effectively applied in various application domains such as the health sector, transportation, area monitoring, military application, environmental sensing, agricultural sector, structural monitoring, and industrial monitoring.

2.5. Wireless Sensor Networks (WSNs) Topology

The advancement and distribution of WSNs have taken network topology in a new direction. Types of wireless sensor networks topologies are mesh, tree, ring, and star. The type of sensor topology employed in this research work is a star topology, whereby Senor nodes are connected to a centralized communication hub (sink), and the nodes are not connected directly. The communication link must be transmitted through the central hub. Each node present in the network is a “client,” while the central hub is the “server or sink”.

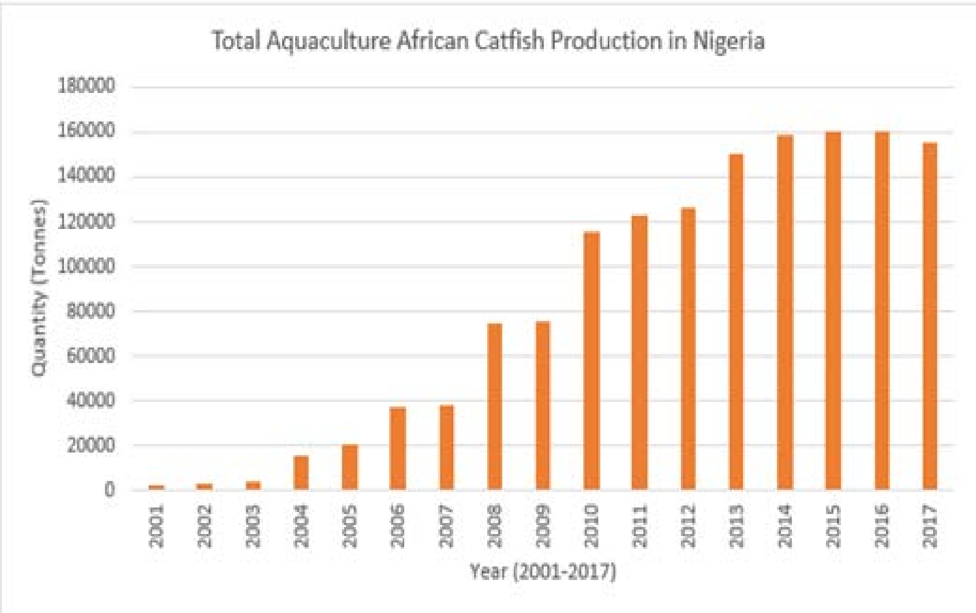


Figure 1. Total Aquaculture *Clarias Gariepinus* Production in Nigeria (2001-2017)

2.6. Related Works

Precision farming is a highly sought-after technology, it has been a field of interest for many researchers, and a lot of research work has been done. Recently, the various smart agricultural-based system has been designed in other to enhance farming practice. A water quality monitoring system for a large aquatic area was developed using wireless sensor network technology. The system detects pH, dissolved oxygen, water temperature, and pH in a pre-programmed time interval. Results showed that the system has excellent prospects and can be used for environmental monitoring by offering interested parties with essential and timely information for sound decision making [10].

Water quality laboratory kits have been the primary tools employed by some farmers to monitor the quality of pond water, but presently farmers are starting to doubt the accuracy and reliability of the kits. It was noted that many of the water quality problems faced by pond owners and fish farmers might not be resolved by the results of water quality laboratory testing [11]. A research on the effect of fish feeding practices on the water quality of some fish ponds in Ekiti State Fish Farm was carried out. Water samples for Physico-chemical parameters were collected fortnightly, from the selected ponds and reservoir for six months. Three different fish diets were used. Parameters of water quality such as dissolved oxygen, pH, temperature, conductivity were checked from time to time against the feed been given to the fish. The study concluded that feed quality and feeding frequency negatively impacted the water quality of the pond [12].

3. Methodology

A monitoring system comprising of four different sensors (temperature, PH, Conductivity, and turbidity) was designed and implemented during the research study. The overall system design was framed in a block diagram linking different interfaces of the hardware subsystem, as shown in Figure 2.

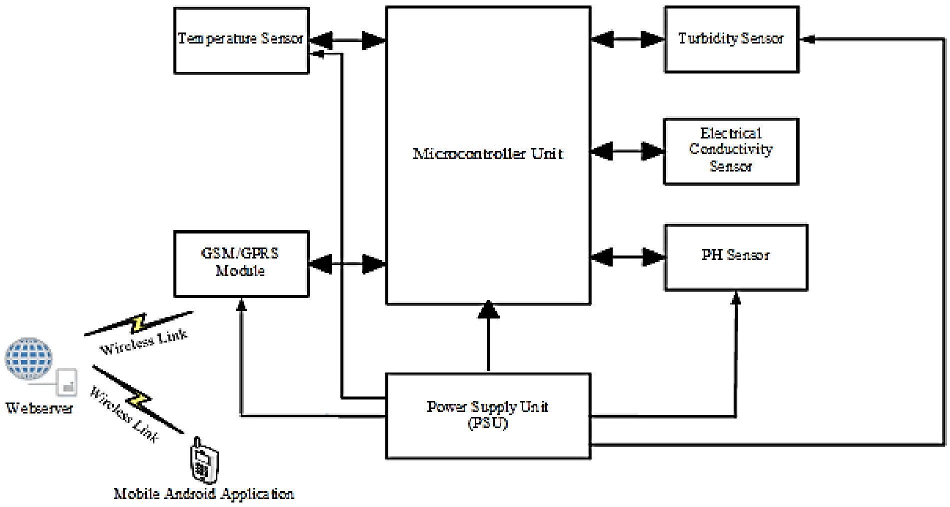


Figure 2. System Block Diagram

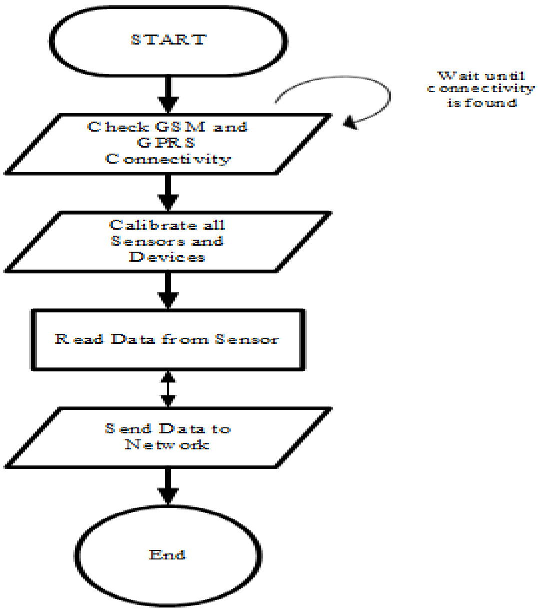


Figure 3. System Flowchart

The system is made up of four different electronic sensors (temperature, turbidity, electrical conductivity, and PH sensor) designed to perform specific functions, update conditions on farmland. The GSM/ GPRS module enabled the microcontroller to communicate the data from the sensors and device to the webserver and the microcontroller, which process the signal from each unit of the system.

An android application was developed, which serves as the monitoring unit for retrieving the data from the webserver and display in a user-friendly format. Data from the android application can be exported as an excel file for further analysis, Figure 3 is showing the system flowchart. The microcontroller used a periodic time-triggered method to read the sensor value and send the data to the webserver.

3.1. Cloud Service Setup

In database service, the first step of the setup is to connect to the cloud server, a service that provides API libraries for a wide range of platforms, including Arduino and python [13]. In this research, phpMyAdmin server was created using PHP code, as shown in Figure 4. The server has six columns (ID, Event, PH, Temperature, Turbidity, and Conductivity). The database was uploaded to an online cloud service. Data retrieved from the field are being logged into the online database from the Arduino microcontroller through the GSM module.

3.2. Farmer's Mobile Application Development

The android application was designed to ease access to the server in the cloud, also was developed with a minimum android target platform of 4.0. It implies that the application is available on devices with an android operating system version 4.0 and above but might encounter an error or might not run in the lower version. It stated that 82% of smartphones devices run on the Android operating system, which further buttresses the choice of this platform for this research study [14].

3.3. Experimental Procedure

The study was conducted at the Uncle B's Farm, Arigbaboola Street, Ondo Town, Ondo State, Nigeria. The study started with 30,000 fishes (8 weeks old) fingerlings of *Heteroclarias* (hybrid) of the average initial weight of 10.00g were breed on the farm. The fish were kept in a static concrete-based pond of 17.3m×25m size with a depth of 5 feet, for four weeks and fed with 3mm Bluecrown (imported feed) for acclimatization to experimental conditions. The choice of floating feeds was because it; improves consumption and feed conversation ratio, reduces feed wastage, counteracts water contamination/development of unsafe microorganisms, and decreases the odds of mortality. In other to maintain optimum production in a fish farm, stocking density and feeding rates were maintained as recommended.

3.4. Feeding Procedure

Fish were fed to satiation twice daily (30kg) in two equal installments based on the temperature status on the pond retrieved through the deployed system. The optimum temperature (26°C-28°C) was tracked every day by the system in other to avoid feeding when the temperature is too low or too high. The initial and final weights of the fish in each tank were recorded using a manual dial-type weighing platform scale. Fish were bulk-weighed (average of 60) every week to calculate their growth response. Good water quality was maintained throughout the feeding period. The broadcasting feeding method was employed throughout the culture period simply because it was adjudged to be the best feeding technique for small fishes that have little or no knowledge about their environment. This method is also preferable when using a floating feed [15].

3.5. Water Quality Parameters

African Catfish, like any other catfish species, requires an optimum level of water quality parameters for survival, growth, and reproduction [16]. The amount of food fish takes in each day depends on the water quality, notably the temperature and any stressors (low Dissolved Oxygen, pH, high ammonia, health conditions) to which the fish are exposed [7]. Failure to maintain an adequate water quality regime in ponds may cause parasitic infection or other diseases and conditions which are very detrimental to the fish. Water quality parameters (temperature, pH, conductivity, turbidity) of the experimental pond was well monitored on a timely basis and with feeding frequency adopted on the farm [17]. Water quality monitoring was aided during the research work through the deployed system.

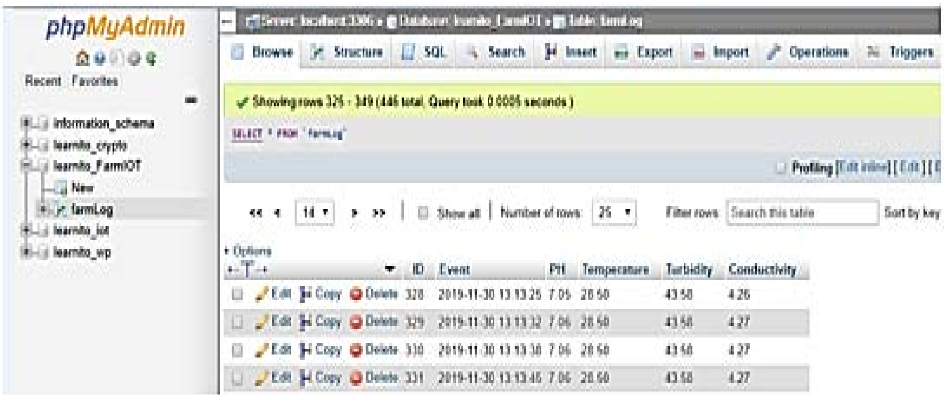


Figure 4. phpMyAdmin Cloud Database

3.6. Growth Performance

In other to analyze the growth rate in fish production, the following parameters of the experimental pond were calculated and compared with the control pond:

Mean Weight Gain (g) (MWG) [18]

$$MWG = Wt_2 - Wt_1$$

Where Wt_1 = initial mean weight of fish at time T_1

Wt_2 = final mean weight of fish at time T_2

Feed Conversation Ratio (g) (FCR) [19]

$$(FCR) = \frac{weight\ of\ feed\ given(g)}{Fish\ weight\ gain}$$

Specific Growth Rate (SGR) [19]

$$(SGR) = \frac{100(\log_e W_f - \log_e W_i)}{Time(days)}$$

Where W_f = final average weight after the experiment

W_i = initial average weight at the start of the experiment

$\log_e$ = Natural Logarithm reading

$Time$ = Number of days for the experiment

Survival Rate (%) [20]

$$Survival\ Rate\ (\%) = \frac{Number\ of\ fish\ that\ survived}{Total\ number\ of\ fish\ stocked} \times 100$$

Production Index [21]

$$PI = \frac{survival\ rate \times (final\ weight(g) - initial\ weight(g))}{Duration}.$$

4. Results and Discussion

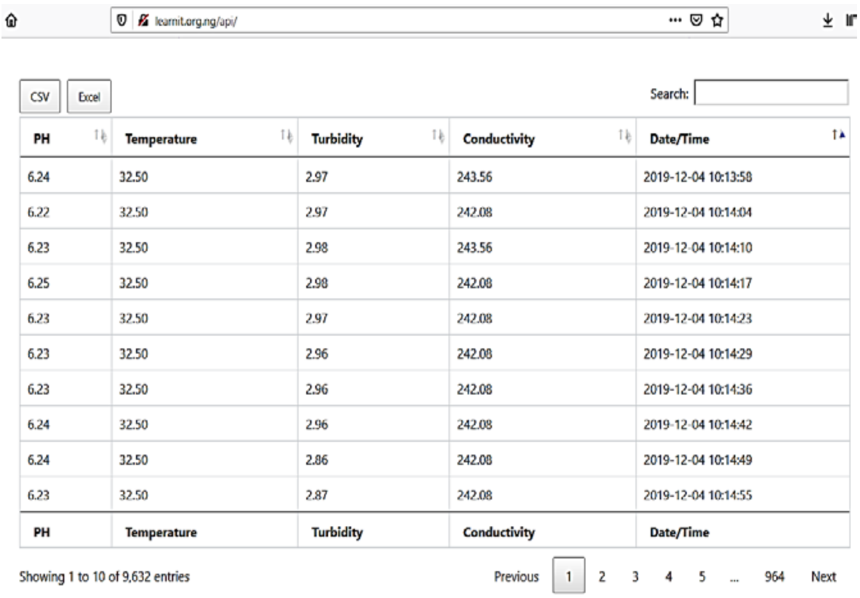
The developed sensor nodes were deployed on the farm, as shown in Figure 5 to measure values such as water PH, water temperature, turbidity, and conductivity sensor as well as monitor the quality of the water in the fish pond.

Figure 5. Sensor Probes deployed in the pond

A fish farmers having access to the status of his/her fish farm, anytime, anywhere from any location is a huge step to put into quick action necessary for optimum production of catfish. Data measured from the sensor nodes was logged into a database hosted online in the cloud through the GSM module, as shown in Figure 6.

4.1. Farmer's Mobile App

Figure 7 shows the developed App. Frontend and graphical View of the Sensed Data. Measured values of the water parameters PH, Temperature, Turbidity, and conductivity are retrieved from the cloud when the mobile phone is connected to the internet. The mobile app shows the current status of the pond water for farmer to make necessary decisions towards positive yield.



learnit.org.ng/api/

CSV Excel Search:

PH	Temperature	Turbidity	Conductivity	Date/Time
6.24	32.50	2.97	243.56	2019-12-04 10:13:58
6.22	32.50	2.97	242.08	2019-12-04 10:14:04
6.23	32.50	2.98	243.56	2019-12-04 10:14:10
6.25	32.50	2.98	242.08	2019-12-04 10:14:17
6.23	32.50	2.97	242.08	2019-12-04 10:14:23
6.23	32.50	2.96	242.08	2019-12-04 10:14:29
6.23	32.50	2.96	242.08	2019-12-04 10:14:36
6.24	32.50	2.96	242.08	2019-12-04 10:14:42
6.24	32.50	2.86	242.08	2019-12-04 10:14:49
6.23	32.50	2.87	242.08	2019-12-04 10:14:55
PH	Temperature	Turbidity	Conductivity	Date/Time

Showing 1 to 10 of 9,632 entries Previous 1 2 3 4 5 ... 964 Next

Figure 6. Overview of sensor values from the sensor nodes logged to the online database

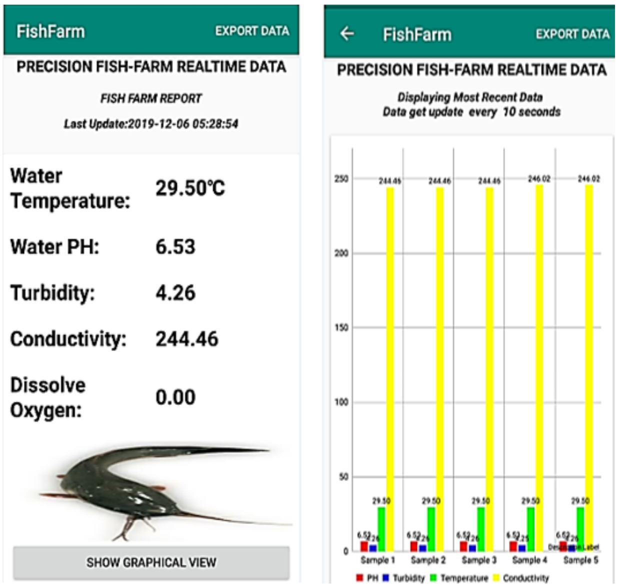


Figure 7. Developed App. Frontend and Graphical View of the Sensed Data

4.2. Evaluation of the Precision Fish Farming System

The precision fish farming model was evaluated through growth performance and statistical analysis of water quality parameters of pond affecting the growth of catfish.

4.3. Growth Performance

The growth performance of the fish under culture is presented in Table 1 to Table 2 and Figure 7 to Figure 10. The initial weight of fish used for the research study was 10g, while the final weight after four weeks of research experiment was 42g and 45g in the control and experimental pond, respectively. Mean weight gain showed a similar pattern to that of SGR. Feed utilization, expressed as the feed conversion ratio (FCR), was low indicating high conversion rate. The survival rate was 82% and 85% for the fish under culture; fair survival rate was recorded due to high cannibalism exhibited by the breed of fish under culture. *Heterclarias* breed of *Clarias* family is known for high cannibalistic behavior. A reasonably good survival rate was also recorded due to the high number of "jumper" fish harvested at the end of the research study. Although the hybrids of *Heterobranchus* and *Clarias* (*Heteroclarias*) exhibit the fast-growing quality of *Heterobranchus*, the factor of cannibalism is a common problem associated with their survival and production. Feed conversion ratio (FCR) is feed per unit of body weight gain) is an essential indicator of the quality of fish diets, and a lower FCR indicates better utilization of the fish feed [22].

Table 1. Growth Performance of Fish under culture

Parameters	Control	Experimental
Initial no	30,000	30,000
Avr. Initial weight of fish (g)	10	10
Avr. Final weight of fish (g)	52	55
Avr. Mean weight of fish (g)	42	45
Feed Conversion Ratio (FCR)	0.67	0.62
Specific Growth Rate (SGR)	65.1	69.75
Survival Rate (%)	82	85
Production Index (PI)	123	136.6

Table 2. Key Growth Performance Parameters between Control and Experimental Pond

Weeks	Control M.W.G (g)	Exp. M.W.G (g)	Control S.G.R (%)	Exp. S.G.R (%)	Control FCR	Exp. FCR
1	8.5	10	8.7	9.9	0.82	0.70
2	22	22	8.3	8.3	0.64	0.64
3	31	33	6.7	6.9	0.68	0.64
4	42	45	5.9	6.1	0.67	0.62

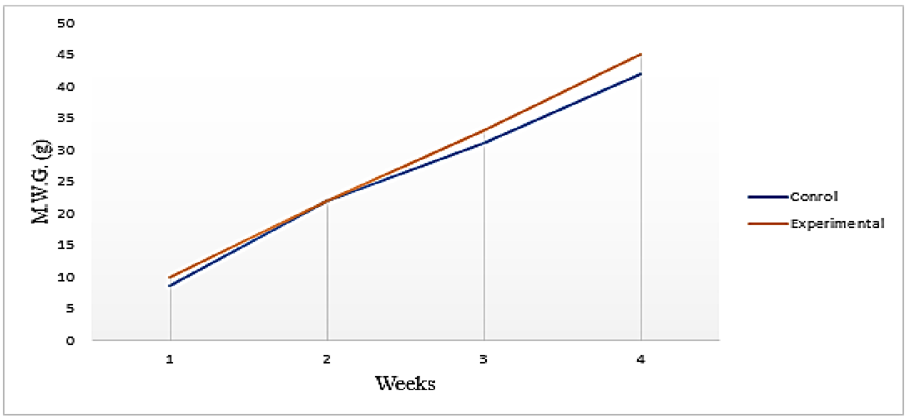


Figure 8. Weekly Mean Weight Gain (MWG) of the juvenile catfish in Control and Experimental Pond

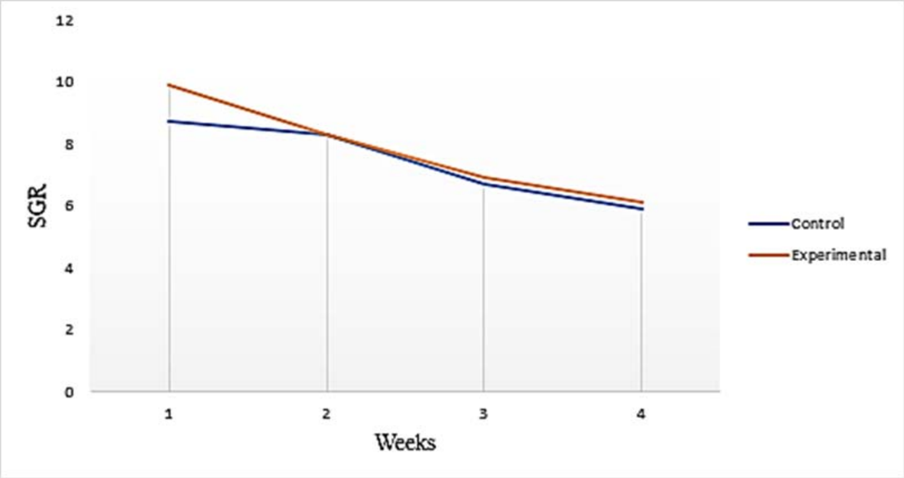


Figure 9. Weekly Specific Growth Rate (SGR) of the juvenile catfish in Control and Experimental Pond

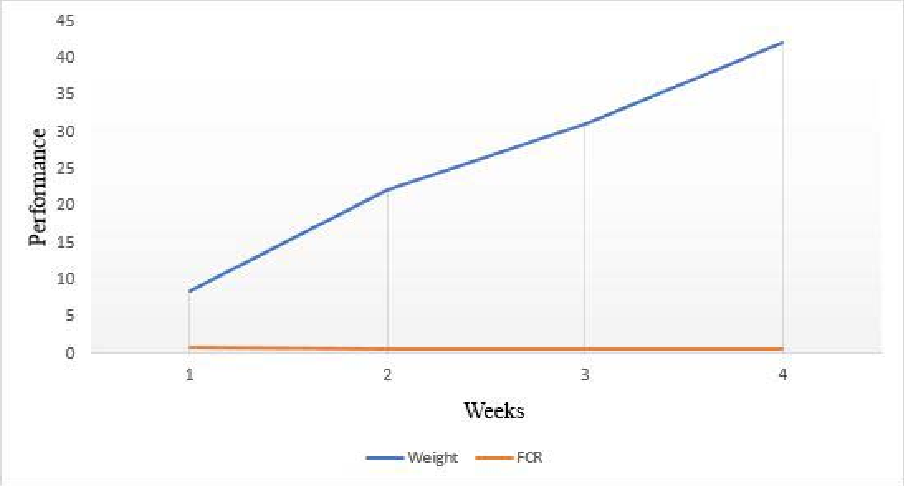


Figure 10. Comparison of weekly weight and FCR of juvenile catfish in Control pond

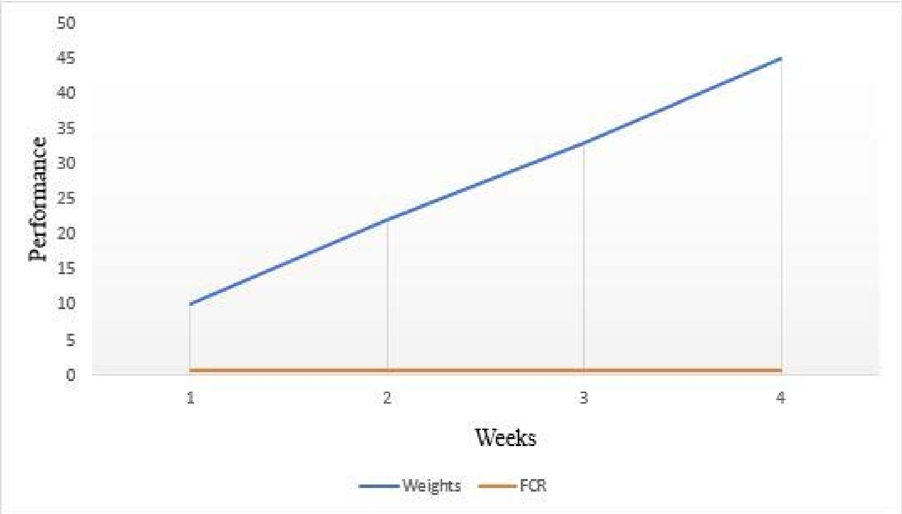


Figure 11. Comparison of weekly weight and FCR of juvenile catfish in Experimental pond

The Mean Weight Gain (M.W.G), Feed Conversion Ratio (FCR), Specific Growth Rate (SGR), and other growth parameters of *Heteroclarias* Juvenile in control and experimental ponds are presented in (Table 2). Highest mean weight gain (MWG) and (SGR), as shown in Figure 8 and Figure 9 respectively, were observed weekly in the *Heteroclarias* reared in both experimental and control pond, except in week two were fishes in the two ponds exhibited same MWG and SGR. The FCR recorded every week as shown in Figure 10 and Figure 11 presented that experimental pond makes good use of the feed administered to them more than the control pond. Better growth performance was achieved in the experimental pond due to been subjected to the designed research monitoring system that captures information of the experimental pond and makes available the status of the pond in other to effect necessary attention from the farmers ranging from feeding to water quality.

4.4. Water Quality Performance

The result of the water quality performance of the experimental pond water for four weeks of research study is presented in Table 3 and Table 4. Water temperature varies throughout the research experiment period (4 weeks); it was within the standard limit, i.e. (25℃-35℃) for fish under culture [23,24]. The maximum temperature (32.589°C) was recorded on week two due to hot weather conditions during that time of research study, and the minimum (27.000°C) was recorded on week four was attributed to the cold weather condition of the time. The mean values obtained for hydrogen ion concentration (pH) were within optimum range. The highest PH of (6.841) was recorded on week three and the lowest of PH (6.136) was recorded on week one as shown in Table 3. The fluctuation in pH result from changes in the rate of photosynthesis in response to daily photoperiod. The PH obtained during the culture period was within this range of values of 6.5 – 9.0 [23,25], but the Lowest PH recorded slightly deviated from the ranges. The highest Conductivity (310.941µS/cm) was recorded on week two while the lowest (7.842µS/cm) was recorded on week 1 as shown in Table 4. The varying conductivity levels observed in the pond could be attributed to the base material on which the ponds were sited and could also be a result of the rock materials used as wall of the pond. The recommended desirable range of conductivity is 100-2,000 µS/cm and acceptable range is 30-5,000 µS/cm for pond fish culture [26]. The highest turbidity (4.307) was recorded on week two while the lowest turbidity (1.251) was recorded on week 1 as shown in Table 4.

Table 3. Weekly mean values of water quality parameters

Weeks	Temperature (°C)		PH	
	Min	Max	Min	Max
1	28.408	31.796	6.136	6.747
2	28.974	32.589	6.184	6.626
3	28.750	30.657	6.493	6.841
4	27.000	29.250	6.585	6.700

Table 4. Weekly mean values of water quality parameters

Weeks	Conductivity(µS/cm)		Turbidity(NTU)	
	Min	Max	Min	Max
1	7.842	292.839	1.251	4.272
2	37.540	310.941	2.679	4.307
3	47.600	276.183	2.745	4.292
4	253.460	269.733	2.942	4.295

4.5. Other Factors Production of Catfish

This research study further revealed other factors hindering catfish production, and are divided into six different categories namely breed of fish, frequent sorting of fish, operational factor, structural factor, human factor, and nutritional factor. All the factors highlighted above are crucial in the production of catfish and must adhere strictly with, in other to achieve profitable production of fish.

5. Conclusions

The precision fish farming model is an initiative to monitor fish farming practice towards optima production. Through the wireless sensor network deployed, the study established a feeding technique by tracking the optimum temperature through the deployed system and administer the feed at the optimum temperature as displayed on the LCD of the system or retrieve through the mobile application. This method helped to achieve a lower FCR in the experimental pond as against the control pond indicating good flesh to feed conversion ratio. The research study also revealed other factors necessary for the optimum production of catfish.

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