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IoT based Aquaculture system with Cloud analytics

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Abstract

The field of fisheries and aquaculture is one of the fast-growing profitable area in the Sultanate of Oman. The average growth in this sector is forecasted at 7% per annum and the total investment is expected to increase to 1.1 billion OMR by 2020 from fishing and fish processing facilities as per the Oman 9th Five-Year Development Plan 2016-2020. However, the current research in this field in the Sultanate of Oman is not enough to popularize the aquaculture to attract many Omani people to invest in aquaculture/fish farming. The proposed research will activate the people who seek to invest money in fish farming. Aquaculture depends on several factors mainly environmental and production factors along with biotic factors. To help aquaculture sustainability and profitability, various parameters must be monitored and controlled. The paper proposes development of an intelligent solar based aquaculture system using Internet of Things and data analytics for monitoring aquaculture farm so that farmers can early detect any problems and take any measures to maintain the suitable conditions for the fish. The system is implemented with Arduino, sensors and actuators to automate the process of controlling the water quality parameters such as water level, temperature and ph. These sensor values are stored in cloud so that farmers can see on their mobiles through mobile app or web application anywhere remotely. The proposed system will attract fish farmers in the Sultanate of Oman who are not having enough power source in their farming place and also it will give facility to monitor aquaculture system remotely using their smart phone.

Keywords: IoT, aquaculture, data analysis, water quality, automation

I. INTRODUCTION

Aquaculture is farming of aquatic organisms through breeding, rearing and harvesting for food or commercial purposes. Fish farming is specifically farming of marine or freshwater fish in enclosed areas of the sea or pond or as on land tanks with artificial environment. The purpose of aquaculture is to meet growing need of world population for marine organisms, help endangered aquatic organisms, for medicinal purpose, reduce overfishing and loss of habitat for aquatic organisms. It has been estimated that world fish supply in 2014 reached 16.2 million tons due to growing aquaculture farms.[1] If well-maintained, fish farm would be successful with high yield and help reduce world food security problems.

Intelligent fish farming is an innovative and effective way of farming fish through use of latest technologies such as Internet of Things, Cloud and data analysis. Fish are sensitive to change in their conditions as they are cold blooded organisms. Slight changes in parameters could also drastically affect the growth of fish and easily cause stress.

The parameters are physical, chemical or biological such as, temperature, pH, dissolved oxygen, algal composition in water etc. Through real time monitoring with high sensitivity sensors the parameters can be accurately measured. These connected via internet over to a database and application will help control and monitor the parameters by farmers remotely and also store the data. The characteristics of intelligent system are that it's real time, automatic control, highly precise data and continual update of data.

Oman has seen 24.3% increase in fish production in the year 2017, from which 0.0% of the production was from aquaculture in year 2017 i.e. about 77 tons of fish. The other major approaches of fishing are traditional fishing, commercial fishing and coastal fishing. [5] Oman has a huge scope for aquaculture as oil preserves are being used up the country is diversifying economy further and also domestic marine fisheries are increasing due to depleting oil reserves.[6]. Overfishing can deplete the fish population and the quality of fish in the wild is harder to monitor. Aquaculture came as solution to maintain balance between rapid rise in fish demand and overfishing problems.

The challenges that are faced in aquaculture are as follows:

1. Water quality

2. Aquatic health

3. Feed management

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Water Quality: For the growth of aquaculture species, the water quality must be good. If the water quality parameters are not taken care, within few hours species can be prone to diseases or even can be dead.

Feed Management: The biggest difficulty in fish farming is fish feeding as it is labour intensive process. The other factors which affect feeding rate are time of day, season, water temperature, dissolved oxygen levels, and other water quality variables. This makes the process time consuming and inefficient.

Traditional methods are unreliable and also a hazardous and unhygienic because farmer has to physically be present in the aquaculture area and measure the parameters. Therefore, this project is proposed to overcome these challenges to automate the monitoring process involved in fish farming in small and medium scale fisheries.

Due to rise in water pollution, wild fish population has also depleted. Therefore to keep a sustainable and environment friendly way of fish farming while meeting the world fish demand, intelligent fish farming has been proposed. Through high performance and low power sensors, fish habitat in the fish farms is observed and this data is stored in cloud, viewed real-time and remotely controlled. This is a helpful technique of effective farming for farmers, investors in aquaculture and fish farm owners.

II. BACKGROUND RESEARCH

Dupont and Cousin [1] have reviewed three European Commission funded projects to understand the importance of IoT in aquaculture for 3 factors. For remote fish farms where monitoring is a tedious task IoT will help to monitor, control from distance and reduce costs. Water quality can easily change due to environmental or physical factor hence through IoT water environment can be monitored real-time so that changes are not missed out. The three factors analysed by the author about an IoT setup are high performance and low cost sensors, affordable and easy to deploy and smarter systems.

When choosing real-time sensors several factors taken into consideration are is farm in remote area, if there is continual power supply, flow system of water and on land or sea. When farms are in remote and open areas power supply is a major concern and availability of service/maintenance. Sensors in general should be weather-proof in all seasons and can be self-cleaned or easily cleaned frequently because sensor should be functional despite changes in weather so that it can be monitored at all times and prevent inaccurate results from debris on probes. These are technical issues faced in selected equipment.

A project by PROTEUS has been analysed for building high performance lost cost sensors. Taking into considerations reliability & accuracy, cost and maintenance management as key factors, a chemical sensor was made with carbon nanotube. The sensor has shown very high precision hence considered reliable and accurate. It’s applications were identified in water quality monitoring for pH, chloride and other parameter with precision of around 0.01 unit in pH. With lifespan of 2 continuous years and 50 times lesser cost than current ones the sensor is a breakthrough in technology.

The WAIZUP project in Ghana was a simple, low power and IoT based aquaculture application. Basic important sensors for temperature, pH and DO was setup. The effect of the environment on sensor was studied and the behaviour of water throughout the day. Temperature had direct impact on DO and pH. With rising temperature, pH and DO levels rose but temperature and DO were within acceptable range although pH was too high because of algae in water and oxygen was slightly lower in the morning. The author has also found a suitable solution that helps maintain both oxygen and pH, i.e., aerate water at night and pour dolomite lime to remove excess algae.

The third experiment was a smart aquaculture system to reduce negative impact of aquaculture in ecosystem. The project is still under process therefore results are not completed. The approach suggested is integrated multi-trophic, means different species in food chain will be integrated to reuse the wasted food and resources. The wastes and food of one species will be collected to recycle as fertilizer or energy for another species.

Overall the projects have helped create sustainable, economic, reduced risk and diverse solutions to problems that arise in aquaculture. The first project developed multi-parameter, highly sensitive and affordable chemical sensor. The second was a simple IoT based aquaculture for small scale farms and third was an intelligent aquaculture system still under process for efficiently farming.

Design and Development of Smart Aquaculture System Based on IFTTT Model and Cloud Integration is the project regarding development of smart aquaculture with cloud and IoT as a solution to problems with water quality management faced by traditional farming methods. The writer has first analysed and prioritised the important parameters for any fish as dissolved oxygen(DO), water temperature, water pH and salinity. The project consists of five parts namely, smart sensor module, smart aeration, local area network, cloud computing and front end to visualize data. The smart sensor was to monitor the water temperature, pH, DO and water level. These sensors have been connected to a central processing unit which sends the data to router using MQTT protocol. The protocol MQTT is suitable because it is ideal for machine to machine communication where the connection is remote and data sent is of low bandwidth. All the other devices in the network are connected to the router so that data from sensor is sent to cloud database and cloud to mobile or web application and vice versa.

From the real-time data stored in cloud the changes will be detected in water. If the value is below the required the aerator is switched on and if above the required value then aerator is switched off. This function is set using the IFTTT protocol between server and aerator and a control device including relay switch and NodeMCU V3 to physically switch on and off the aerator. Connection of all these devices are part of the local area network system and where the data storage and analysis occurs it is the cloud database. In real-time a user can view the data in the sensors and see changes over time as graphs in web application or mobile application.

During implementation the latency time of detecting change in sensor to turning aerator on/off was measured so that reliability and availability of system is understood. The sensor continually monitored the DO level in tank and when it reach below 5 mg/L the system is alarmed and IFTTT is executed to switch on aerator and run it until 10mg/L is reached. The aerator ran for 1199961ms , within which the DO level reached 10mg/L. It was seen that when temperature increased DO level reduces and pH drops too. After the aerator is turned on and DO level increases and pH goes from 6.9 to 7.6. Also the water temperature drops and becomes constant from 28.5 °C to 28 °C. This way it maintains the water quality for the fish.

The author has found that through use of IFTTT the sensors were customized to set within the appropriate range of pH, temperature and DO and through cloud and IoT the tank water was controlled automatically, viewed live data by user in application and user could control the aerator from mobile. [4]

Real time fish pond monitoring and automation using Arduino is to monitor an actual freshwater pond and automate the process of controlling water quality. The work has been carried out in a pond in Malacca, Malaysia for a fish farm to help farmer monitor precisely and throughout without spending money on extra workers to monitor the water conditions. The range of values suitable for fish in three countries have been analysed beforehand.

Using these values the sensors used were of minimum uncertainty and appropriate specifications. The sensors were connected by a microcontroller, Arduino Mega 2560, which had to connection to Arduino shield and Wi-Fi module to connect to the internet. Through the internet the data taken from sensors was stored in online spreadsheets. From the results obtained the researchers used it to analyse and conclude about water conditions. For farmers to view sensor values an LCD screen is connected to the microcontroller directly. The results have shown the experiment is successful for small fish farmers but the results obtained are not very reliable as a large setup is done with results of only 2 days shown.[3]

Feed management is crucial for the survival of fish farms in the long run. When fish are caged in tanks in the sea or on shore the waste excreted by the organisms in the cage and remaining food pellets cause the water to get polluted and as a result can cause spread of diseases among the fish and increase fish death. The author discusses about different methods of controlling the food fed to the fish and creates a method to monitor wastage or leakage of food in marine aquaculture farm. The different methods of feeding fish are distribution by hands, rainbow trout and impelled by air compressors. Some of these foods gets settled in the sea bed and begin to get decomposed; these are monitored by underwater camera and scuba-divers which proved to be costly way to monitor. It has also been studied that certain fish are dominant therefore eat more in quantity and faster than other fish. Due to these reasons and economic reasons feed management is crucial in aquaculture.[2]

The feeding is controlled through the smart management system where algorithm is written for four types of feed ejection speed i.e. regular, slow, very slow and stop. Depending on the conditions the fish will be given amounts of food each time. All the parameters are linked together and the data combined from them helps decide how much food is required. The system is further developed to change the speed by itself, by analysing the data fed and predict how much food the feed dispenser should release next time. Using previous data about fish speed, water temperature and other parameters a probability diagram is made which shows the relation of each parameter to the other and according to that the feeder system will predict the next feed amount. The review of existing systems shows that there is a need for a smart system comprising of all functionalities for complete monitoring and automation of aquaculture in small and medium scale fisheries. Therefore a smart aquaculture system is proposed and implemented for effective fish production.

II. DESIGN

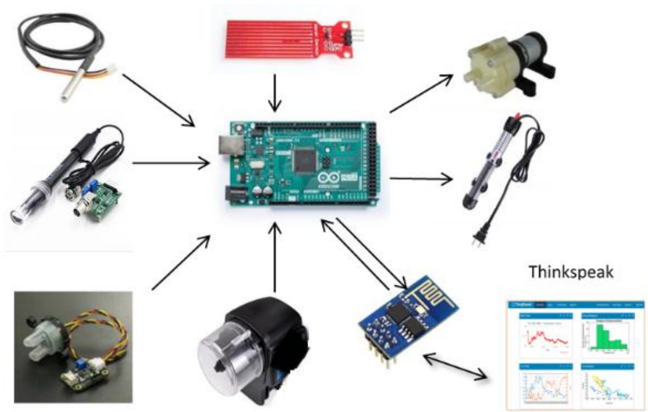

Fig 1. Block Diagram of smart aquaculture system

Figure 1 shows the block diagram of proposed system for monitoring and automation of aquaculture system. The system is controlled through ardunio AtMega microcontroller.

The controller monitors temperature, pH and turbidity through sensor readings and automate switching on/off heater and pump based on sensor readings. The system is connected to internet through Wi-Fi and sensor readings are also sent to the cloud database. Furthermore, the cloud data can be viewed by fish farmers on their mobile and in web application.

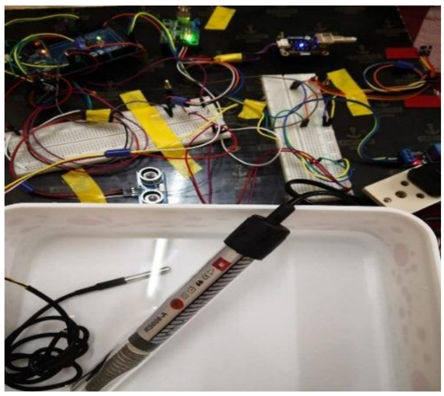

Fig 3. Implementing with temperature sensor

III. IMPLEMENTATION

A. Hardware implementation

The Arduino ATMega is connected to four sensors namely temperature, water level, pH and turbidity as per the circuit design shown in figure 2. The Arduino checks if the water level is between $25^{o}C$ to $30^{o}C$. If it is less than $25^{o}C$, the water is too cold for the fish therefore heater switches on.If it is above $30^{o}C$ the water is too warm therefore the fan switches on. Similarly, the water level is set to be checked for the top 10-20 cm of the tank so that it is always maintained and does not get too low. If the water level is less than 200mm then the pump switches on and when it reaches 200 the pump switches off. For pH of the water 6.5 to 8 is suitable for the fish therefore a change of less 6.5 or greater than 8 will cause the pump to switch on automatically to pump water out in separate tank. Then water pumped in to fill tank from storage tank. For turbidity the measurement is in ntu and if it is less than 2000 ntu the water is still in acceptable turbidity but if it is above the water is too murky therefore the pump gets switched on and dirty water pumped out while the tank is filled with the clear water from the storage tank.

To send data to cloud the Arduino is connected to the ESP 8266, the Wi-Fi is connected to the things speak. So to write data to the cloud the Arduino send's to the ESP 8266 and that sends to the things speak channel, using the API key. The things speak after every 16 seconds updates data

i. Measuring Temperature

The DS18B20 is a waterproof temperature sensor that can work from -10OC to +85oC with an accuracy of 0.5 degrees. This sensor is a 1-wire bus ie. it has single bus to control the device. Therefore the 1-Wire interface is enabled using the 1-wire library. To read the sensor values and convert it to degrees such as, Celsius the Dallas Temperature library is used. This library retrieves temperature reading and understood in degrees Celsius using begin(),requestTemperatures() and getTempCByIndex() methods. Figure 3 shows the circuit for implementing with temperature sensor.

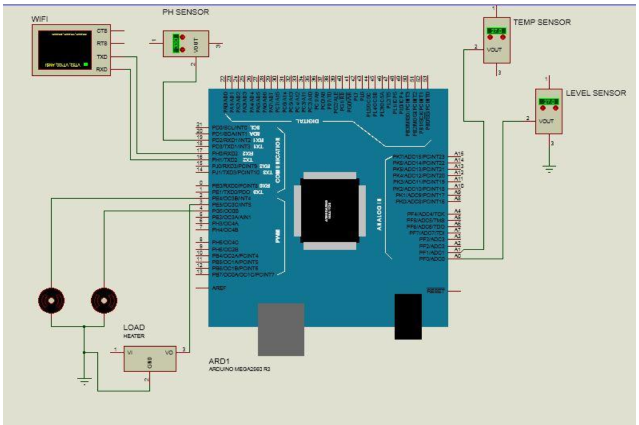

Fig 2. Circuit design of hardware components

ii. Measuring pH

For using the 4250c analogue pH sensor it has to be first calibrated. The calibration is to convert 10bit analogue value to 0-5 voltage(V) accurately. Since pH is 0-14 the pH is mapped with 5 volts such that, pH 7 is 2.5 V, pH14 is 5 and 0 is 0V. The calibration will identify the uncertainty in the readings because pH 7 may not give a reading of exactly 2.5V in actual conversion. The output should be 2.5 as the short circuit represents a pH of 7. Figure 4 shows the implementation for reading pH value.

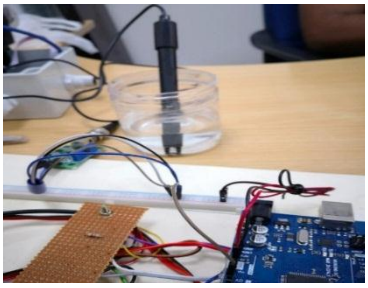

Fig 4. Implementing with pH sensor

ii. Measuring turbidity

The turbidity sensor is a 10 bit analogue sensor shown in figure 5, similar to the pH sensor the 10 bit value has to be converted to voltage and also calibrated. To convert the 10 bit analogue reading i.e., 0-1023 to voltage reading between 0-5V Turbidity is inversely proportional to the voltage, means lower voltage higher turbidity and vice versa.

ntu=-1120.4*square(voltage)+(5742.3*voltage (1)

Equation 1 is to convert voltage to turbidity in ntu units

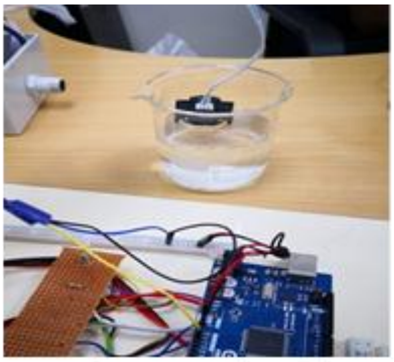

Fig 5. Implementing with turbidity sensor

The actuators are 2 water pumps, water heater, fan and feeder. If water level is below 100mm, relay switches on motor and water is pumped in until it reached 200mm and relay turns off motor.

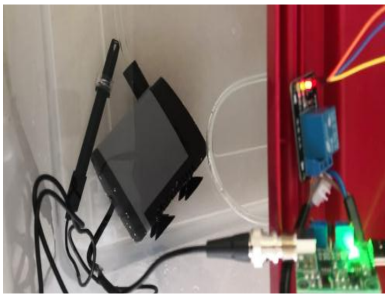

Fig 6. Measuring pH and testing actuator

Similarly, temperature above or below threshold will switch off fan or heater, respectively as shown in figure 6. For the tilapia fish the ideal is 25ºC to 30ºC and when it goes below the relay switches on the heater. For turbidity, 3000 above pumps water out to another water tank. For the fish feeder the time is set and fish is fed during the day by rotating and opening lid automatically.

B. Cloud service

An open source cloud database for IoT projects called Things speak is used to upload the sensor data and visualise it. The data from the sensors are sent to the Wi-Fi network created using ESP8266. Then to connect through Wi-Fi to Things speak, a channel is created with fields Temperature, Water level, pH and Turbidity. Each field represents data from each sensor and the channel has an unique ID which is shown in figure 7. When the channel is created an API is generated with write and read keys. This key is used to connect the channel to the Wi-Fi of the microcontroller and read/write data to the cloud. The Things speak cloud can be used by farmer from mobile and web application which is convenient for the farmer.

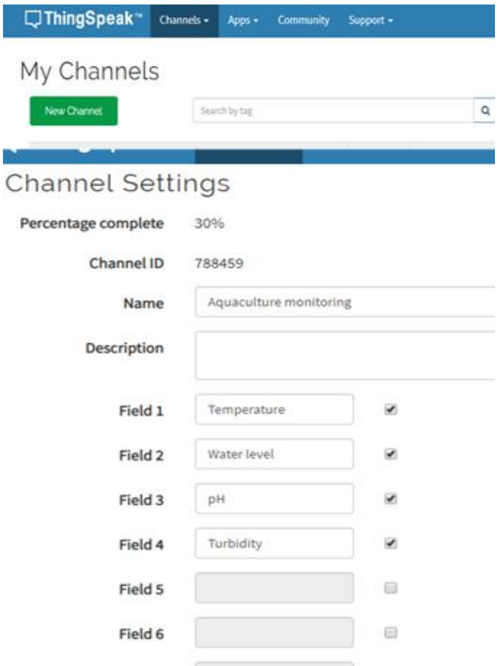

Fig 7. Thing speak channel creation

The API key is very important to keep securely as anyone who has access to the key can use it to write and read the data. There are 2 keys one for read and one for write. The write key is used to connect the microcontroller to the cloud and upload data via Wi-Fi. Along with the key the update channel URL is used to continually update data onto cloud via internet. The results can be seen on the channel's dashboard where the data is represented as a line graph for each parameter as shown in Figure 8.

Fig 8. Data gathered on Thingspeak channel

IV. RESUTLS AND DISCUSSION

The unit testing and system testing was done in water with no fish to avoid harming or killing the fish. After it the testing has progressed successfully the system was installed and run with live Tilapia fish.

The results of the system was seen after installing the setup in fish tank with Tilapia fish. The species of Tilapia used are either Mozambique Tilapia or Nile Tilapia. These species prefer a range of 17ºC-30ºC, the die at temperatures above 40 and below 12. They can survive in depth range of 1m up to 12m. They are freshwater fish that prefer brackish water i.e. slightly high turbidity. They require dissolved oxygen of about 5mg/L for which a continuous supply of oxygen pump is kept. Four Tilapia fish were kept with the system in of already grown 50% when bought.

These data has been sent over Things Speak for few days. The data obtained in Things Speak is analysed to further get insights into the water environment of the fish

A. Temperature

Figure 9 shows the reading of temperature from the tank that is displayed in Thinkspeak. The temperature range is mostly between 27ºC-24ºC, the slight drop in temperature. The external cause could be drop in temperature of the air outside as the sun begins to go down so heat begins to reduce at this time and the tank.

The changes in temperature are within +/-5ºC mostly within the range for suitable fish growth. The changes are cyclical and not very drastic as fish cannot adapt to sudden change in water conditions. The graph is mostly stable for a while then increases. From the image seen above the temperature is shown to rise up to 27ºC and then it becomes stable. Slight fluctuations are possible throughout the day but the stable temperature at 27ºC is most suitable as Tilapia used has large surface area to volume ratio hence more sensitive to loosing heat and adjusting to even the slightest changes. The graph also shows the average temperature, maximum and minimum temperature in the tank for a day, the minimum was below optimal and maximum was within optimum level.

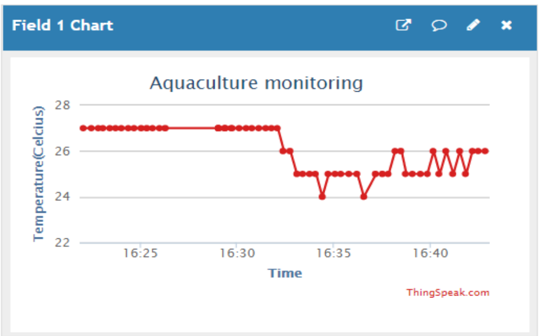

Fig 9. Temperature reading in Thing Speak

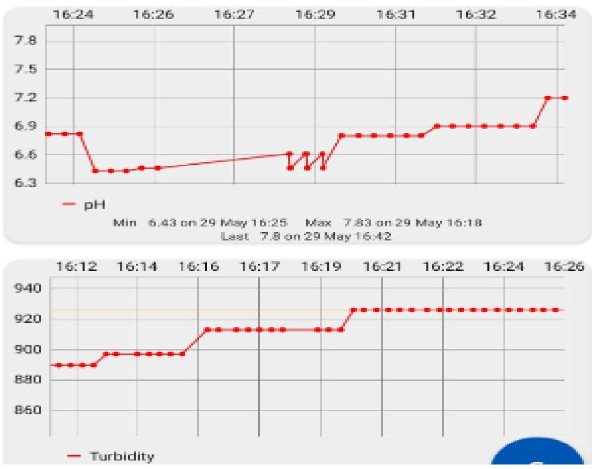

Fig 10. pH compared with turbidity at same timestamp

B. *Turbidity*

The tank had very low turbidity as water is fresh and has no suspended solids. Over time due to excretion, egestion, food remains and other microbial organisms in the water are growing so the water began to get murky. This is a cause of increase in the turbidity of the water. For Tilapia fish it was known that they prefer brackish water .According to research the species of Tilapia prefer 1000-3000 mg/L of total dissolved solids in the water. Due to hygienic reasons the water should not be infected from the wastes that's why the water is not left until it reaches 3000 ntu, a limit of 2000 is kept. The maximum and minimum levels of turbidity shown are within range.

The graph in figure 10 shows turbidity increasing for a while and then stable for a few minutes, this repeats in a cyclic manner. Having a maintained level of turbidity is crucial as it also determines the amount of light in the water. Higher turbidity means less light in the water and lower turbidity means higher amount of light. Too less light would not be good as the microbic animals cannot photosynthesize and produce oxygen for fish. Too much light is also problematic to fish as they are accustomed to slightly murky water and fish are sensitive to changes.

C. pH results

The pH readings in the screen show that the minimum pH for the day was 6.4 and highest was 7.8. The minimum is .1 unit less than threshold and maximum is within optimal pH range for the Tilapia. Drop in pH is due to several factors such as, decreased oxygen level, increase in decomposition within water and toxic wastes released by fish and microscopic organisms. After the drop the pH is seen to gradually fluctuate between 6.5 and 6.6 until it rises upto 7. pH has a small range of 0-14, even the smallest .5 or 1 unit change makes the water acidic or basic both the extremes will reduce the activity of fish. If kept in extremes for too long they eventually die. Therefore the range of pH is strictly monitored and kept within limits. The rise in the pH up to neutral from acidic indicate the automation process is rightly working.

The graph shows that the parameters are fluctuating but within a given limit, the water level can be seen to increase and decrease with the change in pH and turbidity. .

Fig 11. Mobile view of water level readings

The graph of water level shown in figure 11 shows that the water level also drops as the pH drops, this indicates the system has detected a drop in pH below the threshold, therefore it is pumping out the water. When the water is being pumped out after a while water also gets pumped into the tank from the fresh water storage. This causes the water level to increase again and the pH also begins to slightly increase.

The turbidity of the water increases around the same time the pH drops, this means the water is getting murkier due to any excretion or egestion from the fish or any the amount of suspended solids also increasing in the water. The turbidity is yet within the range of the suitable turbidity for the fish. Therefore there is no alarming situation.

From the analysis above it has been found that fish was comfortable in temperatures that are within 20 to 30 degrees range, most activity and increase in growth seen. The water level of the tank is also dependent on the factors like turbidity, pH and fish density. It was observed that the fish had increased movements when the tank was full and very less movement when the tank was half filled. Therefore depending on volume of tank fish of right population should be grown. Other factors are pH and turbidity that change with water level. The pH readings has shown that fish have better stability when pH is stable for long and the pH is not too acidic(<6) or too basic(>9). For turbidity in very clear water fish did not have much activity and very turbid water gave strong stench which indicated water is polluted. Only at slightly high turbidity fish was seen to have better growth and activity therefore for good growth a neutral pH and moderately turbid water is sufficient. Fish having more activity means the fish is using it's muscle and the food eaten will produce more protein in it's body therefore better growth and also increase in fish size is a measure of growth.

V.CONCLUSION

The system's purpose is to give the farmer better growth of fish while controlling costs therefore the system was designed and implemented with the important factors in making the fish population grow healthily. The results show that fish farming can be made easier with less manual intervention in an affordable and highly efficient way. Further using machine learning the system can be enabled to provide recommendations by itself for better managing the aquaculture environment such as, best temperature for breeding and hatching etc.

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