Applied Laser Technology
Vol. 30, No.2,April (2023), pp.06–16

The Design of an Internet of Things-Based Aquaculture Fish Monitoring System

VEMURU PHANIBHSHAN[1],AKURATHI SRINIVASA RAO[2],SK.JAGADEESH BABU[3],
ASSOCIATE PROFESSOR[1,2], ASSISTANT PROFESSOR[3],
DEPARTMENT OF ECE
PBR VISVODAYA INSTITUTE OF TECHNOLOGY AND SCIENCE::KAVALI

Abstract:

Aquaculture mainly refers to cultivating aquatic organisms providing suitable environments for various purposes, including commercial, recreational, public purposes. This paper aims to enhance the production of fish and maintain the aquatic environment of aquaculture in Bangladesh. This paper presents the way of using Internet of Things (IoT) based devices to monitor aquaculture's basic needs and help provide things needed for the fisheries. Using these devices, various parameters of water will be monitored for a better living environment for fish. These devices consist of some sensors that will detect the Potential of Hydrogen (pH) level, the water temperature, and there will be two extra sections where the measurement of dissolved oxygen level and ammonia level using the testing kits can be determined which are needed for proper fish farming in the right water. An android-based mobile application has also been developed. In this system, farmers, fishermen, and people related to aquaculture will be the users of an android application. Via that application and with the help of a device, users will be notified about the amount of dissolved oxygen, ammonia level, pH level, and water body temperature. This monitoring system will help fish farmers to take the necessary steps to prevent any disturbance in an aquatic environment. Though Bangladesh is a riverine country and fish farming has a huge impact on this country's economy, it is necessary to keep in good health to produce more and more fish. But the fisheries of this country are not expert enough to understand how to provide necessary elements to fish and what to do. They might get help from this system and measure the parameters they can give necessary things to grow more fish.

Keywords: Aquaculture; android application; IoT; sensors; dissolved oxygen; pH level; temperature; water pollution; fish health; fish farmers; Bangladesh

Introduction

The importance of aquaculture is beyond description. In the aquaculture system, fish are cultured in confined artificial water bodies such as a tank where they live, eat, grow, and extract waste. There is no

Natural water source, so the quality of water declines quickly, which affects the growth and health of fish. So water quality is a significant factor in the aquaculture system that guarantees the perfect growth and health of fish [1,2]. Yet the proposed system is to meet the demand for fish by maintaining the water quality necessary for producing more and more fish and helping to increase the economic value. The fisheries will become more sufficient, and human health will become wealthier by having fish.

About 3.69% of the country's total Gross Domestic Product (GDP) comes from it and 22.60% of the agricultural GDP is based on aquaculture [3]. For the last 10 years (2004–2005 to 2013–2014 Fiscal Year), the fishing growth was fairly constant, with an average growth of 5.38% per year [4]. From 2009– 2010 to 2013–2014, this sector experienced a consistent growth rate of 7.32% to 4.04% [5]. In recent years, the production of wild capture fisheries has reached 16.78% (oceanic) and 83.22% (freshwater), placing Bangladesh as the world's fifth-largest aquaculture producing country in 2015–2016.Those numbers are considered to be more than half of the country's total fish production (55.15%) [6]. Pond culture is considered the centrepiece of Bangladesh's aquatic production, which contains 85.8% of total production and covers 57.7% of the area of aquatic land [6].

From the statistics of Bangladesh fish cultivation, we found two types of fish growing systems in the inland water, open inland water and close inland water. The nearby inland water contains a large number of ponds, seasonal culture water bodies, pen culture, cage culture, farm, and so on. Ponds cover 384700 hectares of the area, seasonal water bodies cover 136273 hectares, and so on. According to 2016–2017 statistics, there are 833752 hector areas for culturing fish to grow the economy [7]. Department of Fisheries (DOFs) figures indicate that the vast production of pond culture is the production of carps. About 59% of the fish production in ponds is domestic Indian major carps and silver carp. Nonvernacular species account for the remaining 19%. Including all other non-native carp and Indian minor carps measure 88% of the pond fish production in Bangladesh; See Fig. 1.

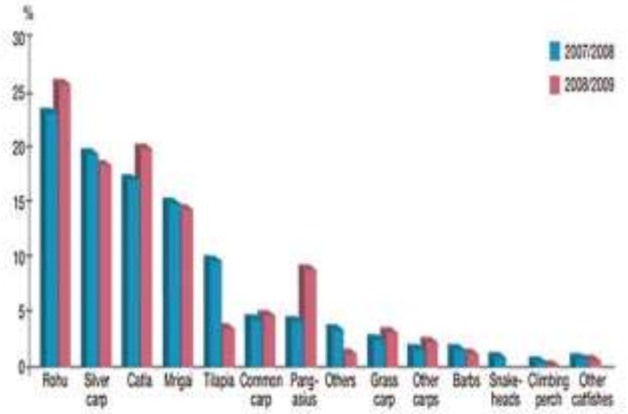

Figure 1: Contribution of each species to total pond production in 2007/2008. (Source: modified from DOF 2009a, 2010) [8]

Bangladesh has earned a lot of money by exporting fish to other countries. This sector earned approximately BDT 4,776.92 core in 2013–2014 by exporting 77.33 thousand Metric Ton (MT) fish and fishing products, which was the highest export earnings in the previous ten years. The high rate of export continued in 2016–2017, and about BDT 4,287.64 crore was earned by exporting 68.31 thousand MT of fish and fishing products [12]. In Bangladesh, many types of fish are cultivated. Tilapia is the best and most profitable fish for firming in every part of the country. Shrimp, crab, and other seafood are also widely cultivated. Shrimp and crab are in high demand in both the local and global markets, so their prices are high. Shrimp and crab are exported in huge quantities. Besides those, bhetki, tangra, horina, chingri, etc. are some common fish species that grow naturally in the saltwater body. Some common freshwater fishes that are cultivated largely are Katla, rui, mrigal, common carp, boal, pabda, chital, koi, shol, gozar, and various types of catfish [13].

With the expeditious growth of the economy, our environment is facing new problems every day. One of the main problems we are facing is water pollution. The most common water quality factors are Dissolved Oxygen (DO), Total Ammonia-Nitrogen (ionized and non-ionized), Nitrite, pH, Alkalinity, Hardness, Carbon Dioxide, Salinity, Iron, Chlorine, Hydrogen Sulphide, and Clarity. Normally, we need to collect samples manually to find these factors and then take them to a laboratory for checking. Thus, this process is a hustle, and we need a long-time to analyze the samples. That's why we need something new to tackle this phenomenon.

A system of aquaculture was developed by Belen [14] in which three parameters were monitored, which were the pH level, the temperature, and the flow rate. There was no correlation between flow rate and pH or

ISSN: 1000-372X ALT

temperature in that experiment. But the temperature was computed by proportioning the pH level inversely. Another system was made by Tolentino et al. [15]. In the system, they computed the aquarium heater, Sodium Hydrogen carbonate, and water pump by measuring some parameters of water and showed them on a web application. The parameters were temperature, pH, Oxidation-reduction Potential (ORP), salinity, and dissolved oxygen. But this system cannot be used for large water bodies for aquatic production. Raj et al. [16] developed a monitoring system that used three sensors named pH, temperature, and ultrasonic. The function of the system was to monitor the feeding of the aquatic organisms in an aquarium. Harun et al. [17] built a system with three sensors named pH, temperature, and Do (Dissolved Oxygen) to measure the levels of the quality of water. Rosalin et al. [18] made a system of these similar works with five sensors named distance, ammonia, salinity, oxygen, and temperature. But the system will cost more while some costs can be reduced. The other system built by Saha et al. [19] is an IoT based automated fish farm aquaculture monitoring system where they used four sensors, which are temperature, pH, conductivity, and watercolor. But for a vast production, these measurements are not enough. The authors of [20] suggested an IoT-based smart agrotech system that takes humidity, temperature, and soil moisture into account as important farming parameters. Authors in [21] presented a VANET for health monitoring application which is not for aquaculture. In this research work an IoT based fish monitoring system for aquaculture has been developed. The purpose of this system is to overcome the lack of other systems in this field. Using this system, fishermen and related people can measure the water quality factors and monitor the health of fish and other aquaculture. The Android mobile application may help to measure these water parameters in real time. By reducing the cost, the system will help to increase the production level by measuring the most important parameters of water.

In aquaculture, there are a few problems to consider. Oxygen depletion means a low level of Dissolved Oxygen (DO). A low level of DO may result in fish mortality. When the DO falls to 2–4 mg/L, almost all species of fish are distressed. This is very harmful to them. Another thing is the pH level of the water, which should not be too high or too low. The other criteria are the water body temperature, which mostly depends on the type of fish. As different fish survive in different temperatures, the temperature of the water body should be checked. Ammonia is known as the silent killer in the aquaculture field. If the ammonia is not lowered intime, then fish will die overnight. The standard level of DO for fish should be 6.5–8 mg/L and between 80– 120% [22]. If the level decreases, fish may feel suffocated and die. pH is another important parameter that should be in the range of 6.5–9.0 [23]. More than or less than the range will harm the fish and they can die. Temperature is a key factor for Coldwater species. They cannot tolerate temperatures above 20–25 degrees Celsius. Warm water species can survive and grow between 10–15 degrees C, even below 10 degrees C but will not reproduce below 20 degrees C. Tropical species need comparatively high temperatures. They will die at 10–20 degrees C, and they cannot grow and reproduce anything below 25 degrees C [24]. Another important element is the ammonia level. It should be in the range of 0.3 to 0.9 mg/L for Coldwater fish; 0.7 to 3.0 mg/L for warm-water fish; 0.6 to 1.7 mg/L for marine fish; and 0.7 to 3.0 mg/L for marine shrimp. If the ammonia level of water increases, fish will die at a high level [25]. So the level of the parameters is very important for culturing more and more fish.

With that vision, Internet of Things (IoT) based devices and mobile applications have been proposed in this paper, which will monitor the aquaculture sector of Bangladesh and help us maintain the eco-friendly environment for the fish at a satisfactory level. This paper describes an Internet of Things-based system that monitors the water body of a pond, bill, or baor where fishermen cultivate fish. A device is built up in this paper, which consists of some sensors. The sensor receives some data from the water and shows the value of the data to an android mobile application. The process will be done with the help of the Esp12E module using the Application Programming Interface (API). After receiving the pH level and temperature data using sensors and mobile application and after testing dissolved oxygen and ammonia using kit, fish, farmers or users can take necessary steps accordingly to provide proper healthy water for the healthy living of fish.

Section 1 provides an introduction. Sections 2 and 3 discuss materials and methods and results, respectively. In Sections 4 and 5, discussion and conclusion are described, respectively.

Materials and Methods

Hardware Equipment for the Development of the System

The proposed system is made for fishermen to monitor the quality of water for a healthy environment for fish to live in. Healthy water is essential for aquatic animals. Water quality is decided by some factors like pH level, oxygen level, temperature etc. Some sensors have been integrated with the proposed system to collect the values of some parameters from the water. For this purpose, pH sensor, temperature sensor, oxygen kit, and ammonia kit have been used. This system was created by connecting a pH sensor, a temperature sensor, and some other equipment.

The temperature sensor and pH sensor collect value from water and send that value to the server through the Wi-Fi module. A mobile application was made to see values. pH level is important for fish. To grow a healthy fish, it's essential to maintain the pH level. So, a pH sensor was used (Fig. 2) [26]. Freshwater ponds have a natural pH in the range of 6–8. When the pH level of water is low, it means the water is acidic, and high pH means it's alkaline. If pond water becomes highly alkaline, it can damage the skin, eyes, and other outer surfaces of fish. Acidic water harms the reproduction of fish. Fish can die because of low pH levels [27,28].

A temperature sensor (Fig. 3) [29] has been used to monitor the temperature of the water. As fish's activity levels depend on temperature, so it's important to maintain the right temperature. Hot water cannot hold enough oxygen for fish, so it is important for fish. Fishes are more active in warm water, so they need more food to survive. In cold water, they are comparatively less active, so they need less food. The temperature level for all types of fish is not the same. Here we used the DS18B20 temperature sensor. DS18B20 is a programmable digital temperature sensor. It works with the method of 1 wire communication. A wide range of temperatures can be measured by the pH sensor (from−55°C to +125°C)with a decent accuracy of ±5°C [30]. Oxygen is an essential element for fish. When the dissolved oxygen level is too low or high, it will affect the water quality. So, oxygen and ammonia kits have been used to measure the water's dissolved oxygen level and ammonia level. Fig. 4 shows an oxygen kit. Here, an oxygen kit is used in the system to reduce the cost of the whole proposed system.

Figure 2: pH sensor

ISSN: 1000-372X ALT

Figure 3: DS18B20 temperature sensor

Figure 4: Dissolved oxygen test kit

This is a way to measure the dissolved oxygen level of water. To measure dissolved oxygen, place 5 mL of water in a jar, add 5 drops of test solution chemical 1 and test solution chemical 2, wait 4–5 min for the water to change color. We will achieve the desired color of water by combining water and oxygen kit solutions. After that, we need to open the dissolved oxygen section in our mobile application. We will match the color of the water in the jar with the color chart in the app. The ammonia kit, shown in Fig. 5, is an efficient way to find the

ISSN: 1000-372X ALT

ammonia level of water. To measure the ammonia of the water, we need to add 4 drops of reagents 1, 2 and 3 in the jar with 2 ml (milliliter) of tank/pond water and wait for 4–5 min to change the color of the water. We will achieve the desired color of water by combining water and ammonia kit solutions. ESP-12E (Fig. 6) [31] is used to establish a wireless network connection for the microcontroller to build this device.

Figure 5: Ammonia testing kits

Figure 6: ESP-12E module

It has an internal 32-bit microcontroller that can perform multiple communications and output signals. We also used a 12 V battery, LM2596 buck converter, 10 k resistor, switch, and some wires. LM2596 was used to adjust input voltage. The Node mcu controller has built-in Wi-Fi. The PH sensor is connected with node mcuanalog pin A0. It has a 10-bit DC converter and a ds18b20 temperature sensor that connects with node mcu digital pin D1. It supports 8-bit input and output. The circuit diagram for the device’s connection is shown in Fig. 7. For the development of the system, many types of equipment have been used in this paper. The below Tab. 1 shows the name and price of the equipments.

ISSN: 1000-372X ALT

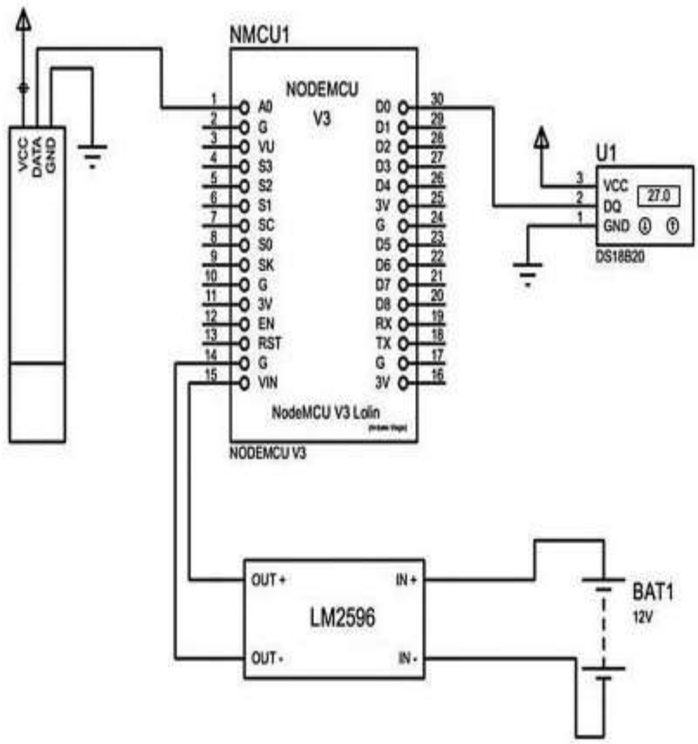

Figure 7: Circuit diagram of connecting the device

Discussions

The result obtained from the device by using the application is information about the pH and temperature of the water body where the fisherman will cultivate fish. The device can put the sensors in the water, and the application will show the value of pH and temperature. The other two components, dissolved oxygen and ammonia level, will be observed by using the test kit solutions. The solutions will create color, and the color will be matched with the color chart given in the application. By that, the users will know about the amount of dissolved oxygen and ammonia in the water body. Tab. 2 shows the comparison between our system and other solutions given on the existing part.

The fish monitoring system for aquaculture is such a helping hand for people because it is easy to access and an automated monitoring system at a reasonable cost. The use of low-cost and available sensors makes the application reasonable and easy to access. We have looked at some existing papers worked by others on this related topic. There are similarities and dissimilarities between them. But we worked for the best way toprovide fish a healthy life. Tab. 3 shows a comparison of the system of this paper and others. From Tab. 3, it is observed that the proposed system in this research has temperature, pH level, dissolve oxygen, and ammonia level measuring sensors. In addition, this system has an android mobile application where other available systems in the literature do not have all the features. This proposed system is very cost-efficient as well: see Tab. 3.

Table 2: Comparison between our system and other solutions given on the existing part

ISSN: 1000-372X ALT

Measurements	By existing solutions	By proposed system
pH level	Calorimetric kits or electric meter	Device and application
Temperature	Thermometer or telethermister	Device and application
Oxygen level	Chemical or electrical methods	Kit solution and application
Ammonia level	Chemical or electrical methods	Kit solution and application

Table 3: Comparison of this design with others

No.	Name	Temperature check	pH level check	Dissolve oxygen check	Ammonia level check	Android application	Web application	Price BD taka
1.	This design	Yes	Yes	Yes	Yes	Yes	No	9270/-
2.	Ref 23	Yes	Yes	No	No	Yes	No	Not given
3.	Ref 20	Yes	Yes	No	No	No	No	Not given
4.	Ref 21	Yes	Yes	Yes	No	No	No	Not given
5.	Ref 19	Yes	Yes	Yes	No	No	Yes	Not given
6.	Ref 22	Yes	No	Yes	Yes	Yes	No	Not given

This proposed system will be sustainable because it will help users understand the water parameters and take the necessary steps to keep the water at a standard level so that fish can be healthy and easily give birth to more fish. This system may help a lot to produce a large number of fish. Fisheries and people in their field will greatly benefit if users keep these devices and the app on their Android phones. If they do so, they will get a huge increase in the production of fish in their pond or cage. Fig. 16 provides global fishing production from 1980–2022 [35].

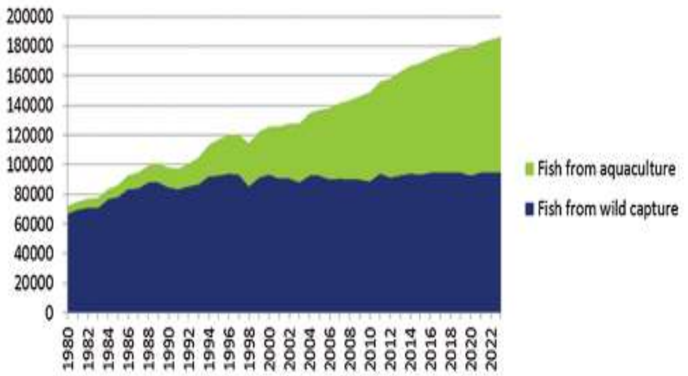

Figure 16: Global fisheries production 1980–2022 [33]

The above graph shows the daily impact of aquaculture on our society and country. The proposed system has a great potential to improve the aquaculture environment for fishing. Furthermore, the economic potentials are enormous as the proposed system will augment the efforts of fish farmers to produce higher yields. This system is saving the lives of fish by assuring the perfect water for their healthy life and so the user gets more and more fish. They can sell the fish in the market and earn more money. Also, they can contribute to the national economy by exporting fish to other countries. This device will be helpful to all people who are closely or

ISSN: 1000-372X ALT

remotely involved in aquaculture. The limitation of this system is that it does not currently have android mobile application features. In the future, integration of iOS-based mobile applications may be considered.

Conclusions

This paper proposes an IOT-based aqua culture system to improve and monitor the quality of water for the fishing industry. In this research, the following important parameters have been considered, such as: the suitable temperature, pH level, quality supply of oxygen, and dissolved ammonia level. It is believed that the proposed system will make the aquatic environment more profitable, productive, and sustainable. This will make an enormous contribution to the health and the economy in Bangladesh. The government should take good care of this sector by investing, making strict environmental policies, and creating reliable communication between the farmers, fishermen, and other people related to this sector. To tackle the huge fish demand for the booming population in Bangladesh. Also, we need to focus on the things that are harming the aquatic environment for the proper development of the fish. For the whole research, the main concern was to secure fish health for more production of fish. For this purpose, an IoT based fish monitoring system was built to check the necessary elements' measurements and ensure whether the fish are healthy or getting all the necessary things for a happy life. By this system, fisheries will know the level of oxygen or ammonia or pH and temperature and provide the equipment to maintain equilibrium level. Thus, the fish will grow healthy.

In the future, we intend to make the device check more parameters and also to provide the necessary equipment to maintain proper health for fish. We are also thinking of providing knowledge to the fish farmers to maintain fish health properly. With this system, iOS based mobile applications can be integrated in the future.

Acknowledgement: Authors would like to thank for the support from Taif University Researchers Supporting Project number (TURSP-2020/211), Taif University, Taif, Saudi Arabia.

References

[1] National Oceanic and Atmospheric Administration, "What is aquaculture," 2011. [Online]. Available: https:// www.noaa.gov/stories/what-is-aquaculture.

[2] B. Jana and D. Sarkar, "Water quality in aquaculture impact and management: A review," The Indian Journal of Animal Sciences, vol. 75, no. 11, pp. 1354–1361, 2005.

[3] Fisheries Resources Survey System, "Fisheries statistical report of Bangladesh, department of fisheries," 2018. [Online].

Available: https://fisheries.portal.gov.bd/sites/default/files/files/fisheries.portal.gov.bd/page/4cfbb3cc_c0c4_4f25_be21_b91f84bdc45c/Fisheries%20Statistical%20Yearboook%202017-18.pdf.

[4] Fisheries Resources Survey System, "Fisheries statistical report of Bangladesh, department of fisheries, Bangladesh," 2015. [Online]. Available: https://drive.google.com/file/d/0B6XjGVIRbmt0ME5lcXhQMzdHZlk/view.

[5] Finance Division, Ministry of Finance Bangladesh, "Bangladesh economic review 2014," 2014. [Online]. Available: https://mof.gov.bd/site/page/44e399b3-d378-41aa-86ff-8c4277eb0990/BangladeshEconomicReview.

[6] Fisheries Resources Survey System, Department of Fisheries, Bangladesh, "Yearbook of fisheries statistics of Bangladesh," 2017. [Online]. Available: http://ganges.bengaldelta.net/resources/year_book/17.pdf.

[7] Department of Fisheries, Ministry of Fisheries and Livestock, "Annual report 2015," 2015. [Online]. Available:
http://www.fisheries.gov.bd/sites/default/files/files/fisheries.portal.gov.bd/annual_reports/f315fb1a_7262_4f0a_80fe_3baa8a62a73b/Annual_Report_2015.PDF.

[8] Ceicdatacom, "Bangladesh exports: Fish and prawns economic indicators," 2020. [Online]. Available: https://www. ceicdata.com/en/bangladesh/trade-statistics-exports-by-commodity-bangladesh-bank/exports-fish-and-prawns.

[9] Bangladesh Foreign Trade Institute, "Study on sector-based need assessment of business promotion councilfisheries products," 2016. [Online]. Available: http://www.bfti.org.bd/pdf/Fishery.pdf.

[10] M. M. Shamsuzzaman, M. M. Islam, N. J. Tania, M. A. A. Mamun, P. P. Barman et al., "Fisheries resources of Bangladesh: Present status and future direction," Aquaculture and Fisheries, vol. 2, no. 4, pp. 145–156, 2017.

[11] M. Shamsuzzaman, M. H. Mozumder, S. Mitu, A. Ahamad and M. Bhyuian, "The economic contribution of fish and fish trade in Bangladesh," Aquaculture and Fisheries, vol. 5, no. 4, pp. 174–181, 2020.

[12] R. Farm, "Fish farming in Bangladesh: Full business guide for beginners," 2021. [Online]. Available: https:// www.roysfarm.com/fish-farming-in-bangladesh/.

[13] A. J. Horne and C. R. Goldman, Limnology, 2nd ed., New York, USA: McGraw-Hill, Inc., 1994. [Online]. Available at: https://www.worldcat.org/title/limnology/oclc/647368081.

[14] M. C. D. Belen and F. R. G. Cruz, "Water quality parameter correlation in a controlled aquaculture environment," in Proc. IEEE 9th Int. Conf. on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment and Management, Manila, Philippines, pp. 1–4, 2017.

[15] L. K. S. Tolentino, C. P. D. Pedro, J. D. Icamina, J. B. E. Navarro, D. J. L. Salvacion et al., "Development of an IoT-based intensive aquaculture monitoring system with automatic water correction," International Journal of Computing and Digital Systems, vol. 20, no. 2210, pp. 1–11, 2020.

[16] A. A. D. Raj, V. K. Swasthik, A. Rakesh and D. M. Sanavanaraj, "Arduino based fish monitoring system," International Journal of Scientific & Engineering Research, vol. 11, no. 7, pp. 1622–1627, 2020.

[17] Z. Harun, E. Reda and H. Hashim, "Real time fish pond monitoring and automation using Arduino," IOP Conf. Series: Materials Science and Engineering, vol. 340, no. 218, pp. 1, 2017.

[18] N. Rosaline and S. Sathyalakshimi, "IoT based aquaculture monitoring and control system," Journal of Physics: Conf. Series, vol. 1362, no. 2019, pp. 1–7, 2019.

[19] S. Saha, R. H. Rajib and S. Kabir, "IoT based automated fish farm aquaculture monitoring system," in Proc. Int. Conf. on Innovations in Science, Engineering and Technology, Chittagong, Bangladesh, pp. 201–206, 2018.

[20] A. K. Poddar, A. A. Bukhari, S. Islam, S. Mia, M. A. Mohammed et al., "IoT based smart agrotech system for verification of urban farming parameters. Microprocessors and microsystems," Microprocessors and Microsystems, vol. 82, no. 104025, pp. 1–10, 2021.

[21] P. Singh, R. S. Raw, S. A. Khan, M. A. Mohammed, A. A. Aly et al., "W-GeoR: Weighted geographical routing for VANET's health monitoring applications in urban traffic networks," IEEE Access, vol. 2021, no. 3092426, pp. 1–19, 2021.

[22] Yokogawa Electric Corporation, "pH in fish farming," 2016. [Online]. Available: https://www.yokogawa.com/ library/resources/application-notes/ph-in-fish-farming/.

[23] C. E. Boyd, "Water temperature in aquaculture," 2018. [Online]. Available: https://www.aquaculturealliance.org/ advocate/water-temperature-in-aquaculture/.

[24] C. E. Boyd, “Ammonia nitrogen dynamics in aquaculture,” 2018. [Online]. Available: https://www. aquaculturealliance.org/advocate/ammonia-nitrogen-dynamics-in-aquaculture/

[25] USGS Water Science School, “pH and water,” 2002. [Online]. Available: https://www.usgs.gov/special-topic/ water-science-school/science/ph-and-water?qt-science_center_objects=2#qt-science_center_objects.

[26] Lenntech, “Effects of acids and alkalis on aquatic life,” 2020. [Online]. Available: https://www.lenntech.com/aquatic/ acids-alkalis.htm?fbclid=IwAR1Tz3BCBKusn9Y82Bn2O7luf5Aku1elmp2B6WBOcd5RDR5Brkp6eIhXotY.

[27] Dfrobot, “Analog pH sensor/meter kit V2,” 2021. [Online]. Available: https://www.dfrobot.com/product-1782.html.

[28] ePal, “DS18B20 waterproof temperature sensor,” 2020. [Online]. Available: https://www.epal.pk/product/ ds18b20-stainless-steel-probe-waterproof-temperature-sensor/.

[29] VSEC Professional Sensor Manufacturer , “Waterproof Ds18b20 temperature sensor,” 2020. [Online]. Available: https://www.vsec.top/product/waterproof-ds18b20-temperature-sensor/.

[30] ITEAD, “ESP8266 module ESP12E nodemcu LUA wifi development board,” 2020. [Online]. Available: https:// www.itead.cc/esp-12e-nodemcu-lua-wifi-development-board.html.

[31] Microcontrollers Lab, “ESP12E pinout, interfacing with Arduino, applications, features, examples,” 2020. [Online]. Available: https://microcontrollerslab.com/esp12e-wifimodule-pinout-arduino-interfacingexamples/.

[32] Information Systems and Technology, “Software distribution,” 2020. [Online]. Available: https://ist.mit.edu/ software.

[33] E. W. Patton, M. Tissenbaum and F. Harunani, MIT app inventor: Objectives, design, and development. In: Computational Thinking Education. Singapore: Springer, 2019. [Online]. Available at: https://link.springer. com/chapter/10.1007/978-981-13-6528-7_3#citeas.

[34] Firebase, “Firebase real-time database-store and sync data in real time,” 2020. [Online]. Available: https://firebase. google.com/products/realtime-database?gclid=Cj0KCQjwpdqDBhCSARIsAEUJ0hOYvX2R0cE4bBZqw25qzp o1M9DAEmu5RBwQpo1Arben-rBl84TV9MoaAoy3EALw_wcB&gclsrc=aw.ds.

[35] OECD-FAO Agricultural Outlook, “Fisheries-OECD-FAO agricultural outlook 2014–2023,” 2021. [Online]. Available: https://stats.oecd.org/index.aspx?queryid=58653.

ISSN: 1000-372X ALT