A Smart Fish Feeding System for Internet of Things based Aquariums

Rufaida Auliar[†]
School of Science and Technology
Middlesex University Mauritius
Flic-en-Flac, Mauritius
r.auliar@mdx.ac.mu

Girish Bekaroo
School of Science and Technology
Middlesex University Mauritius
Flic-en-Flac, Mauritius
g.bekaroo@mdx.ac.mu

ABSTRACT

Effective fish feeding within aquarium environments is essential for proper health and growth of fishes. However, due to busy lifestyles, maintaining proper feeding cycles is a key challenge for aquarium owners. With the emergence of technologies including Internet of Things, various smart aquarium solutions have emerged. However, within existing solutions and published literature, limited work has been done to automate fish feeding for smart aquariums. As such, this paper extends literature on automated fish feeding within IoT-based aquariums through the implementation and evaluation of such a fish-feeding algorithm and system. In this study, a fish feeding algorithm that computes various aspects related to fish feeding (e.g. feeding time and number of pellets) is presented, based on aquarium environmental parameters (e.g. temperature and pH) along with aquarium characteristics (e.g. fish species and density). Based upon the proposed algorithm, a smart fish feeding solution was designed and implemented. For evaluation, the algorithm and system were tested within five aquariums to determine their effectiveness in feeding fish within different aquarium settings. Results showed that precision and recall reduce with increased number of fish species. Based on these limitations, recommendations have been made to enhance the implementation of such systems.

CCS CONCEPTS

•Hardware~Emerging technologies~Analysis and design of emerging devices and systems~Emerging tools and methodologies

KEYWORDS

Fish feeding algorithm, Internet of Things, Smart aquarium, AutoAquatech, Automated system

1 Introduction

Fishkeeping is considered as a popular hobby around the world [1]. Due to its calming and cheering effects, looking at fishes in an aquarium was found to lower the blood pressure of human beings and watching multi-colored fishes within same environment can curtail the disruptive behaviours of Alzheimer patients [2]. Because of its health benefits amongst other reasons, this hobby has been actively studied. Back in the 1800s, when maintaining aquarium was in its initial stage, keeping fish alive was a challenge as various parameters such as water quality and fish feeding were not properly comprehended, until scientific research simplified the process [3]. Properly feeding fish is essential in order to improve fish health and growth. Nevertheless, due to the busy lifestyles of aquarium owners, it is often difficult to maintain regular feeding schedule, whereby adversely affecting health and growth of fish [4]. Consequently, underfeeding can result in death due to starvation, and overfeeding can cause damages to the fish health as water quality worsens due to food residues. As such, effective fish feeding is regarded as a complex task for aquarium owners as it depends on various parameters such as type of fishes, density, water quality and temperature, among others [5, 6].

Recently, with advances in technologies such as Internet of Things (IoT), various smart aquarium solutions such Seneye, Lifeguard by Digital Aquatics and FishBit have emerged, whereby helping aquarium owners to monitor and control aquarium parameters. Nevertheless, existing solutions have emphasized on monitoring and controlling environmental parameters such as temperature, pH and light intensity, among others, rather than effectively feeding fishes [4]. As such, even though the parameters influencing fish feeding have been well studied, limited systems are available that automate fish feeding within aquariums. In other words, limited work has been done to accurately determine feeding parameters (e.g. amount of feed released, type of feed, feeding time and frequency, etc.) during fish feeding in smart aquariums. Taking cognizance of this gap, this paper extends literature on automated fish feeding within IoT-based aquariums through the design, implementation and evaluation of such a fish-feeding algorithm and system.

This paper is structured as follows: In the next section, related works pertaining to smart fish feeding are reviewed. Then, the various parameters that influence fish feeding within aquarium environments are reviewed in order to provide an overview on the factors that need to be kept track of in order to formulate a fish feeding algorithm. Then, an innovative fish-feeding algorithm is presented. Based on this algorithm, the implementation of a fish-feeding system is described. The evaluation method and findings of the study are presented in sections 6 and 7 respectively. Based on identified limitations, recommendations are provided on how the proposed fish feeding algorithm can be enhanced, before concluding the paper.

2 Related Works

Recently, advances in IoT have helped to digitize aquarium environments where various smart systems are either available commercially or have been published in literature, in order to enable monitoring and control of various parameters within such systems. Nevertheless, smart fish feeding whereby efficiently and accurately determining the feeding parameters (e.g. frequency, number of pellets released), has not been much studied. In the area of smart fish feeding, a previous study investigated the utilization of computer vision within a sustainable aquaculture feeding system [6]. This study focuses on estimating the appetite of fishes within the aquarium through the application of computer vision in order to eventually release pellets automatically or manually. Another study used a Peripheral Interface Controller (PIC) microcontroller to implement a pellet dispenser system for controlling the release of pellets within smart aquarium environments [7]. The focus of this study was however on the mechanical component of the feeder rather than effective feeding of fishes based on parameters of the aquarium. In addition, a previous study proposed a fish feeder system that feeds fishes at regular intervals and measures environmental parameters using different sensors [8]. Although this system was found to increase feed efficiency and reduce labor costs, the fish feeding algorithm does not integrate data from the environmental sensors of the pond in order to effectively calculate the correct number of pellets to be released during a feeding instance. Similarly, a fish feeder system was build using Raspberry Pi where users can access feeding processes through a web application [9]. The interface within this system enables manual fish feeding, set and change the feeding plan and contains a camera that allows the user to verify the tank status. As such, although some smart fish feeding systems have been presented in literature, limited work has been done in order to integrate the factors that accurately determine the amount of feed to be released by the feeding system. Hence, the gap addressed in this paper is relevant to study.

3 Deriving the Fish Feeding Algorithm

Due to the limited availability of smart fish feeders for IoT driven algorithms, it becomes important to create one. For this, it becomes essential to comprehend the factors that influence fish feeding within aquariums. Because of the importance of this topic, different studies have been conducted to comprehend these factors, where the key ones have been summarized in Table 1:

Table 1: Factors affecting food intake of fishes in an aquarium

Parameter	Description
Number, species and sizes of fishes	Different species of fish are known to consume varying amount of food pellets. Also, an aquarium may contain various fishes of varying species and sizes and particular attention need to be given to these characteristics when determining the amount and type of feed to be released in the aquarium, among other factors.
Stocking density	Stocking density is the weight of fish kept in a specified quantity of water. It has been reported that an increase in stocking density can be a source of stress with effects including reduced growth rate, health of fish and a range of physiological processes [10]. Similarly, an increase in stocking density can cause a decrease in the consumption of food for some species whereas increasing survival rate and growth for others [11].
Water temperature	Water temperature is a significant factor contributing to the health of fish and every fish species has its own minimum and maximum temperature range and the health of the fish is likely to be affected outside that range [12]. An increase in water temperature can provoke an increase in food intake by certain species of fishes and as such, keeping track of water temperature is essential in order to determine feed released in the aquarium [13].
Water oxygen level	Oxygen is essential for the survival of aquatic species. Generally, a decrease in water oxygen level contributes in the reduction of food intake of fish and to ensure proper feeding, keeping track of optimum oxygen level is essential [14].
pH	Different fish species require different water pH level whereby some aquatic

	animals can tolerate a higher acidity content or pH level than other fishes [15]. As the pH level gets out of the range, it can stress the fish and reduce hatching and survival rates.
Stress	Stress is a condition that causes discomfort that results in physiological responses to threatening situation. Stress has a negative effect on growth, reproduction and digestion, thus, a reduction of food intake and change in the feeding behavior are signs of behavioral response that is associated to stress in fish [7]. According to the same source, when fishes continue to be in stressful conditions, their intake of food decreases and as a result they grow slowly.
Light	Light is a factor influencing the food intake in fish to certain extent [16]. An increase in the level of light encourages feeding however, a decrease in the light level discourages feeding and is thus an important factor to keep track of.
Ammonia	Ammonia is a highly poisonous substance which is a threat to aquatic environment and its presence in an aquarium occurs through overstocking and overfeeding [17]. Raised ammonia level in water causes a reduction in food intake.

In addition to the above factors, decisions have to be taken on the following aspects so as to properly derive the fish feeding algorithm [5]:

- Feed amount:
  Effectively determining the amount of feed released within the aquarium during a feeding instance is essential in order to properly feed fishes and foster growth, while also avoid underfeeding and overfeeding. On a quantitative basis, various factors need to be considered in order to determine the amount of feed released where key ones include the number and species of fishes in the aquarium, type of feed, aquarium environmental parameters (e.g. water quality), stressors (e.g. pollutants) as well as feeding history, as discussed in Table 1.

- Type of feed:
  In addition to the amount of feed, the types of feed consumed by fishes may differ. For instance, a smaller sized fish may consume smaller-sized pellets as compared to larger ones. As such, this factor is essential to consider within the algorithm derived. It should be noted that different types of pellets may be released during a feeding instance, depending on fish characteristics within the aquarium.

- Feeding frequency:
  This factor relates to the number of times fishes are fed on a daily basis. In order to deduce the optimum feeding frequency that guides growth and survival of fish, key parameters need to be considered include fish species, size of fish, environmental conditions of the aquarium, diet and awareness of feeding trail [5].

- Feeding mode:
  Two key modes of feeding are envisaged, notably automatic and manual. It can happen that users feed fishes manually and, in this process, parameters (e.g. food quantity, time of feeding, etc.) need to be properly recorded so that the algorithm properly feeds fishes the next time.

- Feeding time:
  A previous study showed that fish species may have endogenous feeding rhythms that are guided by their nervous and endocrine systems [18]. As such, it is important to determine the appropriate time to feed particular species within the aquarium.

Based on the factors identified from literature, a smart fish feeding algorithm was formulated. The algorithm takes as input different parameters provided in Table 1 in order to compute the feed amount, type of feed, feeding frequency and feeding time. To automatically feed fishes, the algorithm checks if the feeding mode is set to automatic. Else, the process for manual feeding is different and is based on parameters pre-set by the user. For automatic fish feeding, ideal values for the feed amount, type, frequency and time are determined based on the fish details (species and count) along with stocking density. Then, whenever the feeding time has been reached, values from the respective sensors are retrieved. Based on water quality details, the feeding parameters (feed amount and type) are adjusted in order to avoid underfeeding and overfeeding. Eventually, the next feeding time is determined and adjusted. In case the water quality is below a threshold value pre-set by the user, then the algorithm does not feed fishes as the likelihood that fishes ingest the feed is low. In this case, the aquarium owner is notified in order to regulate water quality. The pseudocodes for the derived fish feeding algorithm is provided as follows:

```
Input: P: Pre-determined Number of pellets
       T: Temperature of water
       pH: pH level of water
       L: Light intensity
       Le: Level of water
       O: Water Oxygen level
       A: Ammonia Level
       S.D: Stocking Density of aquarium
       W.P: Array of Water Parameters (T, pH, L,
         Le, O, A, S.D)
       S.P: Array of fish species
```

```
        N.F: Number of species
        F.S: Array of Fish Size
        F.D: Array of Fish Details (S.P, F.S)
        RTC: Current Time
        N.P: Number of Pellets
        F.M: Feeding Mode
        F.F: Feeding Frequency
Output: F.A: Feed Amount
        T.F.: Type of Feed
Begin
        Set     P ← Get value based on FD,
                F.A ← 0,
        Compute ideal W.P for F.D
        Compute T.F. for F.D and S.D
        Compute F.F. for F.D and S.D
        Compute F.A. for F.D
        If (Feeding Mode == Automatic), Then
           While (RTC == T.F)
              Read W.P from respective sensors
              Compare W.P with ideal range for
S.P
                If (W.P within ideal range), Then
                   Adjust T.F based on W.P
                   Adjust F.F based on W.P
                   Adjust F.A based on W.P
                   Trigger Feeding
                   Print ("Feeding successful")
                   Log all parameters
                Else
                    Set F.A as zero
                    Alert user
                End While
        Else
           Fetch manual feeding parameters
           Processes for manual feeding
           Alert User
        End If
        Log all details
End
```

4 Prototype Design and Development

The fish feeding algorithm proposed in the previous section was implemented within a smart fish feeding system named AutoAquatech. The implemented system consists of three components, notably, an Arduino-based system, a database and a mobile application. The Arduino system is the core of AutoAquatech, which implements the fish feeding algorithm in order to enable the feeder to release a controlled amount of feed automatically or manually (if configured on the mobile application) when the conditions within the algorithm are met. The Arduino system encases the circuitry of AutoAquatech. Different sensors such as the temperature sensor, pH sensor, dissolved oxygen sensor and light dependent resistor sensor are connected to the Arduino Mega board, along with various other devices like the buzzer, Light Emitting Diode, servo motor and vibrating motor. In order to setup this system, the sensors and devices mentioned were individually connected to the board and the algorithm was deployed. Arduino IDE was used to develop the system and several libraries were also used in the process including the Wire Library and DS3231RTC Library. The Fritzing diagram of the circuitry of the Arduino system is depicted in Figure 1.

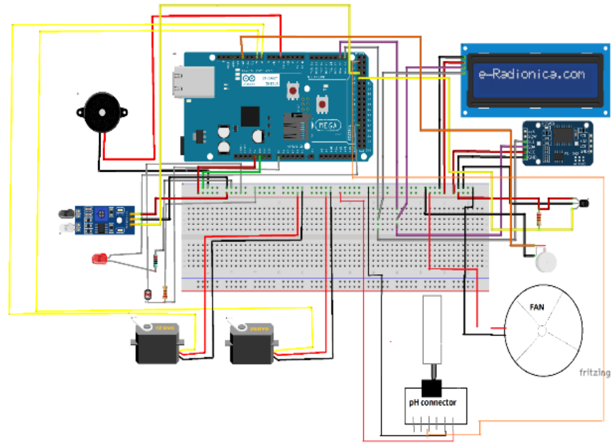

Figure 1: Circuit Design

Along with the Arduino-based system illustrated in Figure 2, a MySQL database was also used in order to store data pertaining to the solution. Key data stored related were system configurations, aquarium setup, data acquired from sensors and feeding history. In addition to the database, an Android-based mobile application was also implemented so that the user can interface with the Arduino system to monitor and control the system. As key features of the mobile application, end users can create their profile and that of their aquarium. In this process, the size of the aquarium and fish details (including number of each species present and size) are setup the first time the user utilizes the mobile application. In case of changes in settings, an interface is also available to update details. In addition, feeding details are also added (notably automatic v/s manual feeding). In case manual feeding is preset by the user, then information pertaining to the feed amount, type of feed, feeding frequency, feeding mode and feeding time need to be configured by the user for the system to release pellets in the water when the conditions are met. An interface for direct feeding is also available where the user can activate the feeder to feed fishes at any point in time. Once the system has been configured, the system automatically feeds fishes based with no user involvement if the automatic fish feeding feature has been selected. As users utilize the fish feeding system on a daily basis, notifications are sent as fishes are fed (including time of feeding and number of pellets fed) and monitoring details can be retrieved at any point in time as reports or even charts. In addition, users can view feeding log to understand whether fishes are being underfed or overfed, so that appropriate corrective measures can be taken. In case the feeder is about to run out of food, the user is also notified so that same can be replenished. In case of poor water, quality, the user is alerted so that corrective measures can be taken in a timely manner, as mentioned earlier in the algorithm design.

Figure 2: AutoAquatech system

5 Evaluation Method

Whilst the core objective of the proposed solution is the fish feeding algorithm, its effectiveness is essential to study in real life settings. For this, evaluation was conducted in order to understanding the extent to which AutoAquatech has achieved its intended goal and produced desired results. As such, for evaluation method, an adapted method utilized in a previous related study was adopted [19].

For this, assessment was conducted to determine whether the fish feeding system was releasing fish pellets as the aquarium owner would normally do. In this endeavour, different metrics were utilized, notably:

- True positives (TP)*: These were feeding instances identified by both the aquarium and the automated feeding system.*
- False positives (FP)*: FP were feeding instances by the automated feeding system only and the aquarium owner had no intention to feed fishes in that instance.*
- False negatives (FN)*: These were feeding instances identified only by the aquarium owner and not by the fish feeding system.*

On the other hand, true negatives were not considered in this study since the judgement and experience of owners were used as a basis to assess feeding of fishes. Based on the above, the precision and recall were resoluted using the formulae below. Whilst recall was computed in order to measure the quantity of feeding instances identified, precision helped to determine the quality of the identified feeding instances. Furthermore, a high precision implies that an algorithm has returned a relatively higher number of relevant outcomes than irrelevant ones and that a high recall implies that an algorithm returned most of the relevant results.

$$Recall = \frac{True\ Positive}{True\ Positive + False\ Negative}$$

$$Precision = \frac{True\ Positive}{True\ Positive + False\ Positive}$$

In order to study the reasons for false negatives and false positives for fish feeding in different aquarium settings, an experiment was conducted. In the experiment, different aquarium setups (e.g. varying size, fish and environments) were established and the owner of the aquarium had to configure and utilize AutoAquatech in automated feeding mode to feed fishes for a week. As procedures of the experiment, aquarium owners were invited to take part in the study and in the process, five participants agreed to participate. Instead of conducting the experiment in lab settings, aquarium owners were involved in the study in order to obtain better insights on how AutoAquatech operates in practice. Every participant was individually briefed on the purpose of the study, data collection and dissemination. Informed consent was also sought from the participants and ethical aspects were established in order to ensure that no fishes were harmed during the study. The aquarium setups of the five participants are described in Table 2 as follows:

Table 2: Profiles of aquariums

Aquarium	Description
A1	This aquarium of size 80cm by 50cm consisted of 2 Goldfish (small-sized fishes) of 3 and 6 months old respectively. The owner of the aquarium is familiar to aquarium environments for 6 months.
A2	This aquarium of size 30cm by 15cm by 20cm consisted of 2 Zebra fish ((2.5cm) of 6 months old and 2 catfish (large-sized fishes) of 2 years old. The owner of the aquarium is familiar to aquarium environment for 4 years.
A3	This aquarium of size 121.9cm by 45.7cm by 61cm consisted of 3 Guppies (Medium-sized fishes) of 3 years old, 1 swordtail (small-size fish) of 2 months and 5 platies (large-sized fishes) of 3 years old. The owner of the aquarium is familiar to aquarium environment for 2 years.
A4	This aquarium of size 20cm by 15 cm by 15cm consisted of 1 fighter fish (5 cm) of 1 year old. The owner of the aquarium is familiar to aquarium environment for 1 year.
A5	This aquarium of size 61cm by 30.5cm by 30.5cm consisted of 2 Angelfish (small-sized fishes) of 1 month old, and 4 tetras (medium-sized fishes) of 1 year old respectively. The owner of the aquarium is familiar to aquarium since 2 years old.

AutoAquatech was deployed in the respective aquariums of the participants and the mobile application installed on their respective mobile phones. Once the feeding system was configured and that pellets were replenished within the feeder, comprehensive guidelines were provided to the participant on how to use the system, the data to be collected and actions to be taken in case the system does not release pellets as expected (e.g. failure to feed, underfeed or overfeed). The participants were then given a week to utilize the system. During the week, participants had to use AutoAquatech as aquarium feeding assistant and assess whether the system was feeding as expected. For instance, ±30 minutes around the normal feeding time (planned by the user), the user should keep track of any feeding notifications received from the system. Based on the outcome, the user should log whether it was a TP, FP or FN for that instance in particular. Details on all the feeding instances were logged for the evaluation period. After a week, the data sheet containing details on feeding history along with the feeding logs retrieved from the system were gathered for analysis. The same process was repeated with every participant.

6 Results and Discussions

Using the methodology described in the previous section, data was collected in order to compute the precision and recall for the different scenarios. Results are provided in Table 3.

Table 3: Results

Aquarium	TP	FP	FN	Recall	Precision
A1	5	1	1	0.83	0.83
A2	4	2	1	0.80	0.67
A3	3	3	1	0.75	0.50
A4	6	1	0	1.00	0.86
A5	2	3	2	0.50	0.40
			Mean:	**0.78**	**0.65**

From Table 3, it could be observed that for Aquariums A1 and A4, the true positives were higher as compared to others. In both aquariums, only one type of fish was present, notably Goldfish and Fighter fish respectively. For both aquariums, higher precision and recall were obtained, to denote that the algorithm returned significantly more relevant feeding instances than irrelevant ones, and that the largest number of feeding instances were identified. The participants of these aquariums also confirmed that the system was particularly helpful to assist in the fish feeding process and that the pellets released were completely ingested by the fishes. The aquarium owners also confirmed that pellets were released as reported by the mobile application.

However, findings for the other aquariums (A2, A3 and A5) were not as positive as compared to A1 and A4. It could be noticed that as the number and species of fishes increased, the number of false positive and false negatives increased. On one hand, the false positives could due to limitations of the algorithm but on the other, since the participants were not experts in the area, the false positives could also mean that participants should have fed fishes at that feeding time. According to two participants, fishes ingested the pellets even though the feeding instances were reported as false positives thus implying that FPs warrant further investigation and could be reassessed by experts. Similarly, some false negatives were reported and according to participants, this was attributed to the fact that the system did feed fish earlier than the participants would normally do. In addition, the owner of Aquarium A5 also suggested that the fish feeder component could better distribute the feed over the entire aquarium rather than just below the feeder in order to avoid competition between fish as this can also increase stress levels for some species.

Overall, although the proposed fish-feeding algorithm and system were able to correctly feed fishes in all the scenarios, some false positives and false negatives were also revealed. The mean recall was 0.78 and the mean precision was 0.65. These values imply that further enhancements are needed in order to enhance accuracy of feeding to accommodate all types of aquariums. In addition, the study could be undermined by a few limitations. Firstly, participants involved had relatively small aquariums. Investigating the application of the proposed fish feeding system within larger aquariums could reveal more insightful information regarding its accuracy and performance. Also, the experiments were only performed for a week at each participant's house and in this process, the data collected was limited. The experiment could have been conducted for a longer period of time in order to acquire more data for analysis. Also, experts in fish farming could be involved to provide justifications on the false positives and negatives.

7 Recommendations

Even though the fish feeding algorithm performed well in aquariums with few species of fishes, different weaknesses also reduced its accuracy. For refining the fish feeding algorithm and system, the following improvements could be made. These recommendations could be considered by researchers and designers of smart aquarium systems in order to potentially enhance accuracy of fish feeding. These recommendations are:

- Extending fish feeding algorithm
  The fish feeding algorithm produced in this study did not take on board all parameters that influence fish feeding as listed in Table 1, including ammonia and stress detection. The proposed fish feeding algorithm could be extended to include all the environmental and fish feeding parameters to potentially enhance accuracy.
- Better feed distribution
  The feeder component could be extended in order to better distribute feed across the aquarium. Better feed distribution decreases competition among fishes

whereby reducing stress [5]. Consequently, the fishes can better ingest the feed amount computed by the algorithm, while also preventing underfeeding and overfeeding.

- Integrating fish appetite monitoring system
  In a previous study [6], computer vision techniques were applied to determine appetite of fishes. The algorithm produced in this study can be complemented with such appetite monitoring system in order improve accuracy on feeding decisions.

- Reinforcement learning
  Results showed that the accuracy of the fish feeding algorithm decreased with increased variety of fishes. In order Results showed that the accuracy of the fish feeding algorithm decreased with increased variety of fishes. In order to address this issue, reinforcement learning algorithms could be introduced and tested. Although, more data and feeding instances from aquarium users will be needed, application of such techniques can potentially improve the accuracy of the algorithm produced in this paper.

8 Conclusions and Future Works

This paper proposed an innovative fish feeding algorithm that aims at automating fish feeding within different aquarium settings. The proposed algorithm computes key aspects pertaining to fish feeding (e.g. feeding time and number of pellets), based on aquarium environmental parameters (e.g. temperature and pH) along with aquarium characteristics (e.g. fish species and density). The proposed algorithm was implemented within a smart fish-feeding system called AutoAquatech. This system consists of an Arduino component, which is installed in the aquarium and is made of two key parts, notably a fish feeder and sensors for gathering environmental data. In addition, the system has a mobile application provides the interface for the end user to interact with the Arduino component (system configuration, obtain sensor and feeding data and generate reports). The proposed algorithm and the AutoAquatech system were evaluated whereby involving five participants who own five distinct aquariums. Participants had to utilize the system for a week on automated mode and provide feedback on the accuracy in terms of its effectiveness in feeding fishes within different aquarium settings. Results showed high precision and recall in aquariums containing low number of varying fish species. However, with increasing fish species, precision and recall were found to reduce. Recommendations were also proposed on how the accuracy and effectiveness of the algorithm can be improved. As future works, enhancements in the algorithm can be made in addition to further evaluation based on limitations discussed in the paper. In addition, Artificial Intelligence (AI) techniques including machine and reinforcement learning could be implemented to retrieve details of different fishes and to intelligently compute the number of pellets based on those details.

ACKNOWLEDGMENTS

We would like to thank Middlesex University Mauritius, Mr. Ridwan Tengur and the participants for their help and support.

REFERENCES

[1] Alberto Maceda-Veiga, Omar Domínguez-Domínguez, Josep Escribano-Alacid, and John Lyons. 2014. The aquarium hobby: can sinners become saints in freshwater fish conservation? *Fish and Fisheries* 17, 3 (Sept 2014), 860-874. DOI: https://doi.org/10.1111/faf.12097

[2] Alex Lieber. 2020. Does Having an Aquarium Decrease Stress? (May 2020). Retrieved June 4, 2020 from https://www.petplace.com/article/fish/general/does-having-an-aquarium-decrease-stress/

[3] Amy Wolff. 2014. History of the Aquarium (December 2014). Retrieved May 14, 2020 from https://www.petplace.com/article/fish/general/history-of-the-aquarium/

[4] Akilesh K Sabari, V Savitha, N Vinithra , and J Dhanasekar . 2017. Smart Fish Feeder. *International Journal of Scientific Research in Computer Science, Engineering and Information Technology* 2, 2 (April 2017), 11.

[5] Ochuko Joshua Eriegha, Paterson Adobeji Ekokotu. 2017. Factors affecting feed intake in cultured fish species: A review. *Animal Research International* 14, 3 (May, 2017), 2697-2709.

[6] Shelby Gerking. 2014. Feeding ecology of fish. Elsevier.

[7] Jer-Vui Lee, Joo-Ling Loo, Yea-Dat Chuah, Pek-Yee Tang, Youg-Chai Tan and Wei-Jian Goh. 2013. The Use of Vision in a Sustainable Aquaculture Feeding System. *Research Journal of Applied Sciences, Engineering and Technology 6, 19 (February, 2013), 3658-3669.*

[8] Mohammad Z. Noor, Ahmad K. Hussain, Mohammad Farid Saaid, Mohammad Ali and Maizatul Zolkapli. 2012. The design and development of automatic fish feeder system using PIC microcontroller. *In Proceedings of the 2012 IEEE Control and System Graduate Research Colloquium*, July 16-17, 2012, Shah Alam, Selangor, Malaysia. DOI: 10.1109/ICSGRC.2012.6287189

[9] Sai Krishna Vaddadi, S.S. Sadistap, A.P. Sharma and Pankaj Kumar. 2012. Embedded Floating Auto Fish Feeder for Smart Pond Management System (2012)

[10] Hidayatul Nur Binti Hasim, Mritha Ramalingam, Ferda Ernawan, and R. Puviarasi. 2017. Developing fish feeder system using Raspberry Pi. In the Proceedings of 2017 Third International Conference on Advances in Electrical, Electronics, Information, Communication and Bio-Informatics (AEEICB), February, 27-28, 2017, Chennai, India. DOI: 10.1109/AEEICB.2017.7972422

[11] Dominic Houlihan, Thierry Boujard and Malcolm Jobling. 2001. Food Intake in Fish. London, United Kingdom.

[12] Thomas Hetch and Walter. Uys.1997. Effect of density on the feeding and aggresssive behaviour in juvenile African catfish. *South African Journal of Science* 93, 11/12 (1997), 537-541.

[13] Rahman Mizanur, Hyeonho Yun, Mohammed. Moniruzzam, Filipa. Ferreira, Kang-woong Kim, and Sungchul Bai. 2014. Effects of Feeding Rate and Water Temperature on Growth and Body Composition of Juvenile Korean Rockfish, Sebastes schlegel. *Asian-Australiasion Journal of Animal Sciences* 27, 5(May 2014), 690-699. DOI: 10.5713/ajas.2013.13508

[14] Carloas Antonio Martinez-Palacios, Cristina Chavez-Sanchez and Lindsay Glenn Ross. 1996. The effects of water temperature on food intake, growth and body composition of Cichlasoma urophthalmus (Günther) juveniles. *Aquaculture Research* 27, 6 (June 1996), 455-461. DOI: https://doi.org/10.1111/j.1365-2109.1996.tb01275.x.

[15] Saravanan Subramanian. 2013. Feed Intake and oxygen consuption in fish.(2013). Retrieved June 4, 2020 from https://research.wur.nl/en/publications/feed-intake-and-oxygen-consumption-in-fish

[16] Alexis Rohlin. 2018. How can pH affect your fish (March 2013). Retrieved January 22, 2020 from https://sciencing.com/can-ph-affect-fish-12101588.html

[17] Phillip Higgins and Colin Talbot.1985. Growth and feeding in juvenile Atlantic salmon. *Nutrition and feeding in fish* 62 (1985), 295-308.

[18] David Randall and Tommy Tsui. 2002. Ammonia toxicity in fish. Marine Pollution Bulltin 45, 1-12 (Sept 2002), 17-23. DOI: https://doi.org/10.1016/S0025-326X(02)00227-8

[19] Sadasivam Kaushik. 2013. Feed management and on-farm feeding practices of temperate fish with special reference to salmonids. *FAO Fisheries and Aquaculture Technical Paper 2013.* Institut national de la recherche agronomique, UMR 1067 Nitrition, Aquaculture and Genomics, St-Pee-sur-Nivelle, France

[20] Borbala Foris, Alexander Thompson, Marina von Keyserlingk, Nina Melzer, and Daniel Weary. 2019. Automatic detection of feeding-and drinking-related agonistic behavior and dominance in dairy cows. *Journal of dairy science* 102, 10 (October 2019), 9176-9186. DOI: https://doi.org/10.3168/jds.2019-16697