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# Integrated Monitoring System for Shrimp Farming: Combining Acoustic and Water Quality Analysis

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**Abstract** The aquaculture industry is a cornerstone of Vietnam's economy, with the cultivation of white-leg shrimp (*Penaeus vannamei*) as a significant contributor to its growth. Efficient feeding practices are paramount in optimizing shrimp growth and reducing waste, which accounts for a substantial portion of the production cost. The paper presents an integrated monitoring system that collects acoustic sound of shrimp feeding behavior and water quality characteristics. Acoustic data, recorded manually and streamed to the cloud, provides insights into shrimp feeding patterns, while continuous monitoring of parameters like pH, dissolved oxygen (DO), temperature, and oxidation-reduction potential (ORP) offers a comprehensive view of water conditions. The system was deployed at a commercial shrimp pond at Cam Ranh, Nha Trang to collect data over a shrimp crop cycle.

The results reveal that acoustic analysis can accurately detect distinct feeding behaviors, suggesting opportunities for precision feeding strategies. Additionally, water quality parameters, especially DO and temperature, follow consistent daily patterns that correspond to solar activity that can be used to optimally control oxygen aerator. It paves the way for further research into precision feeding using

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N. T. Hai et al. (eds.), *EAI International Conference on Renewable Energy and Sustainable Manufacturing*, EAI/Springer Innovations in Communication and Computing, https://doi.org/10.1007/978-3-031-60154-5_39

acoustics and understanding the intricate relationship between water quality and shrimp feeding behavior.

**Keywords** Aquaculture monitoring · Feeding acoustic · Water quality · Efficient feeding

## 1 Introduction

The aquaculture sector plays a crucial role in Vietnam economy, with whiteleg shrimp (*Penaeus vannamei*) being an important species in aquaculture, and its production has been steadily increasing over the years [1]. Currently, the cultivation of whiteleg shrimp is evolving toward intensive and super-intensive methods [2]. However, environmental issues are posing significant challenges. Problems such as water pollution, disease outbreaks, and the increasing impact of climate change, including rising temperatures, irregular rainfall patterns, and saline intrusion, have led to mass shrimp mortality in recent years in the Mekong Delta region [3].

According to Jackson et al., in intensive shrimp farming systems, only 22% of the nitrogen (N) is converted into shrimp biomass, with 57% being discharged into the environment, 14% settling at the pond bottom, and only 3% being lost as ammonia into the atmosphere [4]. The cost of food accounts for 70–80% of the total production cost in intensive shrimp farming [5]. Using good-quality and appropriate food contributes to achieving high economic efficiency for shrimp farmers. However, profits can be further improved if shrimp feeding is managed and controlled rigorously throughout the farming process.

Feeding shrimp insufficient food for an extended period will result in slow growth due to nutritional deficiencies, especially during the early stages of development, limiting their ability to molt. Prolonged food scarcity also leads to competition among shrimp for food, resulting in aggressive behavior [6].

On the other hand, overfeeding shrimp can promote growth during the initial development stage when shrimp are in the rapid growth phase, especially when water quality is still good. However, when shrimp do not consume all the food provided, the accumulation of organic waste from excess food pollutes the water in shrimp farming ponds and also the surrounding water [7]. The accumulation of excess food at the bottom of the pond is a major cause of toxic gas outbreaks, especially when the dissolved oxygen (DO) levels decrease or when algae grow excessively in the pond.

There are many studies and products that have been used to improve the efficiency of food utilization, increasing the feed conversion ratio (FCR). The common method used today is to feed shrimp based on their growth size, adjusting the quantity to match each developmental stage. To enhance feeding efficiency, some shrimp farmers try to calculate the feeding activity in ponds. They place feeding trays in ponds, and the amount of remaining food in the trays after 1 or 2 h of feeding will determine whether to increase or decrease the amount of food to be given the next day. Some farmers use a sediment tray in the feeding area to find any leftover food or the smell of spoiled feed. Experienced shrimp farmers may observe the swimming behavior of shrimp along the edge of the pond 1 or 2 h after feeding to determine if the shrimp have eaten enough. This method is labor intensive and error-prone.

Researchers and companies are trying to use vision and acoustic data when the shrimp is feeding to adjust the feeder [8]. The former faces difficulties with the highly turbid water that affects the camera vision significantly. The former method also get challenges from large background noise such as paddlewheel aerators, air diffusers, pumps, rain, wind, and also human activities. Those background noises also have wide range frequency and overlap with the sound emitted when the shrimp is eating.

In [9], Silvio Peixoto et al. investigated the acoustic characteristics of *Litopenaeus* when fed a different diet. They placed a hydrophone inside an acoustic foam anechoic chamber and recorded the sound in 30 mins when feeding three fastened shrimp with 0.5 g food. Their result shows that the intensity of the snapping acoustic reflects the diet texture. However, the result did not show the difference between feeding phases. Silva et al. evaluated the sound characteristic of different sizes of *Penaeus vannamei* shrimp when feeding with different pellet of food [10]. Acoustic variables such as frequency and sound duration were measured, with the number of clicks per pellet indicating feeding activity, especially in the larger shrimp class during the initial minute after pellet capture, offering a potential method for monitoring feed consumption in captivity. This research focuses in small batch of shrimp, and the research process was conducted in short time.

There is a limited amount of research conducted in commercial shrimp ponds; therefore, the results obtained from these published papers may not be directly applicable to practical applications. Additionally, because commercial shrimp ponds are often located in rural areas, data collection becomes costly and less accurate. Moreover, water parameters significantly influence feeding activity and shrimp growth. To date, there have been no published studies monitoring water quality characteristics and shrimp sounds simultaneously to analyze the correlation between them.

Hence, the objective of the present research is to design, implement, and deploy a monitoring system that enables researchers to obtain all necessary data in a commercial shrimp pond, including real-time and remote acquisition of water characteristics and acoustic data, eliminating the need for frequent site visits.

## 2 Materials and Method

### *2.1 Research Location and Time*

The research was conducted at a commercial pond at CAMRANH City, Khanh Hoa Province, Vietnam. The data was collected from July 1, 2023, to September 10, 2023, from the beginning to the end of one shrimp crop cycle.

## 2.2 Data Acquisition System

For data recording, we design two devices, one for manual recording and one for real-time time streaming all time to the cloud server. Researchers use handheld device to record the shrimp sound when they are feeding. This will help reduce the size of the audio data and make the audio files easier to organize. Also, the manual recording eliminates the audio loss when doing streaming due to network connectivity problem.

The real-time streaming system serves the purpose of streaming audio from the pond to the cloud, enabling researchers to collect acoustic data from the pond over extended periods. In the subsequent phase of the research, the audio streaming system can be seamlessly integrated into the automatic feeding system. This integration allows for the analysis of audio data and precise control of the feeder to provide shrimp with the exact amount of food they require.

### Manual Recording Device Implementation

We use the H1a hydrophone from Aquarian [11] to record the underwater sound. The hydrophone has a very high output impedance, around 1Mohm, so that we need to design a special pre-amplifier to amplify the signal, as well as convert the high impedance of the hydrophone to low output impedance. Figures 1 and 2 illustrate the system's block diagram and the hardware implementation, respectively.

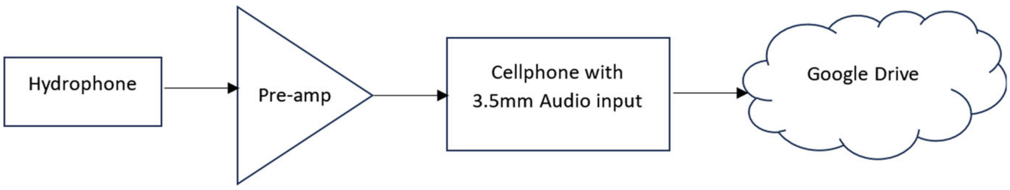



**Fig. 1** Manual recording device block diagram

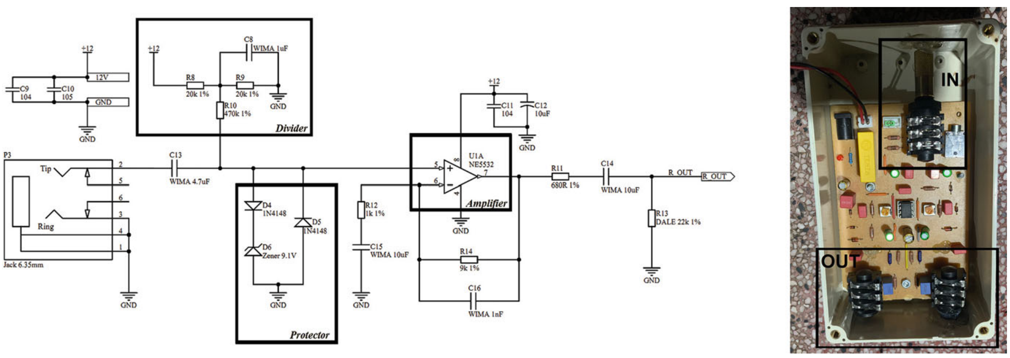



**Fig. 2** Schematic and implementation of the manual recording device

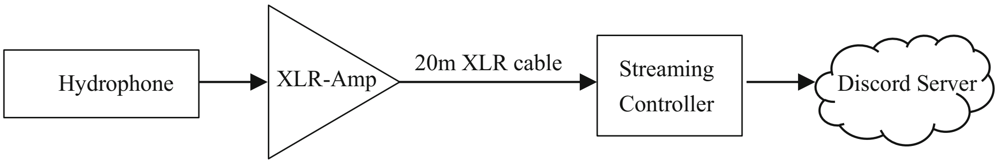



**Fig. 3** Audio streaming system block diagram

The pre-amp is powered using a 12V battery. The design specification is as follows:

- Gain: 1Db
- Bandwidth: 20Hz-20Khz
- Zin: 10Mohm
- Zout: 680 Ohm

To record the shrimp sound, we placed the hydrophone on the pond, connect it to the preamplifier, and then connect the output of the preamplifier to the 3.5 mm audio input connector of a smartphone. The audio is recorded using the recorder app and then uploaded to Google Drive for analyzing later.

## Real-Time Streaming System

Figure 3 illustrates the diagram of the audio streaming system. The system has been permanently installed with the hydrophone and balanced preamp positioned at the pond, while the streaming controller is located indoors approximately 20 m away. Due to this considerable distance, we have designed a balanced preamplifier and utilize XLR cables to transmit the audio signal to the streaming controller. The streaming controller employs a converter to change the balanced signal into a single-ended signal, which is then routed to a Raspberry Pi board through a USB sound card. The Raspberry Pi streams the audio to a Discord Server, enabling researchers to listen to and record real-time data.

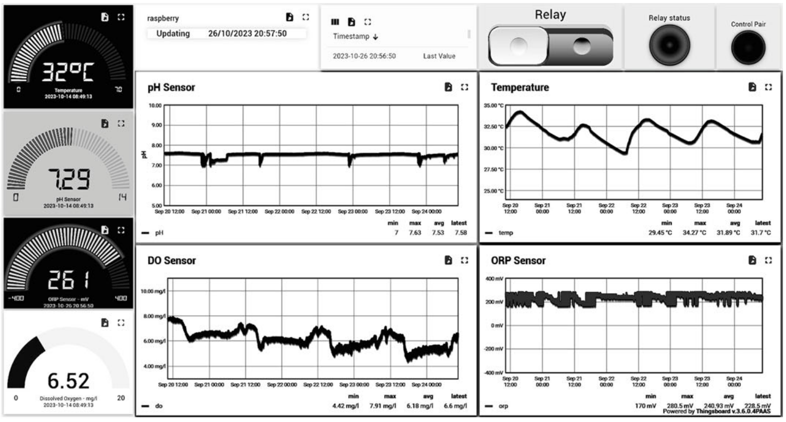
## Water Quality Monitoring System

The water quality index is very important for the health of shrimp; therefore, researchers need to collect and analyze along with the feeding behavior. In this research, we designed a system that monitor PH, ORP, DO, and temperature of the water. Figure 4 shows the hardware and the dashboard for visualizing the collected data.

The system consists of two devices, one sensor node and one gateway. The sensor node is installed at the center of the pond, measuring PH, ORP, DO, and temperature, and send them to the gateway over LORA communication. The gateway receives the data and send it to ThingsBoard platform to store and visualize the water quality index.

(a) Gateway

(b) Sensor node




(c) Visualization dashboard

**Fig. 4** Hardware and software for water monitoring system

## 3 Data Collection and Discussion

### *3.1 Audio Data*

The audio data is manually recorded at the pond each time the shrimp are fed, following a specific procedure:

- Initially, we record the ambient background sound at the pond for a duration of 2 min while the oxygen diffuser and paddle wheel are in operation.
- Next, we turn off both the oxygen diffuser and paddle wheel, proceed with shrimp feeding, and record the snapping sounds for 2 min.
- After feeding, we turn the oxygen diffuser and paddle wheel back on and record the sound for an additional 8 min. This data contains a mixture of snapping sounds and background noise.
- All audio files are named with the recorded timestamp and stored on Google Cloud, simplifying data sharing and analysis for researchers. To obtain clean snapping sounds without background noise, we also record the sound in a fully isolated chamber. This reference data is crucial for extracting shrimp snapping sounds from the data recorded at the pond.

For streaming audio to the cloud, we experimented with various platforms, including Icecast, YouTube, and Discord. Discord streaming platform yielded the best results in terms of low latency, minimal packet drops, and noise filtering capabilities. The audio is streamed in real time with a delay of less than 1 second, and the stream remains stable with a sampling rate of 44.1 kHz.

The streamed audio data can be saved as multiple files and stored on Google Drive using a Python script. This audio stream data is used for analyzing background sounds at different times and under various conditions, such as rain and wind.

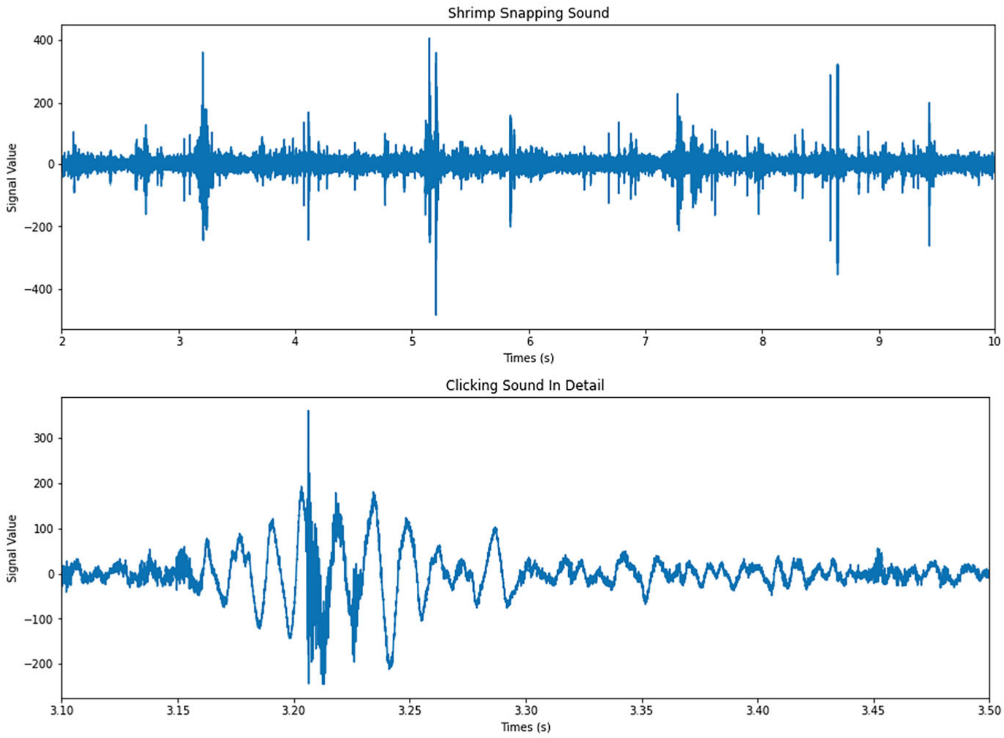



**Fig. 5** Shrimp snapping sound

From the collected audio, we create waveforms in the time domain. As shown in Fig. 5, a substantial number of pulses are generated when the shrimp are feeding. These detailed waveforms, characterized by their unique shapes, can serve as the foundation for frequency-based algorithms, energy analysis, or artificial intelligence techniques for analyzing the shrimp feeding process.

## *3.2 Water Quality Index*

Water quality data, including parameters like dissolved oxygen (DO), temperature, pH, and oxidation-reduction potential (ORP), were collected at five-minute intervals and seamlessly transmitted to the cloud platform. This data collection spanned over three months, encompassing the entire shrimp crop cycle, and demonstrated a robust performance with no data losses.

Regarding the DO levels in the pond, we've noticed a consistent pattern each day. It begins to rise around 7 am, coinciding with sunrise and the initiation of the photosynthesis process by the water algae, which produces oxygen. As the day progresses, typically around 3 pm, we observe a gradual decline in DO levels due to reduced solar irradiation. At precisely 4 pm, the aerator is temporarily switched off to facilitate shrimp feeding, and it's then reactivated at 6 pm. This action is

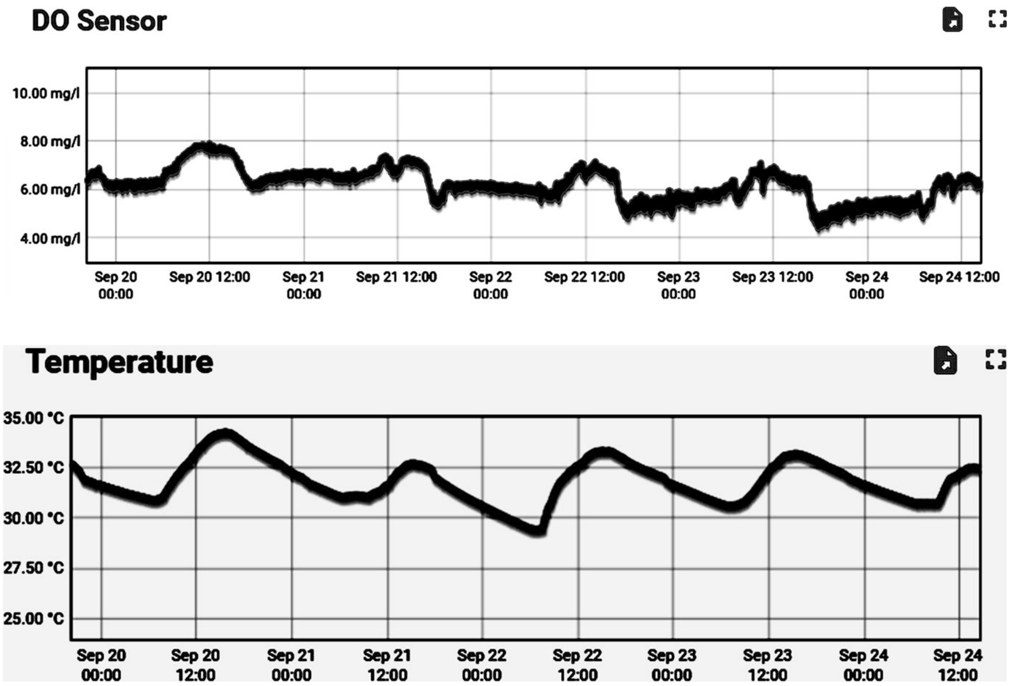



**Fig. 6** Real-time graph of DO level and water temperature

clearly depicted on the chart, with the DO levels reaching their lowest point at approximately 6 pm and subsequently rising to a stable value over the course of the night. This observation can be used to adjust the oxygen aerator and diffuser operating schedule. The aerator speed can also be controlled optimally by the DO level and the current time to achieve the stable DO level and save energy.

Similarly, the lowest water temperature in the shrimp pond is 30° at 8 o'clock in the morning, and the warmest is at 3 o'clock in the afternoon. This is entirely consistent with the sun's activity at the observation site.

The PH and ORP level are stable all time. Because this is a commercial shrimp pond, so the farmer keeps the optimal environment for the shrimp, pH level in the range from 7 to 7.5, when ORP slightly fluctuates from 180 to 220 mV (Fig. 6).

## 4 Conclusion and Future Work

This study represents a significant departure from previous research in the field of shrimp farming and aquaculture monitoring. The key differentiating factors and the impact of our platform for data collection are highlighted below:

Firstly, while previous research primarily focused on laboratory or controlled environments with small batches of shrimp, our study successfully collected acoustic data in a commercial shrimp pond. This real-world application allowed us to capture the complexities of feeding behavior under practical conditions, making our findings more applicable to the industry.

Secondly, unlike earlier studies that often relied on periodic manual data collection, our integrated monitoring system enabled continuous real-time data collection. This approach provided a wealth of information covering an entire shrimp crop cycle, offering a more comprehensive understanding of shrimp behavior and water quality dynamics.

Thirdly, our platform integrated the monitoring of various water quality parameters (DO, pH, temperature, ORP) with acoustic data. This simultaneous collection of multiple datasets allowed us to explore the intricate correlations between shrimp behavior and environmental conditions, a feature lacking in previous research.

Last but not least, the availability of continuous, high-quality data from our integrated monitoring system opens up numerous possibilities for further research. Researchers can leverage this rich dataset to delve deeper into precision feeding strategies, optimize aeration schedules, and gain a more nuanced understanding of the factors influencing shrimp health and growth.

In our future work, we aim to utilize the collected data for implementing and testing algorithms designed to effectively filter out background noise to get the shrimp sound. The goal is to leverage the recorded audio for the detection and classification of shrimp feeding activities. After validating with a small number of shrimp, the algorithm will be deployed to control an automatic feeder in a commercial pond, thereby validating the system's effectiveness.

**Acknowledgement** The authors would like to express our gratitude to NICT, Japan and to the members of our REAS-SEA project, Asean IVO, sponsored by NICT.

We also acknowledge Ho Chi Minh City University of Technology (HCMUT), VNU-HCM, and Nha Trang University for supporting this study.

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