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Online Analytics for Shrimp Farm Management to Control Water Quality Parameters and Growth Performance

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Abstract: An online analytic service system was designed as a web and a mobile application for shrimp farmers and shrimp farm managers to manage the growth performance of shrimp. The MySQL database management system was used to manage the shrimp data. The Apache Web Server was used for contacting the shrimp database, and the web content displays were implemented with PHP script, JavaScript, and HTML5. Additionally, the program was linked with Google Charts to display data in various graphs, such as bar graphs and scatter diagrams, and Google Maps API was used to display water quality factors that are related to shrimp growth as spatial data. To test the system, field survey data from a shrimp farm in southern Thailand were used. Growth performance of shrimp and water quality data were collected from 13 earthen ponds in southern peninsular Thailand, located in the Surat Thani, Krabi, Phuket, and Satun provinces. The results show that the system allowed administrators to manage shrimp and farm data from the field sites. Both mobile and web applications were accessed by the users to manage the water quality factors and shrimp data. The system also provided the data analysis tool required to select a parameter from a list box and shows the association between water quality factors and shrimp data with a scatter diagram. Furthermore, the system generated a report of shrimp growth for the different farms with a line graph overlay on Google Maps™ in the data entry suite via mobile application. Online analytics for the growth performance of shrimp as provided by this system could be useful as decision support tools for effective shrimp farming.

Keywords: shrimp; water quality; web application; mobile application; google map

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1. Introduction

Agriculture has played an important role in the Thai economy and affects local foods and related culture. The agricultural development approach taken by Thailand has evolved from import substitution to export industry orientation and has been supported by national policies and plans [1]. Aquaculture has long been a very important agricultural sector in Thailand. Amongst other intensive aquaculture, the black tiger shrimp *Penaeus monodon* is an indigenous marine shrimp species of Thailand. Since it was first developed in 1989 in the coastal areas of central Thailand, namely in Samut Sakorn, Samut Songkram, and Samut Prakarn [1], it has become the most valuable aquaculture produce in the country for more than two decades. Black tiger shrimp aquaculture has been developed continuously and has spread throughout the coastal areas of the country, making Thailand the world's leading farmed black tiger shrimp producer and exporter. The production of this marine shrimp species peaked at about 420,000 mt (metric tons)/year in 1998 and 1999 [2]. However, black tiger shrimp aquaculture was hard-hit with several problems between 2002 and 2004. The slow growth phenomenon may have been caused by inbreeding, infections, or environmental impacts, and the massive mortality of cultured shrimp may have been caused by virulent infectious diseases such as the white spot syndrome virus (WSSV), Vibriosis, and many others [3,4]. Considering the uncertainty in black tiger shrimp aquaculture performance during these periods, the Specific Pathogen Free (SPF) Pacific white shrimp (*P. vannamei*) was attractive as an exotic marine shrimp species introduced to Thailand in 2002. Many shrimp farmers in Thailand had tested culturing this species between 2003 and 2004, and since then, the majority of Thai shrimp farmers (>95%) have switched to rearing the Pacific white shrimp from 2005 onward. The main reasons include a lower risk of infections and reliability in making an economic profit from farming shrimp. Thereafter, until early 2011, the aquaculture production of Pacific white shrimp in Thailand increased to an average of about 620,000 mt/year with the production of black tiger shrimp only about 1–2% of total shrimp production [2]. The Pacific white shrimp aquaculture in Thailand suffered from incidents of a new emergent disease known as early mortality syndrome (EMS) or acute hepatopancreatic necrosis disease (AHPND). The disease was caused by a toxin-producing strain of *Vibrio parahaemolyticus* [5]. It was first reported in China in 2009 and then spread to other Asian countries including Vietnam in 2010, Malaysia, in 2011 and to eastern shrimp farms region in Thailand in late 2011 [5]. Since then, EMS/AHPND has affected the production of the Pacific white shrimp in Thailand, dramatically dropping the production to about 217,437 mt/year in 2014. Not only did the outbreak of EMS/AHPND reduce production but also the fear of it hindered recovery [6]. Many shrimp farmers in Thailand have now pulled out of the shrimp farming business, and others have gone back to culturing black tiger shrimp using SPF broodstock produced by private companies.

It has been known that farmed aquatic animals including shrimp are easily affected by diseases with high mortality rates. This is partly caused by reduced immunity when shrimps are exposed to suboptimal water quality. Consequently, the management of water quality is important when it comes to shrimp production [7]. Several water quality parameters, both physical and chemical, including temperature, pH, dissolved oxygen (DO), salinity, turbidity, hardness, alkalinity, ammonia nitrogen (NH_3-N), nitrite (NO_2-–N), nitrate (NO_3), phosphate, and silica, affect the growth performance and health of shrimps [8,9]. These kinds of water parameters in shrimp ponds, should be monitored daily, weekly, or upon request and should be manipulated to the optimal ranges, particularly in intensive aquaculture systems. Otherwise, there may be bad consequences to farmed shrimp production [10,11]. Certainly, most shrimp farmers in Thailand regularly monitor the pond water quality and growth of shrimp at their farm sites. However, these data might only be printed on paper or accessible on a desktop computer and may not be utilized in the timely management of the water quality in ponds. Therefore, besides the farm data measurements, adopting current technology to track changes in pond water quality in near real time for shrimp health, displaying the data to farmers themselves, may be useful and could be a key element in supporting successful farming of shrimp in Thailand.

Currently, information technology in the context of aquaculture is mostly used by research in implementing aquaculture technology and innovation platforms in Asia [12], in a web-based public decision support tool for integrated planning and management in aquaculture [13], in monitoring the quality of water in shrimp ponds and forecasting dissolved oxygen levels by using Fuzzy C means clustering-based radial basis function neural networks [14], in satellite-based monitoring and statistics for raft and cage aquaculture in China's offshore waters [15], in using information technology in aquaculture management [16], and in mobile-platform based colorimeter for monitoring chlorine concentration in water [17]. This study developed a service system for monitoring and assessing the performance of shrimp using information technology as an application in aquaculture research. Additionally, this study used the shrimp farm and water quality data sampled from the Surat Thani, Krabi, Phuket, and Satun provinces. The results help in decision-making and planning of aquaculture businesses. Using information technology in aquaculture make data collection efficient and can present the performance of shrimp rapidly. This information is important for shrimp farming and for analyzing shrimp growth and health and benefits farmers and the national economy by supporting export quality production.

2. Materials and Methods

2.1. System Architecture

The system was designed in the form of a web application and a mobile application for two groups of users: administrators and members. The shrimp database was developed in MySQL on an Apache Server, and this Web Server was programmable in PHP script, JavaScript, and HTML5. The program was also linked with Google Charts to display data in various graphs such as bar graphs and scatter diagrams. The Google Map API was also used to display water quality factors as spatial data (Figure 1).

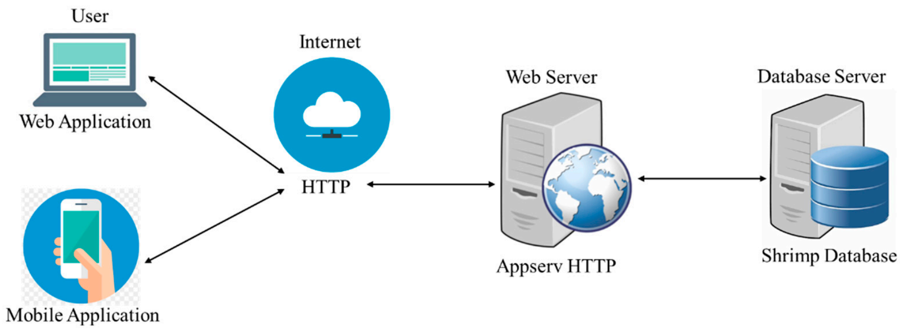


Figure 1. System architecture.

2.2. Data Collection

The field data used to test the above designed system were obtained from a project entitled "Evaluation of growth performance of the black tiger shrimp, *Penaeus monodon* in farmer rearing ponds using post-larvae generated from the selective breeding program of the National Science and Technology Development Agency (NSTDA)". The data included the growth of reared shrimp and water quality analyses in the same pond for 13 earthen culture ponds in total during the production of crops between 2016 and 2017. All of the culture ponds were located either in the eastern or the western coasts of southern peninsular Thailand. Seven ponds were located in Surat Thani, four ponds were located in Krabi, and one pond was located in each of the Phuket and Satun provinces (Figure 2). The geographic coordinates (namely latitude and longitude) of the pond locations were processed using Google Maps™ API. One month after stocking reared shrimp, culture water in each culture pond was characterized using established procedures reported elsewhere [18,19]. The source of samples, sampling points, main parameters determined, and data generated to evaluate the growth of shrimp and their effecting factors are shown in Table 1.

Table 1. Source of samples and data on shrimp and culture water in earthen ponds located in southern Thailand.

Sample Source	Sampling Point	Parameter Analyses	Data Generated
Shrimp	Day 1	Number of stocking larvae	Culture density (shrimp/hectare)
	1, 2, 3, and 4 mo. after stocking	Body weight and length	Growth parameters - Average body weight (g) and length (cm) - % weight gain - average daily growth (ADG, g/day)
		Total bacteria count and total Vibrio count in hepatopancreas (HP) of test shrimp	Health parameters - Total bacteria count (CFU/g) - Total Vibrio count (CFU/g)

Table 1. *Cont.*

Sample Source	Sampling Point	Parameter Analyses	Data Generated
Total feed used and harvest shrimp	All feed used in each culture pond	Feed conversion ratio (FCR) Harvest production	Productivity characteristics - FCR - Total production (ton) - Survival (%)
Culture water	1, 2, 3, and 4 mo. after stocking	Temperature, pH, dissolved oxygen (DO); alkalinity, salinity, NH_3-N, NO_2- −N, total bacteria count, total Vibrio count, water color, and Dominant plankton species	Physical parameter - Temperature (°C) Chemical parameters - DO (mg/L) - Alkalinity (mg/L) - Salinity (ppt) - NH_3-N (mg/L) - NO_2- −N (mg/L) Biological parameters - Total bacteria count (CFU/mL) - Total Vibrio count (CFU/mL) - Dominant plankton - Species

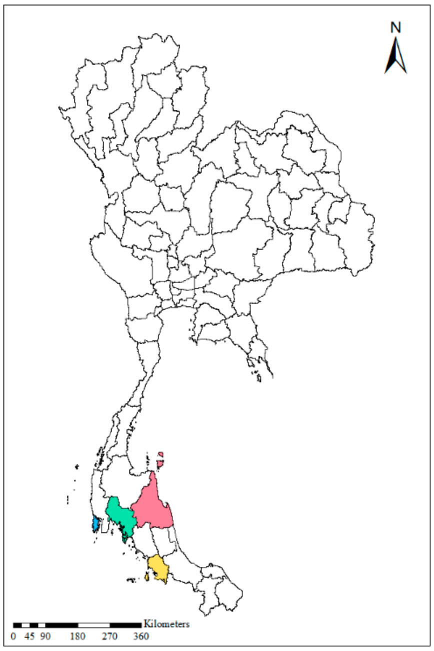


Figure 2. Study sites in peninsular Thailand were in the ( ) Surat Thani, ( ) Krabi, ( ) Phuket and ( ) Satun provinces.

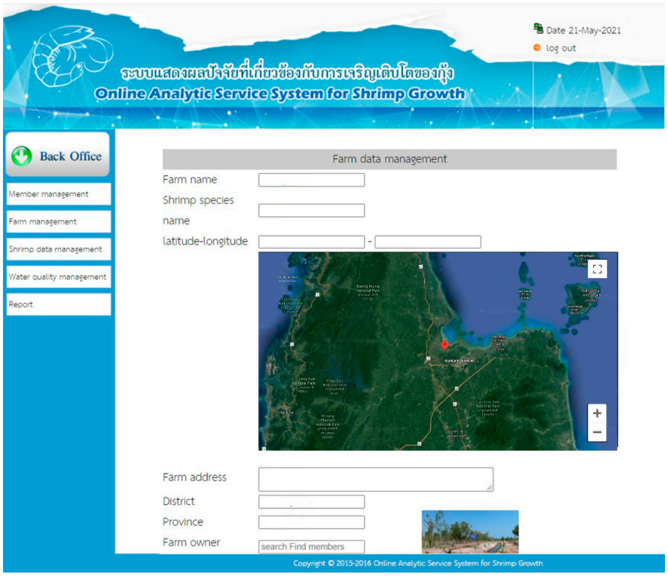
3. Results

3.1. Farm Data Summary

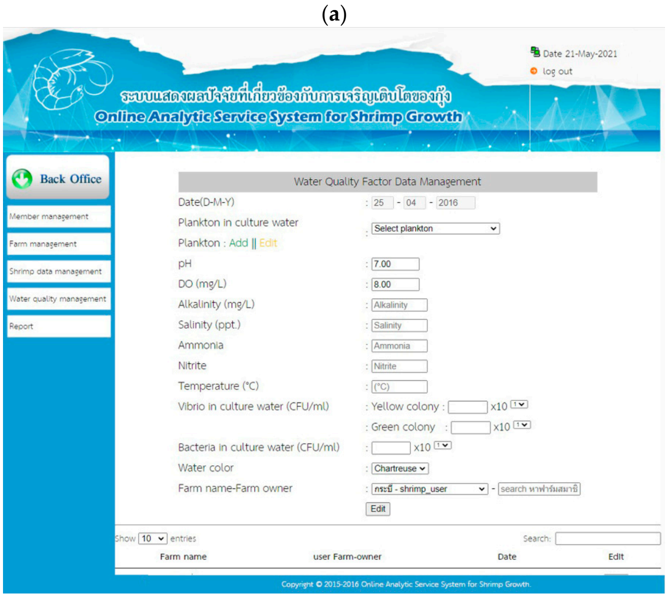
The actual farm data were collected from samples of shrimp and culture water in the pond of shrimp farms located in four provinces of southern Thailand: the Surat Thani, Krabi, Phuket, and Satun provinces. The farms' data analyses were conducted in another project, and the manuscript is currently being revised (Ruangsri et al., unpublished). In summary, it was found that shrimp reared in different ponds and at different farm sites had differences in their growth performances and final productivities. The ADG varies from 0.18 to 0.38 g/day; survival rate ranges from 42.5 to 88.4%; and total production ranged between 4.38 and 9.38 ton/hectare with a final harvest shrimp size of 22–33 g/individual. The lower growth rates of cultured shrimp were observed for ponds with suboptimal water quality relative to the optimal ranges known. In particular, the culture ponds occasionally had water pH in excess of 8.25; salinity in excess of 30 ppt; or accumulated levels of NH_3-N and NO_2- –N higher than 0.1 and 1 mg/L, respectively. Higher bacterial counts of either total bacteria or total Vibrio count were certainly observed more in the shrimp habitats that had suboptimal water conditions than in optimal cases (data not shown).

3.2. Data Management Suite

The system provided the data management suite. Users can access the system using a username and password, and they can manage their personal information by adding, editing, or deleting information. The system also provides geographic coordinates through Google Maps for adding latitude and longitude automatically. Users can also manage the shrimp farm data by adding new farm information and by editing or deleting their farm information (Figure 3a). Users can also access the system for data management that keeps the water quality data from their farm (Figure 3b). For security reasons, the system will alert users with a message if they missed typing in a username or password. Additionally, when a user fails to remember their username or password for login, the system will provide a recovery system via an e-mail address associated with that account.



(**a**)



(**b**)

Figure 3. Data management suite: (**a**) Farm data management and (**b**) water quality data management.

3.3. Data Analysis Tool

The system supports data analysis for its users. First, the user can view the data in bar chart format, and the system provides a comparison of shrimp growth between two study sites (Figure 4a).

(**a**)

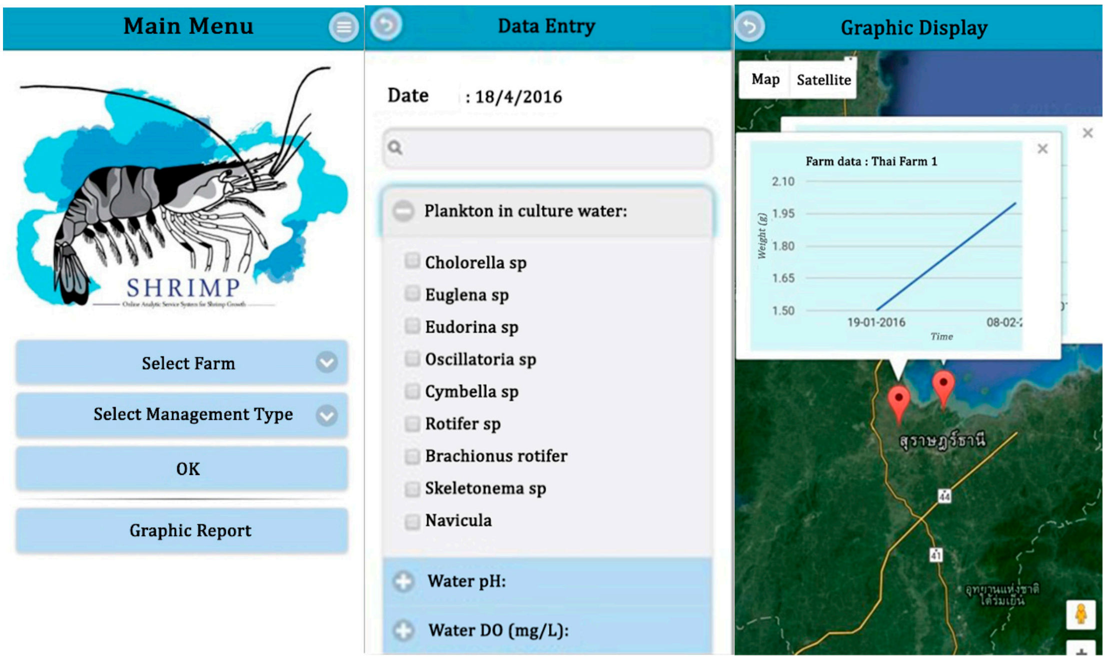
(**b**)

Figure 4. The data analysis tool: (**a**) comparing shrimp growth in bar chart format, and (**b**) the association between water quality factors and shrimp growth with scatter diagram and regression analysis.

Next, the users can find associations between the water quality factors (namely, water temperature, pH, DO, alkalinity, salinity, total NH_3-N, total NO_2- –N, total Vibrio count and total bacteria in the culture water, water color, and plankton genera) and shrimp growth and shrimp health condition (namely, body weight, body length, ADG, weight gain, total Vibrio count, and total bacterial count in shrimp hepatopancreases). Additionally, the system shows a scatter diagram and a regression model for selected factors (Figure 4b).

3.4. Data Entry Suite

The system was designed specifically for data entry, showing graphical information in the mobile application (Figure 5a). Users can access the system for to perform data entry in real-time from the field sites on shrimp farms (Figure 5b). When users click on the study site on the map provided by Google Earth™, they can also view the shrimp growth in a bar chart and can compare that growth to different shrimp farms overlaid on Google Earth™ (Figure 5c).



(**a**) (**b**) (**c**)

Figure 5. Mobile application for shrimp performance: (**a**) main menu for the system, (**b**) data entry, and (**c**) graphical display.

3.5. System Testing

The system was designed in the form of a web application and a mobile application for two groups of users: administrators and members. After the system was tested with the actual farms' data, we found similar trends in system generated data (Figure 4a,b) and the laboratory data analyses summarized in Section 3.1.

Therefore, the system has been available online at URL http://www.s-cm.online/shrimp since 2018 (accessed 10 May 2018). The system was tested for the user interface in the Thai version of the applications. Subsequently, the adaptation to an English version is ready for other shrimp farms in more regions of Thailand or other countries. The system was also tested with shrimp farmers for data entry, data management, and data analysis via mobile application and web application.

3.6. Evaluation of User Satisfaction

The results in Table 2 show the quantitative study derived from the evaluation of an online analytics for shrimp farm management to control water quality parameters and growth performance, rated for user satisfaction by 50 shrimp farmers. The mean and standard deviation results for each statement, on a five-point Likert scale, are also shown in Table 1. The shrimp farmers appeared satisfied with the quality of online tools in online analytics for shrimp farm management to control water quality parameters and growth performance, including the materials in the system, online tools, and application for the knowledge of shrimp performance with water quality and related fields (Table 2).

Table 2. Evaluation of the system users' satisfaction. Each statement was given a score of 1–5 on a five-point Likert scale.

Evaluation of System Users' Satisfaction	Mean ± SD
The quality of online tools (layout, text, image, and color)	4.635 ± 0.359
The consistency of online tools and engaging knowledge on shrimp performance and water quality	4.750 ± 0.320
The meaning of information is easy to understand	4.523 ± 0.548
The knowledge on specific vocabulary on shrimp performance and water quality	4.465 ± 0.372
The usefulness of online data management suite	4.630 ± 0.550
The usefulness of online data entry suite via mobile and web applications	4.825 ± 0.450
The usefulness of online data analysis tool with statistical model between water quality and shrimp growth performance	4.670 ± 0.320
The usefulness of the system for monitoring the shrimp farms	4.735 ± 0.430
The usefulness of the system for planning of shrimp growth performance	4.840 ± 0.535
The usefulness of the system for engaging knowledge on shrimp and related field	4.790 ± 0.305

4. Discussion

This study implemented information technology applications for aquaculture science research, specifically for real-time online data management in both a web and a mobile application. The system was tested by shrimp farms in southern Thailand, specifically in the Surat Thani, Krabi, Phuket, and Satun provinces. In the past decade, information and internet technologies have radically transformed our societies and day-to-day lives by changing the ways we interact with others. Computers and mobile devices are increasingly faster, more portable, and higher-powered than ever before. This evolution in technology has also made conducting research more efficient by improving access to tools and information. Information technology also plays an important role in improving product quality and production efficiency, reproducibility, and collaborations in aquaculture science and research [20–22].

The results in this study on accessing data and real-time analytics are responding to innovation policies that encourage dynamic scientific enterprises to contribute to identifiable social outcomes, such as in areas of health, energy, and the environment [23]. There are several techniques and technologies for monitoring the quality of water in aquaculture research [14,15,22] such as monitoring the quality of water in shrimp ponds using neural networks [14], designing water quality monitoring system for aquaculture ponds using Internet of Things (IoT) [22], and monitoring aquaculture in China's off-shore waters with satellite-based techniques [15]. The availability and ubiquity of information technology have emerged as powerful facilitators for achieving automatic farm management and monitoring [22,24,25].

Recent advances in information technology (IT) have had profound impacts on all walks of life. Aquaculture is no exception [16]. In Asia, information and innovation technology has been implemented in aquaculture science in Bangladesh, Vietnam, and Thailand with different kinds of outcomes in each of the three countries [12]. The results from this study on data analysis tools confirmed a previous study's [12] finding that technology and innovation platforms have the potential to address a range of both short-term production risks and even longer-term goals of sustainable intensification. In addition, mobile applications are increasingly used in the shrimp farm industry in Thailand. In this study, we developed a mobile application for data entry from the field sites and for monitoring water quality in the farms. Our results are in agreement with a previous study [17] that developed the mobile platform for monitoring the concentration of chlorine in the water.

Geographic Information System (GIS) technology has been used in this study for providing the geographical information on graphical shrimp growth performance in different shrimp farms overlaid on Google Earth™. This technology is also widely used in planning tools, providing integrated assessment and mapping of 30 indicators reflecting economic, environmental, inter-sectorial, and socio-cultural risks and opportunities for proposed aquaculture systems in marine environments [20].

The system was evaluated by the users from shrimp farms in Southern Thailand using a purposive sampling technique. The shrimp farmers reported satisfaction with the system's effectiveness for relevant information in displaying the shrimp performance and water quality information. Testing with actual data and farmers was necessary for improving the shrimp industry in Thailand. A prior study has tested a mobile platform-based colorimeter prototype with good satisfaction from farm workers [17].

The data analysis tools in this study can be used for water quality monitoring and management of shrimp farms. Our results did not cover other environmental factors. However, a prior study [26] was concerned about the social and environmental impacts of shrimp farming in Thailand. With shrimp farming practices in Thailand coming under increasing criticism for mangrove destruction, the shrimp culture industry has endorsed "sustainable" shrimp farming practices [27,28] and argues that Thailand's shrimp farming industry is now "mangrove friendly" [29]. Additionally, the Thai government subsequently banned inland shrimp farming in designated freshwater areas [26]. The current debate over the potential environmental impacts of inland shrimp farming revolves around three key questions: (i) the ability of so-called "closed" production systems to minimize environmental impacts, (ii) the capacity of the Thai government to enforce environmental protection regulations, and (iii) the potential emergence of cumulative environmental impacts [26]. Thailand's seafood industry supplies produce to the global market, and the shrimp industry needs a lot of human-power: it has absorbed some from neighboring countries. There have been instances of profiting from the villagers' poor work conditions and of violating the Trafficking Victims Protection Act [30]. However, a prior study [31] showed that inland brackish water fisheries are a source of income, employment, necessary nutrients, and engagement of rural and marginal workers and provide livelihoods for the farmers with valuable overall contributions to the social and economic development of the area [31]. Additionally, shrimp export products are being grown in farms in Thailand that meet or exceed the stringent standards of responsible farming, sustainability, and fair employee conditions as established by the Global Aquaculture Alliance. Moreover, seafood buyers typically visit the ponds and packaging facilities in Thailand to conduct firsthand inspections [30]. The growth trend in shrimp exports also affects shrimp farming in Thailand. In recent decades, brackish water shrimp farming has had a significant role in the socioeconomic development of coastal areas of Southeast Asia. The potential negative environmental impacts envisioned include salinization of soil, reduced water flow, unwanted salinization, depletion of ground and surface water supplies, reduction of wild fish and shrimp populations, and biological pollution of native shrimp stocks [31].

5. Conclusions

In this study, monitoring the quality of water in shrimp farms was facilitated by providing an online analytic service comparing the water quality in different farms and correlating for associations between water quality and shrimp growth performance. Additionally, scatter diagrams and regression models presented associations between shrimp growth and water quality parameters. The system also showed a performance comparison of shrimp growth between two selected farms. Another major focus of this study was to provide data entry and graphical report overlays on Google Maps™ in order to display water quality factors related to shrimp growth as spatial data in a mobile application that would support decision making on farm management, monitoring of water quality from outside the farm, and planning for shrimp growth performance.

As in any research, this study had limitations that should be mentioned to ensure that the study findings are fairly interpreted. Most shrimp farmers in Thailand often measure both water quality in shrimp ponds, and shrimp health and growth performance. However, the hardcopy with raw data in the farms might not clearly show any trend or pattern in the data. The application of information technology to shrimp farming could help the farmer more clearly perceive trends in data and more rapidly react with effective management. Sharing data between farms could be interesting for experts to advise on shrimp farm management. However, the system was employed and tested in only the southern peninsular region of Thailand. The data entry from the field sites has been available for access via the internet. Future work relates to the improvement of data entry on environmental factors and the extension of our mobile application to advanced analytics services. The system could be applied to other shrimp farms within the shrimp industry in Thailand for improved shrimp farming sustainability.

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Informed Consent Statement: Not applicable.

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Conflicts of Interest: The authors declare no conflict of interest.

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