

Water quality management in shrimp aquaculture ponds using remote water quality logging system

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Abstract

Currently an institutional co-operation project funded by NORAD is evaluating different environmental management strategies for sustainable aquaculture in India. A brief description of a remote water quality logging system installed in shrimp ponds to obtain real-time data on vital water parameters and to monitor the ponds is presented. The potential application and advantages of such automated data loggers vis-à-vis traditional (conventional) methods of measurements installed in shrimp ponds in the coastal Karnataka are discussed. The data logging system consists of two remote monitoring units and one base-station unit. Data generated on physico-chemical variables such as dissolved oxygen, temperature, salinity, pH, turbidity, redox-potential from remotely logged units were compared with manual analytical methods which revealed that results from two types of analyses were comparable. The advantages of using these automated systems are that a large number of samples could be processed in short time within minimum cost compared to the manual methods. The study also revealed that the data logging system could be effectively used to improve the understanding of the processes occurring at sediment-water interface in aquaculture pond. Further the data generated could be effectively used to optimize the amount of aeration in shrimp ponds, thus resulting in considerable energy savings. In addition, continuous loggers equipped with alarm systems could also act as early warning systems to the farm managers on the water quality conditions prevailing in different ponds and to take appropriate management decisions for water quality.

Keywords: Water quality management, shrimp aquaculture, remote water quality logging

1. Introduction

Pond-based coastal aquaculture, particularly of marine prawns, has gained considerable momentum in India, due to its high demand in both national and international markets and rapid financial returns. During the last decade, there has been a remarkable increase in annual shrimp production from 35,500 t (1990-91) to 1,45,906 t (2000-2001), with an increase in farm area from 65,100 ha in 1990-1991 to 1,40,906 ha in 2000-2001 (Rao and Ravichandran, 2001). However, the

economic and social benefits of shrimp aquaculture in India have gradually been outpaced by problems associated with environmental degradation which aspect can be relieved through application of eco-friendly technologies for waste disposal. In order to maintain desirable water quality and to bring down the organic nutrient load in culture systems, shrimp farmers carry out regular water exchange. The wastes/nutrients release from the shrimp ponds has now been recognised as one of the most serious environmental problems faced by the shrimp culture industry.

With the aquaculture industry moving in the direction of intensive culture, management practices will become crucial. Accurate and reliable measurement and understanding of the culture environment through automation is crucial for successful aquaculture operations for improved understanding of the environment (Rusch *et al.*, 1993), reduce catastrophic losses, reduce production costs and improved product quality. However, the use of automatic surveillance solutions in aquaculture is limited in Asia. Currently an R&D project funded by Indo-Norwegian Programme for Institutional Co-operation (INPIC) being implemented in the Kumta region (Karnataka state, India) focusing on eco-friendly and socio-economic management of shrimp farming in coastal areas. Presented in this paper is a brief description of a remote water quality logging system (Yeo-kal Electronics Pty Ltd., Australia) used in two identical trial ponds. This remote surveillance system is used to obtain real-time data on vital water quality parameters and to monitor the ponds with a discussion of the capabilities and reliabilities of this system and an indication of relative advantages and cost of this technology *vis a vis* traditional conventional methods of measurements.

2. Materials and methods

Shrimp farm located close to the Kumta town in the Karnataka state ~ 180 km south of Goa, India was chosen for the study. The farm covers a total area of 7 ha, from which two ponds with almost similar area and locality of 0.65 ha were selected for the experimental purpose. Pond 1 (P1) was designated as 'Aerated' while Pond 2 (P2) was designated as "Control" pond (Fig 1). Four Numbers of HOBAS aerators were installed at four corners in pond1 in such a ways that complete circulation of pond water is ensured (Fig. 2).

Collection and analysis of physico-chemical water and soil quality parameters was done simultaneously and results were compared with that of the real time data collected with the help of remote water quality system for checking the efficiency and to keep track of probe sensor system.

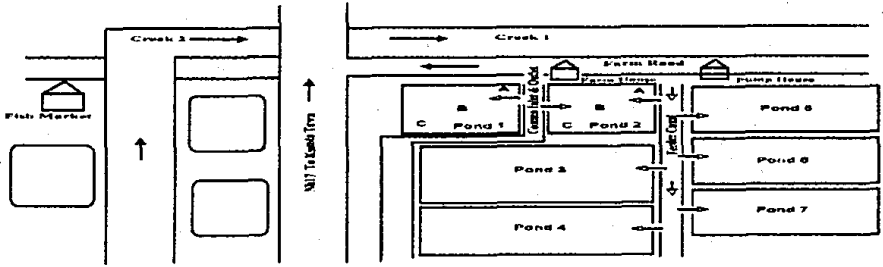


Fig. 1 Adjacent infrastructure - experimental demonstration farm at Kumta, Karnataka

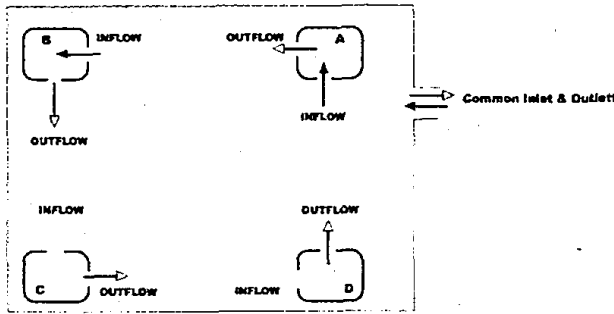


Fig. 2 Position of aerators and current flow in aerated pond (P1)

2.1 Description of the remote water quality system

The Model 613 is an instrument designed for continuous measuring of water quality parameters in a water main. The instrument consists of three parts as Remote monitoring units (Radio modems), Main Probe assembly with sensors and the reader-Logger Unit.

2.1.1 Remote monitoring units

The remote water quality logging system consisted of three remote monitoring units two at field and one at a base station to receive signal (Fig. 3). Two remote units consisting of radio modems were connected to Real-time Probe assembly unit with power supply (optional solar panel), rechargeable battery and bulkhead lightning protection unit. The base station also consisted of one radio modem, bulkhead lightning protection unit, rechargeable battery and Laptop.

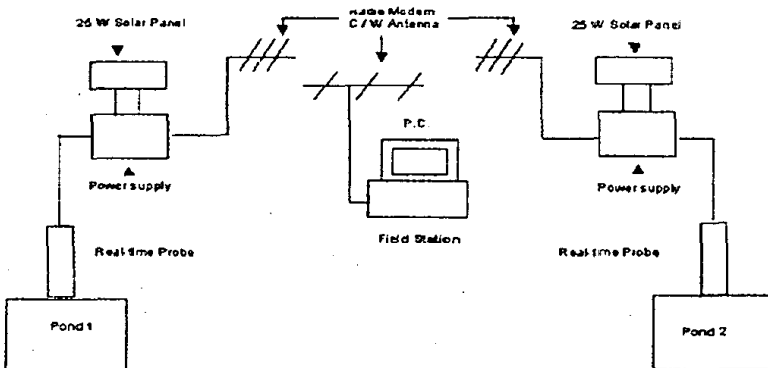


Fig. 3 Schematic diagram of the remote water quality logging system installed in shrimp pond at Kumta, Karnataka

2.1.2 Probe assembly

Two probe systems were positioned with the help of indigenously developed stand, holding probes at a distance of 46 cm above bottom in the two ponds. The probe consists of sensors, cable and a connector. The body of the probe is made of PVC with a sensor guard. The interface cable is permanently connected to the probe body. In the event of the cable being cut the probe has a waterproof seal between the cable connection and the electronics package. At the other end of the cable is a corrosion and water – resistant connector for attaching the assembly to reader unit. Sliding the sensor guard up and rotating the bottom section of the probe can easily access the sensors.

Model 611 Water Quality Analyzer consists of seven water quality parameter measurement sensors such as temperature, pH, ORP, salinity, dissolved oxygen, % dissolved oxygen, turbidity and conductivity which logs data and can be downloaded remotely. Description of sensors and sensor specifications are given in Table 1.

Table 1. Sensor specifications of the probes used in remote water quality logging system

Sensor	Range	Accuracy	Resolution	Sensor type
Temperature	0-50 °C	0.1 °C	0.1 °C	Platinum-Resistance Thermometer (PRT) stainless steel sleeve
Conductivity	0-80 ms cm ⁻¹ 0-8,000 us cm ⁻¹	0.1 ms cm ⁻¹ 3.0 us cm ⁻¹	0.01 ms cm ⁻¹ 2.0 us cm ⁻¹	Four electrode cell
Salinity	0-60 ppt	0.1 ppt	0.01 ppt	Calculation from temperature Dissolved
Oxygen	0-200 %sat. 0-20 mg l ⁻¹		1 %	1 % Active Pb/Ag sensor with Teflon membrane And built in stirrer
Turbidity	0-600 ntu	0.3 ntu	0.3 ntu	Nephelometric measurement from a 90sensor with pulsed infrared light source
pH	0-14	0.01	0.01	Combination Ag/AgCl type with sintered teflon junction
ORP	-900 to +	5 mV 900 mV	1 mV	Combination bear metal electrode common reference junction with pH electrode

a. Temperature sensor

The temperature sensor consists of a PRT (Platinum-Resistance Thermometer), housed in stainless steel sheath for robustness and corrosion resistance. The temperature sensors require little maintenance however the temperature measurement is used for calculating the dissolved oxygen in mg l^{-1} and for temperature correction of the conductivity sensor, so it is important that the temperature sensor is properly calibrated.

b. Dissolved oxygen sensor

Dissolved oxygen is measured using an active type membrane covered sensor. The sensor itself consists of lead and silver electrode and 25 μm teflon tm membrane, which is filled, with an electrolyte of 1M potassium hydroxide. A constant flow of water over the stirrer located at the bottom section of the probe maintains current over the sensor.

Any oxygen dissolved in the electrolyte rapidly gets consumed at the cathode so that the oxygen pressure in the electrolyte is zero. The rate at which oxygen diffuses through the membrane is proportional to the absolute pressure of the oxygen outside the membrane and the electrical current flowing through the sensor is proportional to this diffusion rate. Therefore, the current that is measured by the sensor is proportional to the dissolved oxygen concentration of the sample in which the probe is immersed.

The dissolved oxygen sensor periodically requires a new membrane and electrolyte. A unique knurled membrane-retaining nut is used to hold the sensor membrane in position without over stressing the membrane. This gives long-term stability and allows easy membrane replacement. The sensor can be removed from the probe for servicing.

c. Conductivity sensor

Conductivity is measured using a 4-electrode bridge. The four-electrode system uses automatic compensation to overcome any build up of Contamination on the electrodes. The electrodes are made from fine platinum and are coated with platinum black to enhance the long-term stability and sensitivity of the sensor.

d. Turbidity sensor

The turbidity sensor is located in the hole that runs through the bottom section of the probe and lined with glass tube. Turbidity is measured by the nephelometric method. This method uses a light source and a detector, which measures light, scattered at 90° to the incident light beam. A pulsed infrared light source is used.

e. pH and ORP sensor

The pH and oxidation-reduction potential (ORP) are measured using a single sensor. This consists of a glass pH electrode and a platinum electrode for ORP measurements with a combination of internal reference electrode. The sensor only requires maintenance if there is a build up of contamination on the electrodes or the reference reservoir becomes exhausted.

2.1.3 Reader/Logger

The reader/logger is CPU based. This unit is operated using its keyboard and LCD display. The unit is watertight and can be left unattended. This unit can record up to 600 sets of readings by pressing the STORE key or it can be set to automatically log over 2000 sets of reading of each sensor where one set includes a record of each sensor plus date/time. The fastest sample rate is one set of sample per minute, while the slowest is one set of sample per day. This model can be used in two modes "Remote" (connected by telephone, radio or a laptop) or "standalone" mode where it is set and read from the keypad and LCD. In the present study Turo Software (T-611P, www.turo.com.au) was used to download this data and switch between two different probe assemblies installed in two ponds.

3. Results

During experimental study, wide daily variations were observed in the water parameters monitored (Table 2). The time series data on important water quality parameters such as dissolved oxygen, percent dissolved oxygen, pH, ORP, salinity and turbidity in aerated and control ponds is depicted in Fig 4 and 5, respectively.

Table 2. Comparison of water quality characteristics measured by conventional (manual) analysis in aerated and control shrimp ponds at Kumta, Karnataka

Parameters	Aerated - P1 (HOBAS-Aeration)	Control- P2 Non-aerated
Temperature	26-31	26-33
pH	7.11-.08.32	7.16-.08.50
Eh (mV)	62.80-112.77	54.60-94.03
Salinity (ppt)	9.40-41.89	8.10-41.89
DO (mg l ⁻¹)	4.88-6.78	4.76- 8.01

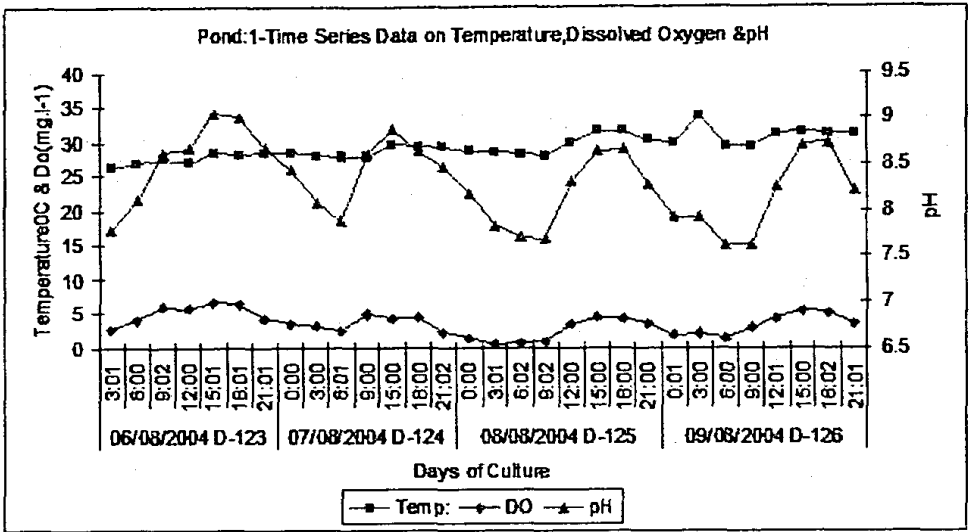


Fig. 4 Time series graphs showing Temperature, Dissolved oxygen, and pH behaviour in aerated pond at Kumta, Karnataka

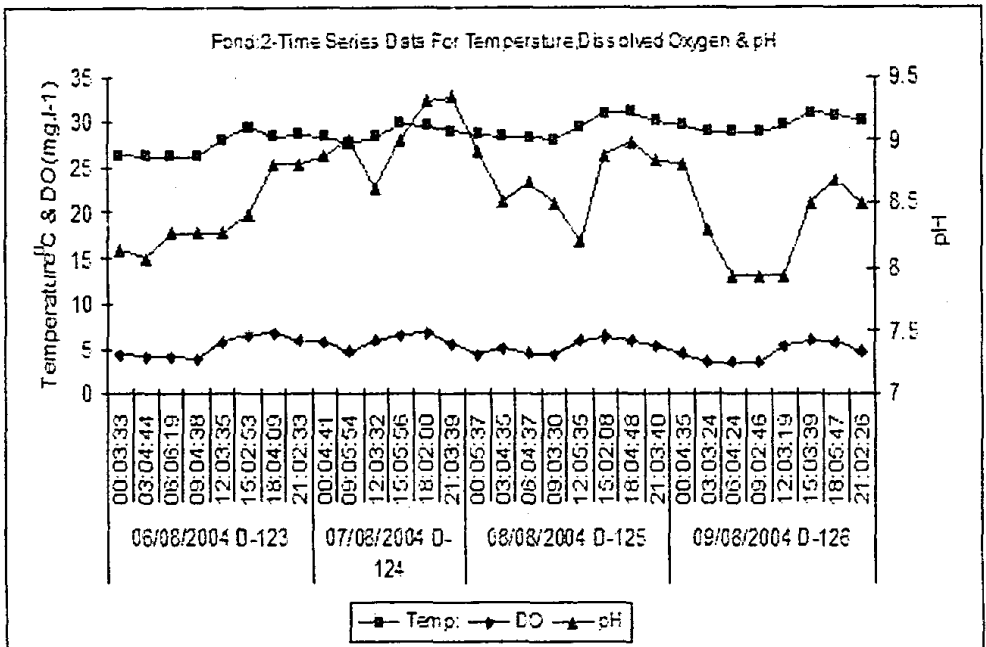


Fig. 5 Time series graphs showing temperature, dissolved oxygen and pH behaviour in control pond at Kumta, Karnataka

Temperature was found to be in the range of 26 °C to 30 °C during the culture period. Monitoring the dissolved oxygen concentration throughout 24 h, the well-known diurnal DO fluctuation pattern was revealed with peak in the afternoon and early morning drops in both ponds. In P1, the DO concentration was though less (3-5 mg l⁻¹) as

compared to P2 (4-6 mg l⁻¹), which most possibly can be attributed to higher density (12 PL m⁻²). Values for pH ranged from 6.5 to 9.0, but none of the ponds revealed sub-optimal concentrations of un-ionised ammonia (NH₃).

The results, first and foremost, indicate that using remote water quality instruments will enhance the management control and ease the ability to initiate mitigating measures to ensure proper pond environment throughout culture cycles.

It is also found that this automatic water analyser instrument could be effectively used to improve the understanding of processes taking place in aquaculture pond and further the data generated was also used to optimise the amount of aeration in shrimp ponds thus saving energy costs. Such models can be used as research tools to developed test hypothesis prior to field-testing; they can also be used in the day-to-day management of pond.

4. Discussion

The importance of water reuse to the shrimp industry has increased with the growing emphasis on environmental quality. Simultaneously over the last decade, the level of water exchange has been decreasing steadily. In some areas this is a consequence of more strict environmental legislation and regulations (USA and Latin America). However, the most common reason in Asia has been that farmers are forced to reduce water exchange in order to reduce the risk of pumping poor quality or infected creek water into the shrimp ponds. In such circumstances pond as an entire unit can behave dynamically and in this concern such automated measuring systems, the one used in present study can play a pivotal role in forecasting the changes occurring in the pond environment and take the appropriate measures to prevent the possible catastrophes. Table 3 lists the advantages of the automated system (Real Time data collection) *vis-à-vis* the manual analytical methods.

Table 3. Possible advantages of automated measuring systems over manual analysis

Automated analysis	Manual analysis
Reduction of human participation to avoid error: Cut costs	Manual analysis requires skilled labour and human participation.
Chemicals required only initially for standardization of probes	Chemicals required every time the analysis is carried out
Lowering consumption of sample and chemical reagents thus	Chemical cost is very high as reduce cost of chemicals required they are required frequently.
Processing of large number of sample in short time.	Processing of large number of sample takes long time.

<p>Determination of several components in the same sample for collection of samples for every parameter separately or in No such errors as standardisation is done Initially</p> <p>Continuous collection of data is possible by observing which, one can take the required measures in case of critical conditions be disadvantageous in case of</p>	<p>Requires different sampling equipments and methodologies large amount.</p> <p>May give wrong results due to standards and analytical errors. Data requires manual collection of samples which have limitations in a way that continuous data can not be obtained which can critical decision making</p>
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5. Conclusions

When systems are intensified in terms of higher stocking densities, the ponds will turn from being autotrophic to heterotrophic systems. Heterotrophic systems (e.g. external input of feed) produce more excretion products, and are more susceptible to larger fluctuations in water quality parameters. Hence, under intensive farming, the influences from different technologies applied are more evident (Drengstig *et al.*, 2004). This corresponds to the results obtained in the present study, although more data is needed. Thus this quality analyzer sensor provides accurate long-term measurement under a wide range of environmental conditions.

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