JOURNAL OF MECHANICS OF CONTINUA AND MATHEMATICAL SCIENCES
www.journalimcms.org

ISSN (Online) : 2454 -7190 Vol.-18, No.-9, September (2023) pp 10-19 ISSN (Print) 0973-8975

# OSCILLATION OF HYDROLOGICAL PARAMETERS IN SHRIMP PONDS WITHIN MANGROVE-DOMINATED INDIAN SUNDARBANS

**Suvadeep Samanta[1], Prosenjit Pramanick[2], Sufia Zaman[3], Abhijit Mitra[4]**

[1, 2, 3] Department of Oceanography, Techno India University, Kolkata 700091, West Bengal, India

[4]Department of Marine Science, University of Calcutta, Kolkata-700 019 West Bengal, India

Corresponding Author : **Suvadeep Samanta**

Email: [1]samantasuvadeep@gmail.com; [2]ppramanick660@gmail.com; [3]zamansufia123@gmail.com; [4]abhijit_mitra@hotmail.com

https://doi.org/10.26782/jmcms.2023.09.00002

(Received: July 02, 2023; Accepted: September 06, 2023)

**Abstract**

*The survival rate of Penaeus monodon was monitored for a decade (2010-2019) in two shrimp culture ponds at Chemaguri located at Sagar Island in the Indian Sundarbans delta complex. The two ponds exhibited significant variations in terms of the survival rate of the cultured species, which is attributed to variations in nitrate, phosphate, and dissolved oxygen. The root cause of such difference is related to variation in stocking density of the cultured species (10 $PL_{20}/m^2$ in pond 1 and 25 $PL_{20}/m^2$ in pond 2) which resulted in the generation of nutrients (except silicate) and alteration of Dissolved Oxygen (DO). Optimization of stocking density and introduction of a biotreatment pond may restore and ecologically balance the situation in the shrimp culture sector of the Sundarban region.*

**Keywords:** *Penaeus monodon*, Indian Sundarbans, survival rate, dissolved oxygen, dissolved nutrients, shrimp culture.

## I. Introduction

The population of the planet Earth is increasing at an exponential rate and is expected to reach a figure of around 9.6 billion in 2050. This scenario has a high probability of providing great challenges in the domain of food and environmental security. In the case of the Indian sub-continent, the problem may be more acute as the country has exceeded China in recent times. The maritime state of West Bengal with a population of around 100,896,618 [III] needs sustainability in terms of protein-rich food and a healthy environment for maintaining a stable life and livelihood. In this context, the culture of shrimp is a potential option. In the early nineties, shrimp culture in West Bengal reached its peak, but with the passage of time, there was an exponential crash. During the last decade, the attack of the virus on shrimps led to white spot disease that crashed the industry in the country (Fig. 1).

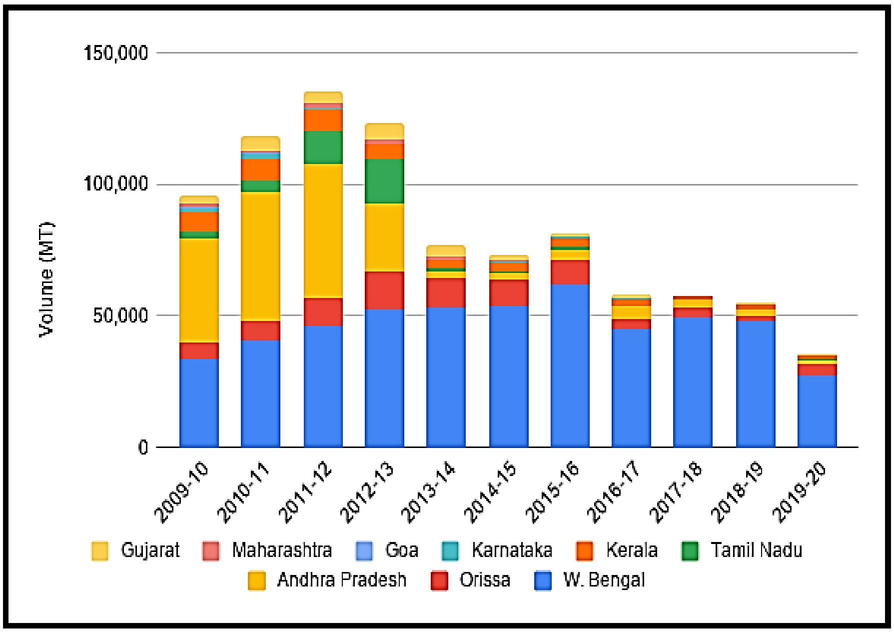


**Fig. 1.** The production volume of black tiger shrimp per state in India from 2009 to 2020

Source: [II]

This drastic fall in the sector of black tiger shrimp farming is attributed to the mindset of the shrimp culturist. Most of the shrimp farmers wanted to have a short-term profit instead of looking into a long-term benefit. Hence, the culture was done with high stocking density [IV], [V], [VI], [VIII], [IX], [X], [XI], [XII]. This resulted in the fall of DO in the culture pond and the enrichment of nutrients (preferably nitrate, phosphate, and silicate) leading to deterioration of water quality in ponds. According to Yang et al. [XV] "Intensive shrimp farming is generally accompanied by nutrient enrichment and gradual eutrophication which imparts major threats to shrimp culture ecosystems". Shrimp farming with high stocking density has been adopted in many Asian countries only because of high economic returns [I].

## II. Materials and methods

### Study area

Our experiment was performed at Chemaguri (21°39'49.32"N and 88°09'11.88" E), which is situated on the southeastern side of Sagar Island, the largest island in Indian Sundarbans. Two ponds were monitored for a decade (2010-2019) to observe the survival of the cultured species *Penaeus monodon* along with the other environmental variables (dissolved nutrients like nitrate, phosphate, silicate, and dissolved oxygen) during the culture period of four months (March-June) in every year. The stocking density in Pond 1 was 10 $PL_{20}/m^2$. whereas in Pond 2, the stocking density was 25 $PL_{20}/m^2$.

**Nutrients Analysis**

Samples of water from the two ponds were collected during the entire culture tenure of 4- months for 10 successful years (2010-2019) in clean tarson bottles. The collected water sample was separately passed through 0.45 µ Millipore membrane to screen out all the microbiota and detrital particles. The resultant water was analyzed for the selected nutrients using standard procedure [XIII] through a UV-Spectro photometer. Analysis was carried out with three water samples collected from the same pond at 200-250m apart as a part of quality assurance and the mean of three analyses was considered for statistical computation. Water samples were also collected to assess the Dissolved Oxygen (DO) levels in the two ponds by Winkler's methods [XIV].

**Survival rate**

Survival of the cultured species was enumerated using the expression:

$$Survival = \frac{Number\ of\ fish\ harvested}{Number\ of\ fish\ stocked} \times 100$$

**Statistical Analysis**

Analysis of Variance (ANOVA) was applied to understand the variation of the selected parameters. This phase was carried out using an IBM PC with the help of the MICROSTAT package.

## III. Results and discussion

It is observed that the selected dissolved nutrients in both ponds follow the order silicate > nitrate > phosphate. The average nitrate levels in ponds 1 and 2 are 21.71 ± 3.92 µgatl$^{-1}$ and 37.77 ± 5.86 µgatl$^{-1}$ respectively. The average phosphate level is3.63±1.51 µgatl$^{-1}$ in pond 1, and 5.30 ± 0.84 µgatl$^{-1}$ in pond 2. In the case of silicate, the average levels are 82.48 ± 10.17 µgatl$^{-1}$ and 82.77 ± 14.78 µgatl$^{-1}$ in Pond 1 and Pond 2 respectively. It is to be noted that nitrate and phosphate levels are higher in Pond 2 compared to Pond 1 and exhibit an increasing trend (Figs. 2 and 3). However, silicate does not show any definite trend (Fig. 4).

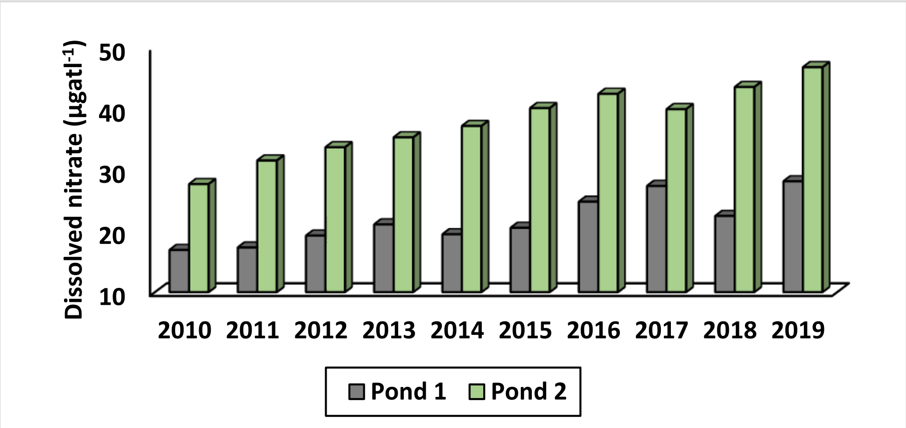


**Fig. 2.** Levels of dissolved nitrate (in µgatl$^{-1}$) in the two ponds during the study period

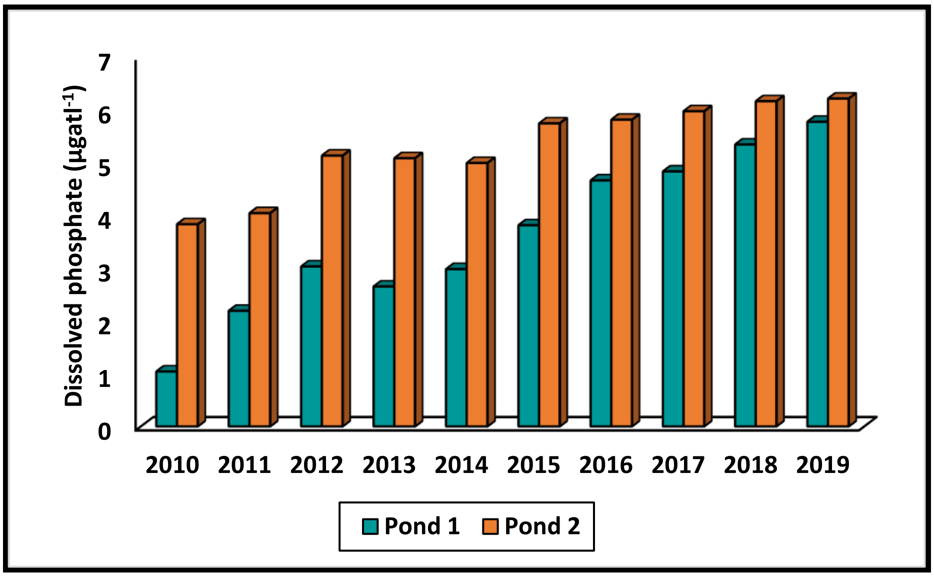


**Fig. 3.** Levels of dissolved phosphate (in µgatl$^{-1}$) in the two ponds during the study period

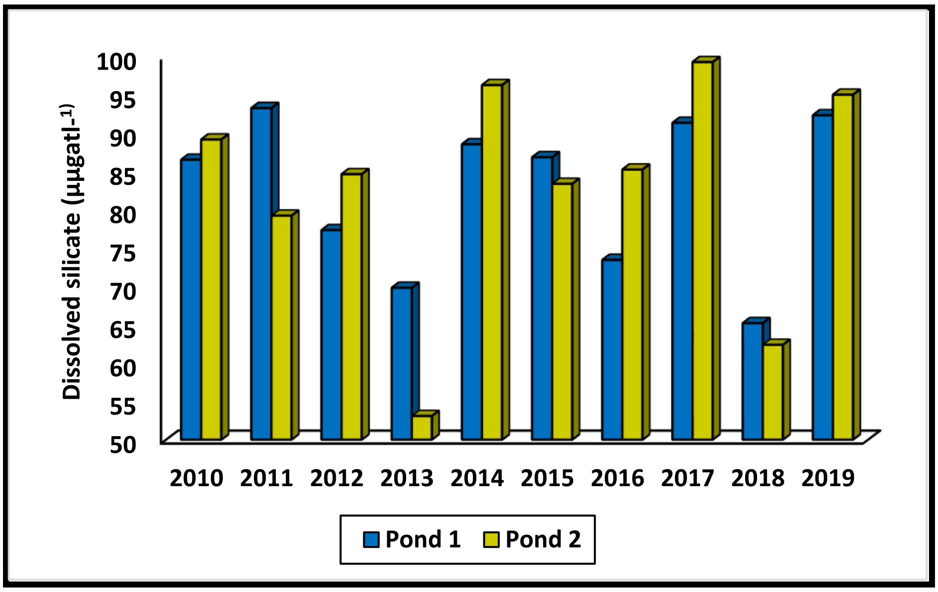


**Fig. 4.** Levels of dissolved silicate (in µgatl$^{-1}$) in the two ponds during the study period

The DO level in Pond 1 is relatively higher (mean value 4.59 ± 0.28 ppm) compared to Pond 2 (mean value 4.43±0.30 ppm) (Fig. 5).

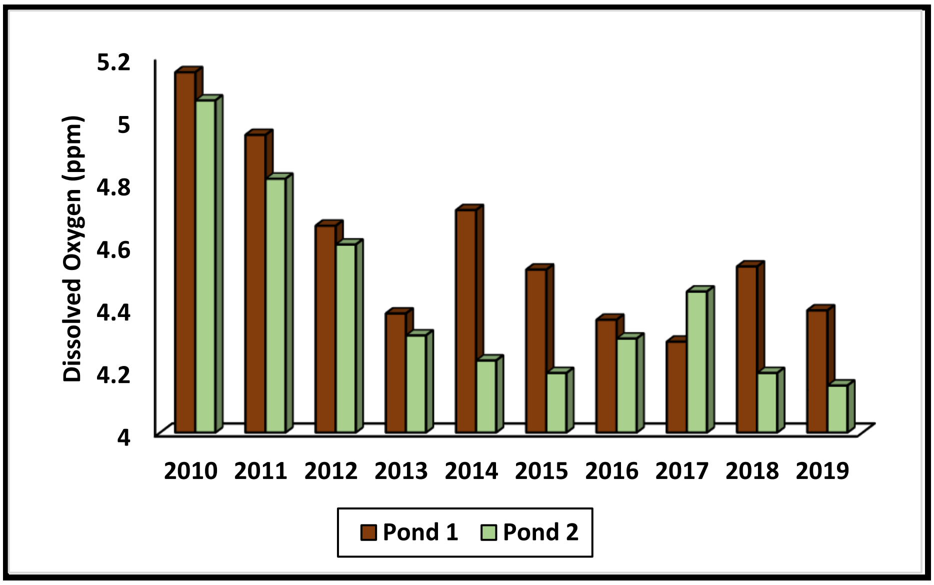


**Fig. 5.** Levels of dissolved oxygen (in ppm) in the two ponds during the study period

The survival rate of the culture species (*P. monodon*) is higher in pond 1 (mean value 73.90 ± 5.84 %) compared to pond 2 (mean value 72.10 ± 5.13 %) (Fig. 6).

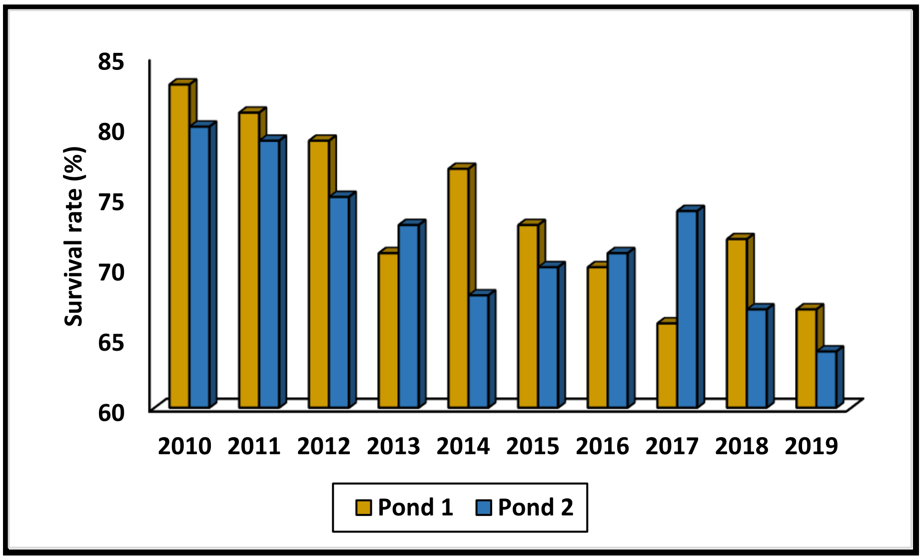


**Fig. 6. Survival rate (in %) in the two ponds during the study period**

It is clear from the data sets that Pond 1 is much better in terms of hydrological parameters compared to Pond 2. This is the basic cause of the high survival rate of the species in Pond 1 compared to Pond 2.

Trend analysis of the hydrological parameters shows significant $R^2$ values for nitrate and phosphate for both the ponds, which imply a steady increase of these nutrients that are generated from unutilized food matter and excreta of the cultured species (Mitra, 1998; Mitra, 2013; Mitra et al., 2022) (Figs. 7 and 8) [VI, VII, XI]. However, silicate has practically no definite trend in both the ponds and indicates no relationship with the culture process (Fig. 9). In the case of DO, the decreasing trend is as per the normal natural law, which states that as the species grows in biomass, the consumption of DO increases due to which the DO level falls (Fig. 10).

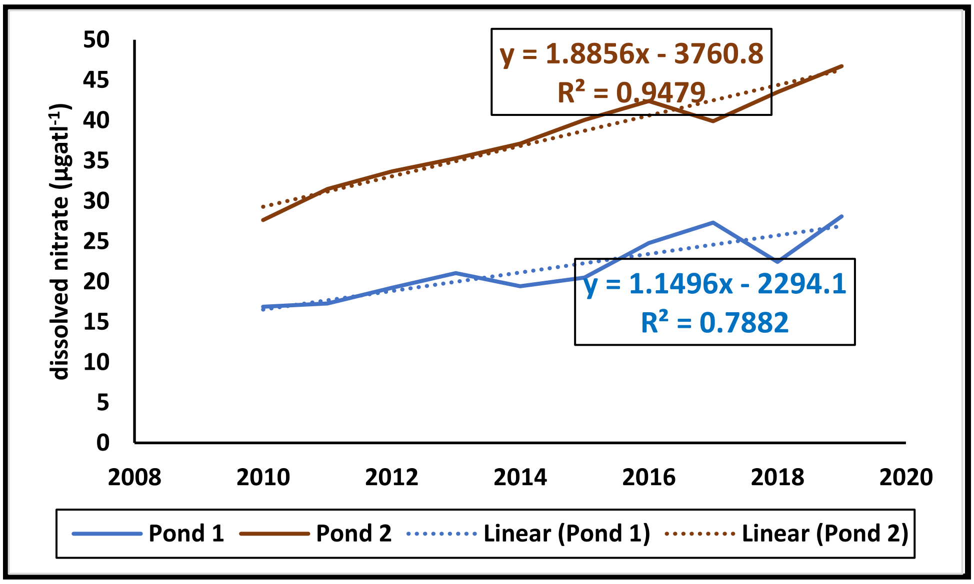


**Fig. 7.** Trend analysis for dissolved nitrate in two ponds

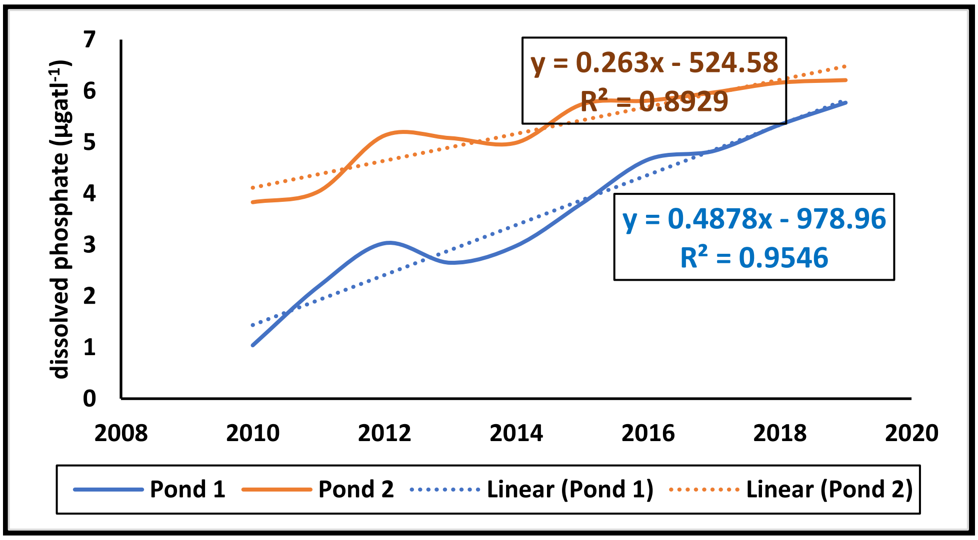


**Fig. 8.** Trend analysis for dissolved phosphate in two ponds

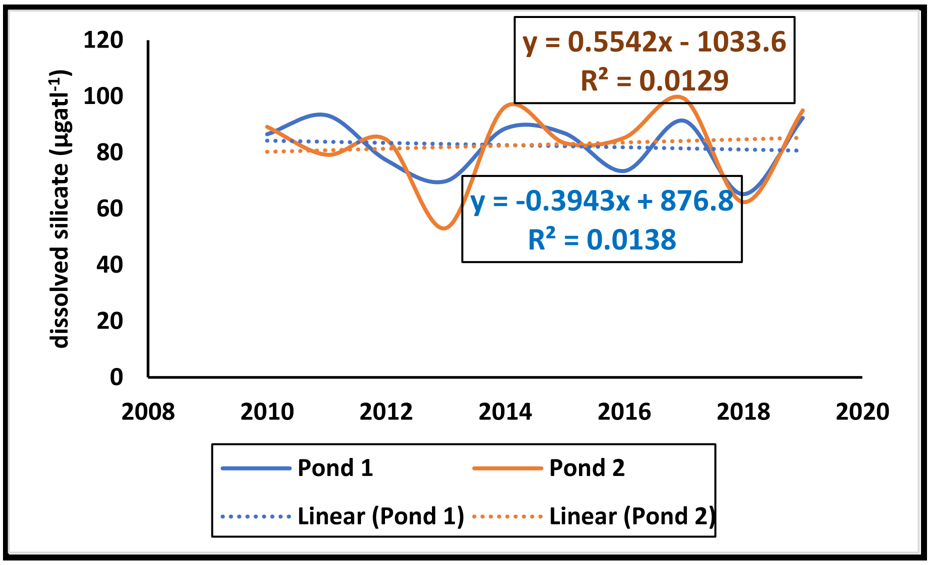


**Fig. 9.** Trend analysis for dissolved silicate in two ponds

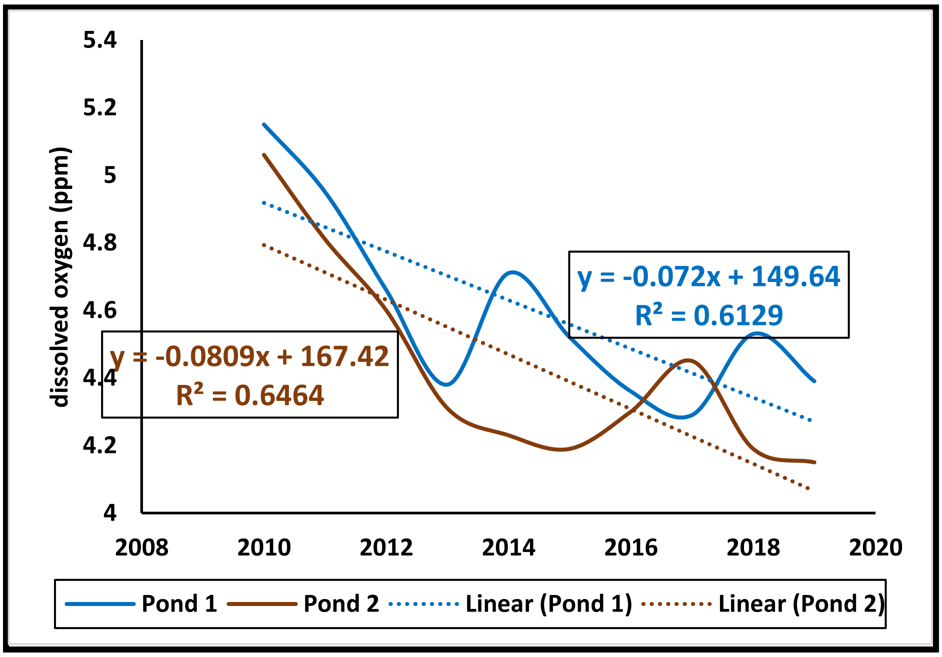


**Fig. 10.** Trend analysis for dissolved oxygen in two ponds

The oscillation/pattern of hydrological parameters in shrimp ponds is a function of the stocking density of the cultured species considering water quality management, and feed quality as mostly constants.

We evaluated the variations of hydrological parameters between the two ponds from the statistical point of view using ANOVA (Table 1). The results show significant variations between the ponds and the years ($p<0.01$) except for the silicate level between the two ponds. Such variations in hydrological parameters determine the survival of the cultured species. To eco-restore the situation, well-defined scientific water quality management is very important along with the setting of bio-treatment pond for bioremediation.

**Table 1: ANOVA computed based on ground zero data on hydrological parameters and Survival Rate**

| Variables | $F_{cal}$ | $F_{crit}$ |
|---|---|---|
| **Dissolved nitrate** | | |
| Between years | 8.07 | 3.18 |
| Between ponds | 235.26 | 5.12 |
| **Dissolved phosphate** | | |
| Between years | 9.74 | 3.18 |
| Between ponds | 49.77 | 5.12 |
| **Dissolved silicate** | | |
| Between years | 6.02 | 3.18 |
| Between ponds | 0.01 | 5.12 |
| **Dissolved Oxygen** | | |
| Between years | 9.03 | 3.18 |
| Between ponds | 8.02 | 5.12 |
| **Survival rate** | | |
| Between years | 4.74 | 3.18 |
| Between ponds | 7.54 | 5.12 |

## IV. Conclusion

Shrimp culture is a viable livelihood option for the people of Indian Sundarbans. However, without having any far-sightedness, the system was initiated to make short-term gains in the early nineties. This made the culture system non-sustainable and the water quality deteriorated as observed in the present case study. The culture system can be eco-restored through scientific water quality management and optimization of the stocking density of $PL_{20}$.

**Conflict of Interest:**

There is no conflict of interest regarding this paper

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