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Mohankumar KC
Department of Fisheries Engineering and Technology, College of Fisheries, Mangaluru, Karnataka Veterinary Animal and Fisheries Sciences University, Bidar, Karnataka, India

Varadaraju S
Department of Fisheries Engineering and Technology, College of Fisheries, Mangaluru, Karnataka Veterinary Animal and Fisheries Sciences University, Bidar, Karnataka, India

Gajendra
Department of Fish Processing Technology, College of Fisheries, Mangaluru, Karnataka Veterinary Animal and Fisheries Sciences University, Bidar, Karnataka, India

Sarojini A
Paraprofessional Institute of Fisheries Technology, TNJFU, Madhavaram, Chennai, Tamil Nadu, India

Corresponding Author:
Mohankumar KC
Department of Fisheries Engineering and Technology, College of Fisheries, Mangaluru, Karnataka Veterinary Animal and Fisheries Sciences University, Bidar, Karnataka, India

Influence of Physico-chemical properties of pond sediment and water on the growth of *Litopenaeus vannamei*

Mohankumar KC, Varadaraju S, Gajendra and Sarojini A

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Abstract
Shrimp farming plays an important role in the economic development of many countries because of its high economic returns. In shrimp pond, bottom soil plays an important role not only in influencing productivity but also acts as a store house of nutrients, helps in organic mineralization process, absorption and release of nutrients to water. It provides shelter and food to bottom biota, influence water quality and hence the survival and growth of shrimp. The pond sediment and water quality determine the growth rate of shrimp and in turn, their profit. To study the physico-chemical changes in soil and water quality during culture and its influence on the growth of *Litopenaeus vannamei*, soil and water samples were collected fortnightly from the shrimp culture ponds. The pond sediment quality parameters studied were pH, organic carbon, electrical conductivity, total phosphorus, total potassium, and total nitrogen. The water quality parameters studied were temperature, pH, turbidity, salinity, dissolved oxygen, total dissolved solids, ammonia-nitrogen, nitrite-nitrogen, nitrate-nitrogen, phosphate-phosphorus, and alkalinity. The overall observation of all the ponds about the influence of water quality parameters on the growth of the shrimp, it was noticed that temperature, pH, ammonia-nitrogen, alkalinity, and total dissolved solids were found to be significant. The soil quality parameters analysis with the growth of the shrimp, it was noticed that the electrical conductivity and total nitrogen of the soil were found to be significant. The average production of 3 tons per hectare per crop was obtained at Hejamadi ponds, and 7 tons per hectare per crop was obtained at Kundapura ponds. The survival rate observed ranged from 79 to 86%. The individual shrimp weight achieved varied from 25.32 g to 31.26 g for a culture period of 105 days.

Keywords: Shrimp culture, Sediment properties, Water properties, Litopenaeus vannamei

1. Introduction

The success of shrimp culture mainly depends on pond bottom soil and water quality. Soil quality plays an important role in fish pond productivity as it controls pond bottom stability, pH and salinity, and it also regulates the quality of the overlying water (Ekubo and Abowei, 2011) [11]. The nature of the pond bottom soil is of great importance in brackishwater aquaculture. Accurate information about the physico-chemical parameters of pond sediment and water, the dynamic interaction between sediment and overlying water, and the ecological interaction of cultured animals living in that environment are essential components to be studied to check the suitability for the development and management of shrimp aquaculture. It is very essential to study the soil and water quality of the source since they influence the productivity of shrimp. Deteriorating water quality is a major factor that affects shrimp production (Ferreira *et al*., 2011; Ma *et al*., 2013) [19, 27]. The water quality parameter is a very important indicator for evaluating the feasibility of shrimp farming (Ma *et al*., 2013) [27]. The condition of the pond bottom and the exchange of substances between soil and water can influence the water quality of the fish ponds (Boyd, 2008) [9]. Stable water quality parameters improve productivity and reduce the frequency of disease outbreaks (Ariadi *et al*., 2020) [3]. In the present study, the physico-chemical properties of sediment and water were studied in selected ponds in Kundapura and Hejamadi regions along Dakshina Kannada and Udupi districts.

2. Materials and Methods

The present research was aimed to study the influence of pond soil and water quality parameters on growth and survival of *Litopenaeus vannamei*. Totally four ponds were selected at Kundapura (Two ponds) and Hejamadi (Two ponds) along Udupi and Dakshina Kannnada Districts. The shrimp culture was carried out by keeping the stocking density of post-larvae at 30–40 PL/m^2 during the culture period from November to March.

2.1 Sediment sampling

To study the physico- chemical changes in soil and water quality during culture and its influence on the growth of shrimps, soil and water samples were collected fortnightly from the shrimp culture ponds. The sediment was collected using PVC pipes at 3-4 points in different locations of the ponds, the samples were shade dried, mixed thoroughly and analysed for various parameters using standard methods. The pond sediment quality parameters studied were pH, organic carbon, electrical conductivity, total phosphorus, total potassium, and total nitrogen. Sediment pH was measured by using a digital pH meter (WTW pH 320), organic carbon was analyzed by the El-Wakeel and Riley method (1957) [18] and total nitrogen was estimated by the Kjeldahl method. Total phosphorus was analyzed by the hydrochloric acid extraction method (Piper, 1967) [40], total potassium of the soil was measured by the flame photometric method (Marwin and Peach, 1951) [29], and electrical conductivity was measured using the digital conductivity meter (Centuary CC 601). To study the influence of the soil and water quality parameters on the growth of *Litopenaeus vannamei*, *ten* post larvae were collected using check trays and placed on pre-weighed polythene sheet and weighed using electronic micro balance during the initial days of culture. From 55th days of culture onwards cast net was used to collect sample fortnightly till the end of the culture.

2.2 Water sampling

Water samples were collected fortnightly from the pond during the culture period. Water samples were collected at a depth of 10–15 cm below the water surface. The parameters studied were temperature, pH, turbidity, salinity, dissolved oxygen, total dissolved solids, ammonia-nitrogen, nitrite-nitrogen, nitrate-nitrogen, phosphate-phosphorus, and alkalinity. Air and water temperatures were measured by a standard Mercury Glass thermometer and pH by a digital pH meter (WTW pH 320). Dissolved oxygen was analyzed by Winkler's method and salinity was measured by a hand refractometer (Atago cat no 2442). Alkalinity was analyzed by the titrimetric method (APHA, 1998) [1] and turbidity was measured using the digital Nephelo turbidity meter (Systronics µc 135). A total dissolved solids was measured by the filtration method (Strickland and Parsons, 1972) [46] and ammonia-nitrogen by the phenol-hypochlorite method (Strickland and Parsons, 1972) [46]. Nitrite-nitrogen, nitrate-nitrogen, and phosphate-phosphorus of water samples were analyzed by the standard method (Strickland and Parsons, 1972) [46].

3. Statistical analysis

The sediment and water quality parameters were correlated with the growth of the shrimp. Correlation was done with the Ridge regression method by using the NCSS (Number Cruncher Statistical System) software trail version.

4. Results and Discussion

4.1 Properties of pond sediment

4.1.1 Sediment pH

The sediment pH is one of the most important factors for maintaining the productivity of the water body since it controls most of the chemical reactions. The variations in sediment pH during the culture period at different ponds are shown in Fig. 1. It was observed that sediment pH values slightly varied in all the ponds throughout the study period. The highest soil pH of 6.7 at Hejamadi Ponds and the lowest of 5.6 at Hejamadi Pond 2 were recorded on the 45th day of culture. The normal range of soil pH required for brackish water shrimp culture is 6.5 to 9. The low pH of the pond bottom sediment indicates an unhygienic condition that needs regular check up and monitoring of the soil (Gupta *et al*., 2001) [22]. The water pH of 8.504 was observed before stocking of Whiteleg Shrimp *Litopenaeus vannamei* and at the end of the culture period, the pond pH of 8.086 was observed (Mustafa *et al*, 2022) [35]. Praphrutham (1985) [41] reported that decomposition in sediment would liberate hydrogen ions and decrease the pH during the harvest period. The pH usually declines in water-logged soils as the redox potential declines as a result of microbial activity in the absence of molecular oxygen (Boyd, 1995) [11].

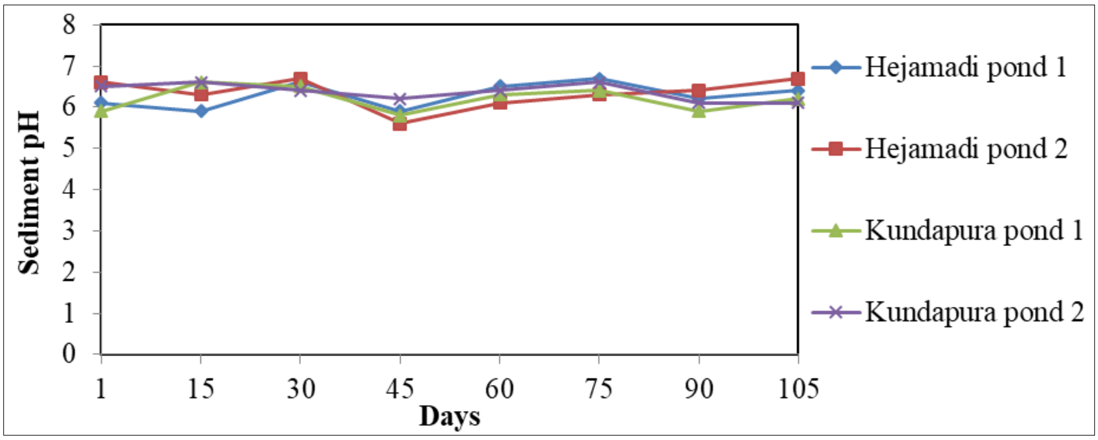

Fig 1: Variation of shrimp pond sediment pH

4.2 Total organic carbon

Organic carbon concentration in the pond bottom soil is an important factor in aquaculture. It influences various physico-chemical properties of the bottom soil and releases different nutrient elements in more available forms in the pond environment. It controls an important property of the pond ecosystem, *viz*., the oxidation-reduction reaction. The values of the total organic carbon content of sediment from different ponds during the culture period are depicted in the Fig. 2. The values of organic carbon ranged from 0.16 to 0.61% during the study period, with the minimum value observed on the 15th day at Kundapura Pond 2 and the maximum on the 15th day at Hejamadi Pond 1. There was not much variation in organic carbon content in the ponds during the study period, except in Hejamadi Pond 1. Application of manure and fertilizer in the pre-stock management of ponds may be the reason for the high organic carbon content at the beginning of the culture. Organic carbon content of more than 2.5% is not suitable for shrimp production since it may lead to an excessive bloom of microbes and oxygen depletion in the water. The major sources of organic carbon in aquaculture ponds are settled uneaten feed, faeces, and dead plankton (Boyd *et al*., 1994) [10]. Studies on organic carbon concentration in shrimp ponds (Munsiri *et al*., 1996) [34] and freshwater ponds (Munsiri *et al*., 1995) [33] revealed that carbon concentrations do not accumulate at higher rates. It influences various physico-chemical properties of the bottom soil and releases different nutrient elements in more available forms in the pond environment. It controls an important property of the pond ecosystem, *viz*., the oxidation-reduction reaction.

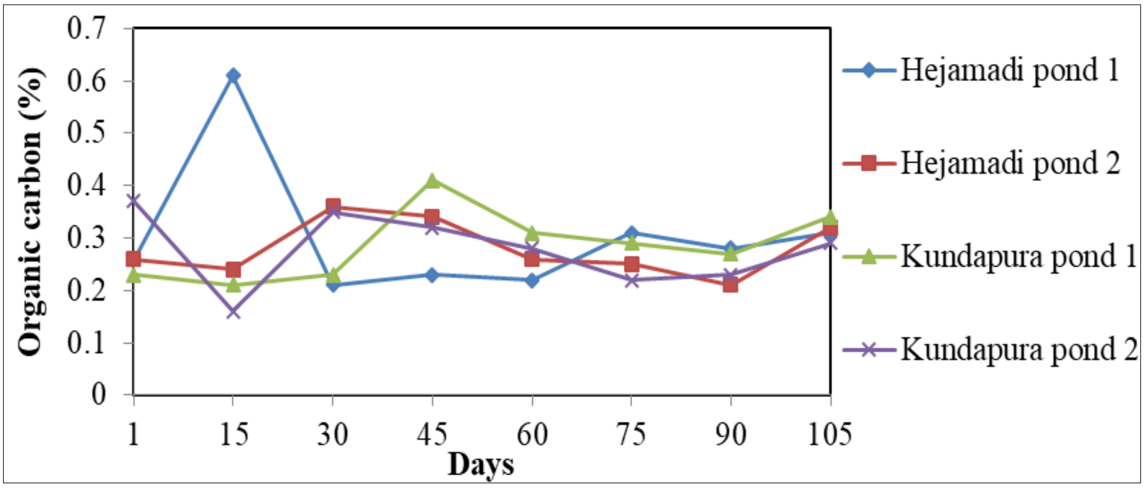

Fig 2: Variation of shrimp pond sediment Total organic carbon

4.3 Electrical conductivity

Electrical conductivity (EC) is closely related to the sum of cat ions or anions, as determined chemically, and usually correlates with the amount of total soluble solids. A change in the EC is associated with the release or depletion of soluble ions in the soil-water system. The sediment electrical conductivity of different ponds during the culture period is given in Fig. 3. There was not much variation in the electrical conductivity values of the pond sediment during the study period, and the values ranged from 0.43 to 7.74 mS/cm. Among the studied culture ponds except Hejamadi Pond 1, not much variation in electrical conductivity was observed. Varadaraju *et al.* (2011) [48] observed the highest electrical conductivity of 54.03 mS/cm at Hoigegudda Pond 1 and the lowest value of 24.47 mS/cm at Moodahodu Pond 2.

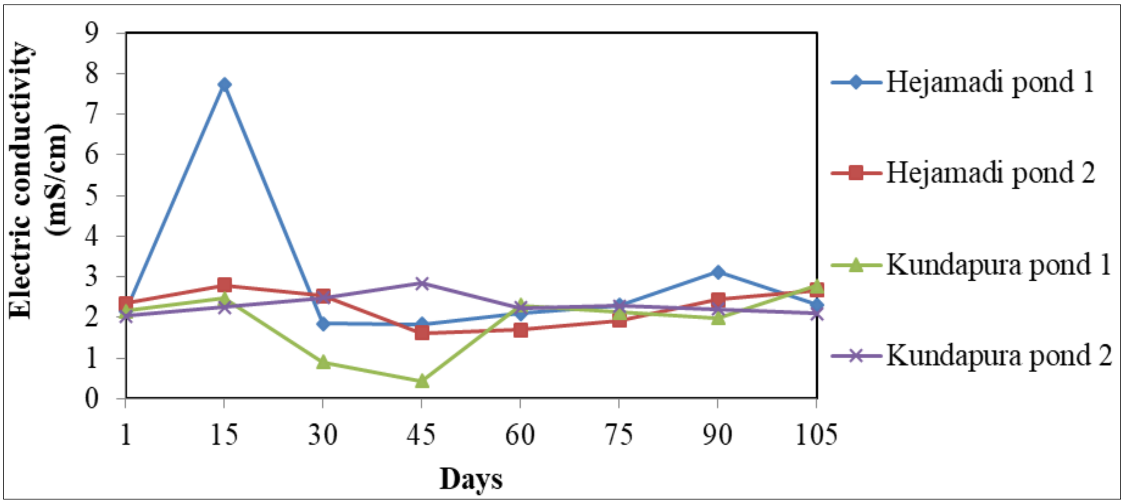

Fig 3: Variation of shrimp pond sediment Electrical conductivity

4.4 Total Phosphorus

The deficiency of total phosphorus element leads to retardation of phytoplankton growth, leading to decreased productivity in the system. The concentrations of total phosphorus in pond sediment are presented in Fig. 4. The highest total phosphorus concentration of 43.49 mg/100g of soil at Hejamadi Pond 1 on the 1st day and the lowest of 1.17 mg/100g of soil at Hejamadi Pond 2 on the 30th day of culture were recorded. The total phosphorus was higher at the beginning of the culture, which may be due to the application of organic manure and fertilizers before the commencement of the culture. A considerable amount of variation was also observed during the study period.

Sonnenholzner and Boyd (2000) [45] reported that the average concentration of phosphorus was 461 ppm in brackish water shrimp ponds. Waheb *et al*. (2001) [49] found that the total phosphorus was in the range of 33.20 to 40.70 mg/100 g of soil in the shrimp farms in Khulna, Bangladesh.

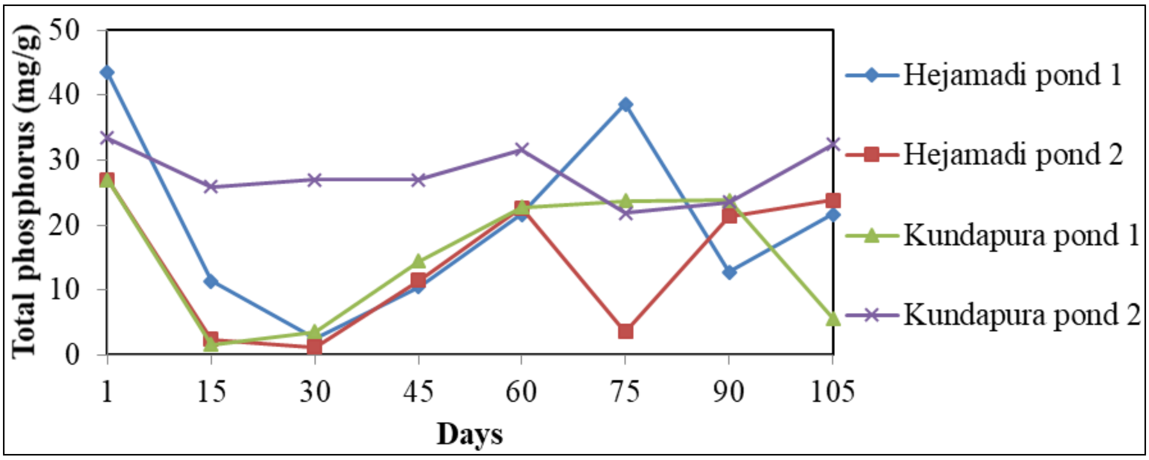

Fig 4: Variation of shrimp pond sediment Total phosphorus

4.5 Total potassium

Fish ponds exhibit a good occurrence of potassium, and the availability of this nutrient element does not usually create much trouble. However, in ponds with bottom soils with poor potassium content or where high doses of other nutrient elements have been added, the availability of potassium appears to be an important factor (Dobbins and Boyd, 1976; Chattopadhyay, 1998) [14, 15, 16]. Variations in the total potassium concentrations of the pond sediments are depicted in Fig. 5. The total potassium value of the pond sediment ranged from 56.42 mg/kg on the 30th day to 182 mg/kg on the 30th day. The highest value was observed in Hejamadi pond 1 and the lowest at Kundapura pond 1. It was observed that the total potassium value changed considerably in the beginning and gradually increased in the pond sediment during the culture period. An increase in the total potassium content in the ponds may be due to the addition of fertilizers, and a decrease may be due to the utilization of total potassium by fish food organisms like plankton. Sonnenholzner and Boyd (2000) [45] found that the total potassium concentration was in the range of 214 to 2594 mg/kg in shrimp farms in Ecuador. Boyd *et al.* (2002) [12] reported that sodium, potassium, and sodium nitrate can be applied to wet soil to encourage organic matter decomposition by denitrifying bacteria and to oxidize ferrous iron, manganese, and hydrogen sulphide.

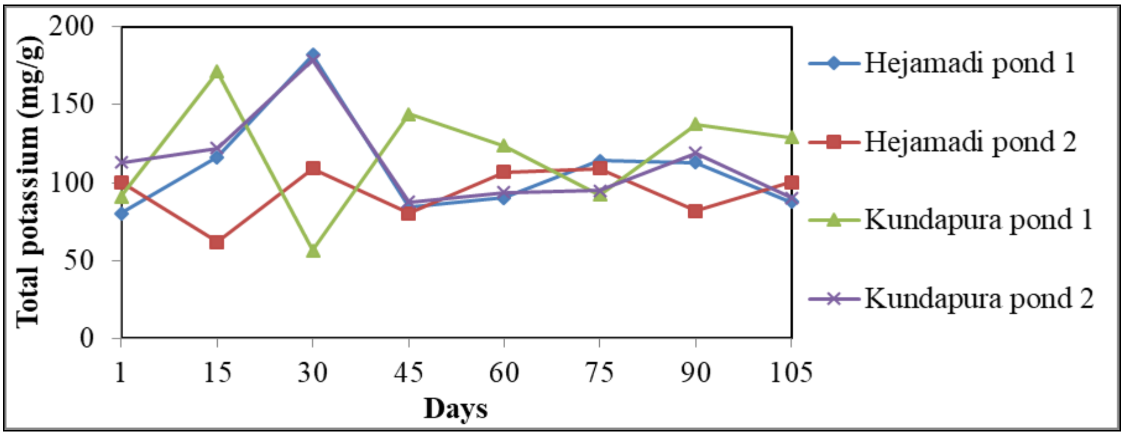

Fig 5: Variation of shrimp pond sediment Total potassium

4.6 Total nitrogen

The sediment total nitrogen content at different ponds during the study period is presented in Fig. 6. The highest value of 200mg/100g was observed at Kundapura Pond 2 on the 90th day and the lowest value of 140mg/100g at Hejamadi Pond 2 on the 15th day of the study period. It was observed that total nitrogen content gradually increased in the cultured pond sediment during the study period, and a high concentration of nitrogen was observed in Hejamadi pond 1 and Kundapura ponds 1 and 2. According to Smith (1996) [44], the average nitrogen concentration in shrimp pond soils in Ecuador was 0.16%, and ninety percent of the pond sediment samples contained less than 0.25% nitrogen. Martin *et al*. (1998) [28] reported that up to 38% of the total nitrogen input accumulates in the sediments of shrimp ponds. High nitrogen concentrations in shrimp pond soils are mainly due to uneaten feed, shrimp faeces, and dead plankton (Boyd, 1995) [11].

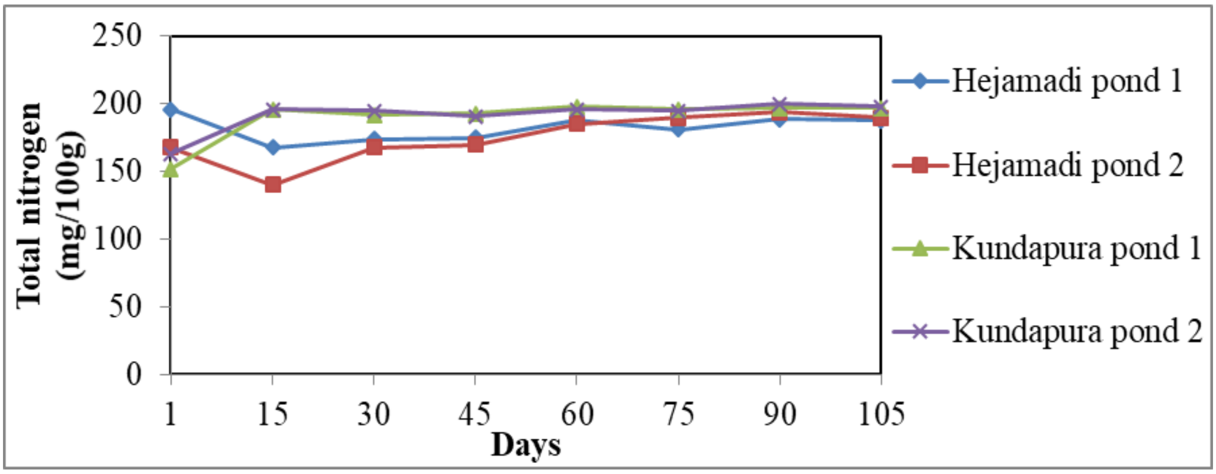

Fig 6: Variation of shrimp pond sediment Total nitrogen

4.7 Properties of pond water

4.7.1 Water temperature

Water temperature generally depends on climate, sunlight, and the depth of water in the pond. The change in water temperature during the culture period is presented in Fig. 7. The water temperature varied from 26.10 °C to 32.60 °C; the maximum and minimum water temperatures were recorded on the 105th and 30th days at Kundapura Pond 1. It was observed that there was not much variation in the water temperature of the culture ponds during the study period, and it was within acceptable range required for shrimp culture. Gopalkrishnan (1994) [20] observed that water temperatures up to 32 °C are favourable for the survival and growth of *P. indicus* in the semi-intensive and intensive brackish water shrimp ponds of Tuticorian. The water temperature of 28.59 was observed before stocking of *Litopenaeus vannamei* and at the end of the culture period, the water temperature of 28.14 was observed at Bonto Bahari Subdistrict (BB) location (Mustafa *et al*., 2022) [35]. The temperature varied from 24.2 to 30 ºC in the brackish water shrimp farms of Raigad district, Maharashtra (Bansode *et al*., 2020) [5].

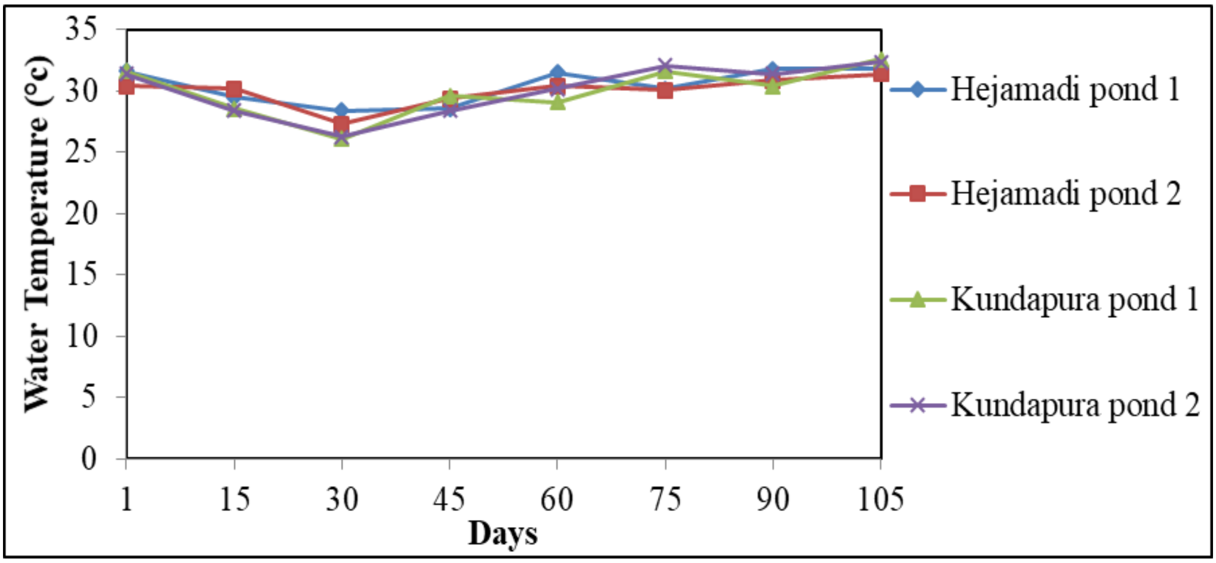

Fig 7: Variation of shrimp pond water Temperature

4.8 Water pH

The pH of the water is one of the vital environmental parameters that determines the survival and growth of shrimp; it also affects the metabolism and other physiological processes of shrimp. The variation of water pH at different ponds during the study period is depicted in Fig. 8. The highest water pH of 8.15 was recorded at Hejamadi Pond 1 and the lowest of 5.54 at Kundapura Pond 1 on the 45th and 1st day, respectively. The water pH was within the desirable level required for shrimp culture, and no sharp peak was observed during the culture period. Slightly less pH was observed at the beginning of the culture in Kundapura Pond 1, and in the other ponds, it was within the permissible limit required for shrimp culture. Gunalan *et al.* (2011) [21] reported that pH values ranged between 7.90 to 8.80 in the morning and 8.20 to 9.10 in the evening at coastal shrimp farms in Tamil Nadu. The pH of pond water is influenced by many factors, including the pH of the source water, the acidity of the bottom soil, shrimp culture inputs, and biological activity. Singh (2001) [43] recorded the pH values, which fluctuated between 6.66 and 7.85 in brackish water ponds in Mangalore. The water pH of brackish water farms in Raigad district, Maharashtra, is within the range of 7.2 to 8.2 (Bansode *et al*., 2020) [5]. Howerton (2001) [24] reported that in brackish water ponds, pH values usually ranged between 8.00 and 9.00 and did not change much during the day. He also mentioned that pH levels generally vary between 6.00 and 9.00 in the pond water, and the same range is considered as safe for aquatic animals.

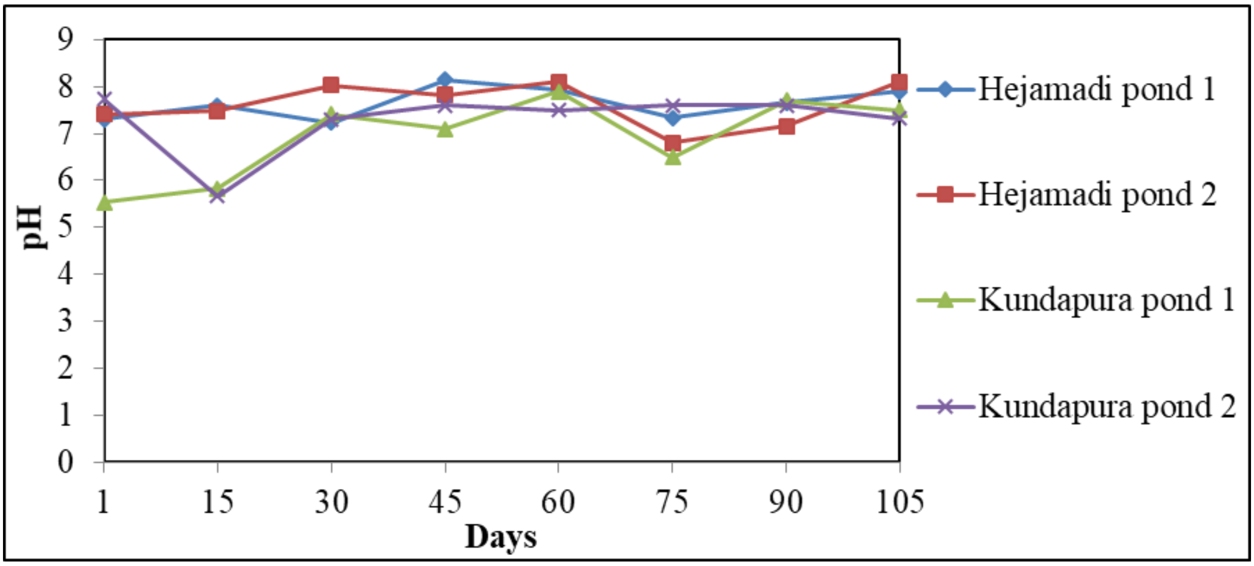

Fig 8: Variation of shrimp pond water pH

4.9 Turbidity

Generally, the water becomes turbid due to the presence of organic matter as well as silt, clay, and other materials. Turbidity may also be caused by the planktonic population in the water. The turbidity of different pond water is presented in the Fig. 9. The highest turbidity of 18.5 NTU at Kundapura Pond 1 and the lower of 1.0 NTU at Hejamadi Pond 2 were recorded on the 30th and 15th day, respectively. Considerable variation in water turbidity was noticed in Kundapura Pond 1, and very slight variation was observed in the rest of the ponds. Hajek and Boyd (1994) [10] reported that turbidity ranges from 0 to 25 NTU are considered as slight, 25 to 100 NTU as moderate, and greater than 200 NTU as severe for aquaculture. In the present study, turbidity lied in the slight range, and it was within the permissible limit required for shrimp culture. The abundance of fish food organisms like plankton also creates turbidity in pond water and may be considered desirable up to a certain limit (Chottopadyaya, 1998) [14, 15]. Recorded the highest turbidity of 75.10 NTU at Chitrapu Pond 1 and a lower value of 3.00 NTU at Moodahodu Pond 1.

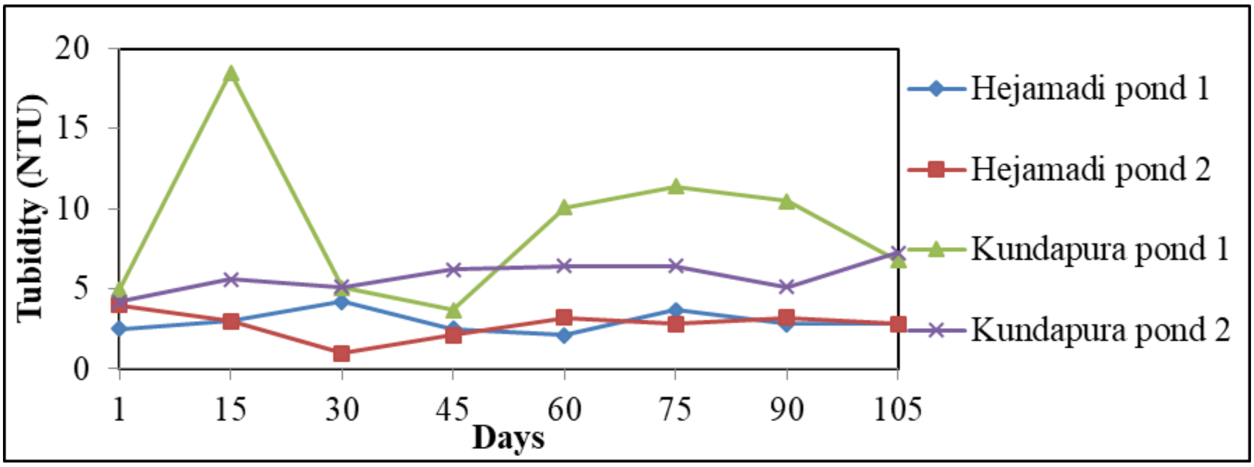

Fig 9: Variation of shrimp pond water Turbidity

4.10 Salinity

It is well known that salinity variation in brackish water has a significant influence on the maintenance and distribution of living organisms. The salinity of brackish water is influenced by rainfall, evaporation, runoff, and the degree of dilution of sea water by freshwater. Fortnightly variation in water salinity recorded at different culture ponds during the study period are presented in the Fig. 10. Salinity values observed in the culture ponds ranged from 19 ppt to 33 ppt during the culture period, and a minimum value was observed in Kundapura Pond 2 on the 1st day and a maximum value was observed in Kundapura Ponds on the 15th and 105th days. There is a slight variation in the salinity in Kundapura Pond 1 and Hejamadi Ponds. It was observed that salinity gradually increased at Kundapura Pond 2 in the months of February and March due to a higher evaporation rate, shallowness, a lack of fresh water flow, and seawater influence, as well as the presence of salt-impregnated marshy areas in the region. The salinity of 33.87 ppt was observed before stocking of *Litopenaeus vannamei* and at the end of the culture period, the nitrite content of 38.493 ppt was observed at Bonto Bahari Subdistrict (BB) location (Mustafa *et al*., 2022) [35]. The normal range of salinity required for brackish water shrimp culture is 10–35 ppt and optimum level required for brackish water shrimp culture is 15-25 ppt.

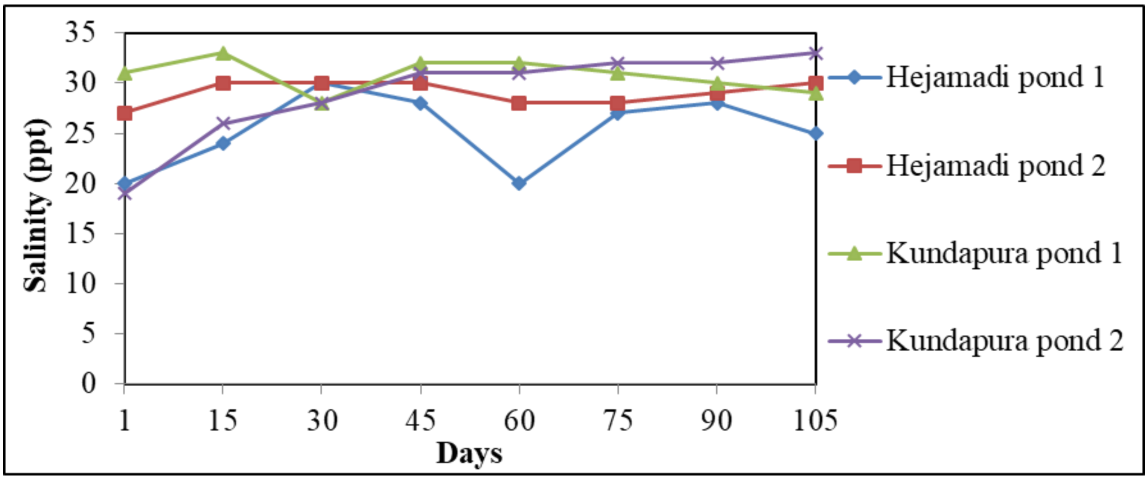

Fig 10: Variation of shrimp pond water Salinity

4.11 Dissolved oxygen

Dissolved oxygen concentration is the most important and critical water quality parameter because of its direct effect on the feed consumption and metabolism of shrimp as well as its indirect influence on the water quality. Dissolved oxygen was found to be a crucial factor for the survival, growth, and other biochemical reactions of fish (Boyd, 1992) [8]. The spatial and temporal variations of dissolved oxygen concentration in different ponds are given in the Fig. 11. The highest dissolved oxygen value of 7.70 mg/Lwas observed at Hejamadi Pond 1 and a lower value of 4.07 mg/L at Kundapura Pond 1. The variation in oxygen level was observed among the ponds during culture. The higher value of dissolved oxygen coincided with higher phytoplankton production, and the lower concentration may be attributed to the decomposition of organic matter by bacteria in the pond and also to the consumption of DO by aquatic animals. The normal and optimum range of dissolved oxygen concentration required for brackish water shrimp farming are 3–10 mg/L and 4–7 mg/L, respectively. An oxygen content of 5.00 mg/L was considered to be the most ideal condition for the growth of finfish and shellfish (Boyd, 1989) [7]. The Dissolved oxygen of 7.089 was observed before stocking of *Litopenaeus vannamei* and at the end of the culture period, the dissolved oxygen of 5.827 was observed at Gantarang (GT) Subdistrict (Akhmad Mustafa, 2022) [35]. Chapman (1992) [13] found that the concentration below 5.00 mg/L adversely affect the physiological functioning and survival of biological communities, and concentrations below 2.00 mg/L lead to the death of the fish.

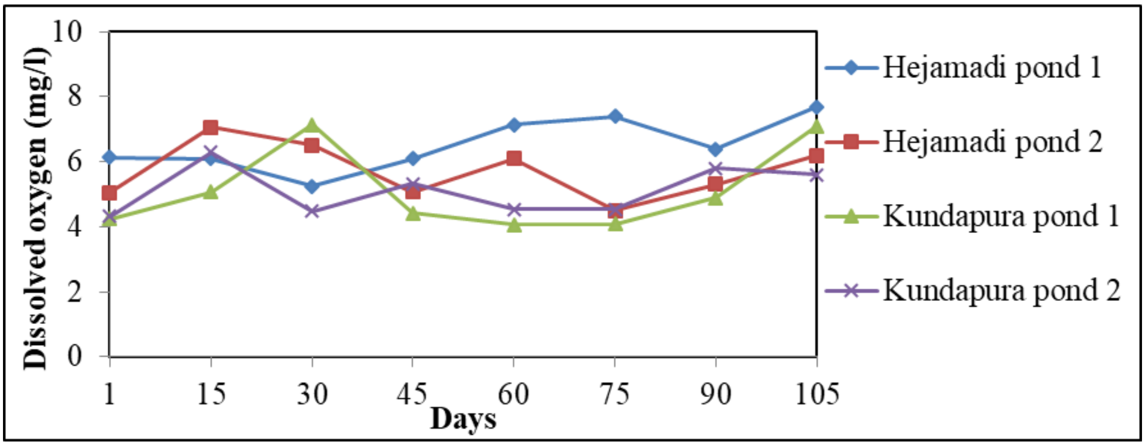

Fig 11: Variation of shrimp pond water Dissolved oxygen

4.12 Ammonia-nitrogen

Ammonia-nitrogen is the reduced form of the nitrogen nutrient. Because of its reduced form, it is preferred among nitrogenous nutrients by phytoplankton and plants. It is generally observed in the form of trace or moderate concentrations in natural waters. Ammonia-N is the most toxic form of inorganic nitrogen produced in pond water. It is the reduced form of nitrogen, and it originates from the mineralization of organic matter by heterotrophic bacteria and as a by-product of nitrogen metabolism by aquatic organisms. Ammonia will be nitrified to nitrite or denitrified to nitrogen gas in the pond by nitrogenous bacteria. The distribution of ammonia-nitrogen in shrimp ponds is given in the Fig. 12. The ammonia-nitrogen content of ponds ranged from 0.08 to 9.41 µg-at./L, maximum was observed at Kundapura Pond 1 on the 30th day, and the minimum at Hejamadi Pond 1 was observed on the 15th, 75th, and 105th days. There was considerable variation in the ammonia-nitrogen concentration; it may be due to the dynamics of pond water in all the ponds. Heterotrophs mineralize the major portion of organic matter in the ponds to produce ammonium. In addition to high feed loading, shrimp excreta can also contribute to high ammonia concentrations (Shan and Obbard, 2001) [42], and the main sources of ammonium in the culture system are excretion and decomposition of detritus (Montoya *et al.*, 2002) [32]. The ammonia content of 0.08504 mg/L was observed before stocking of *Litopenaeus vannamei* and at the end of the culture period, the nitrite content of 0.13616 mg/L was observed at Bonto Bahari Subdistrict (BB) location (Mustafa *et al.*, 2022) [35].

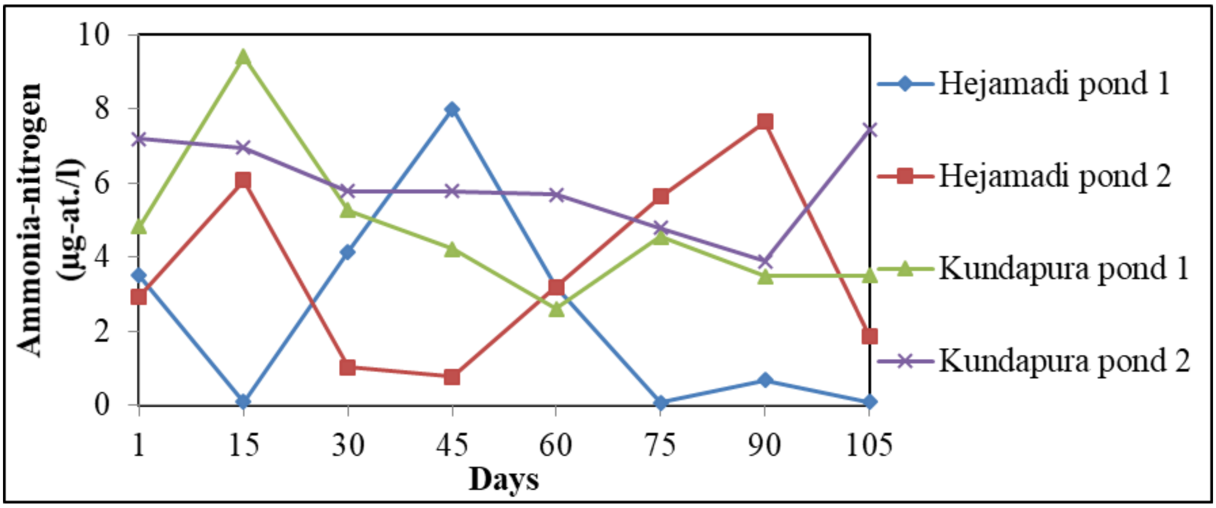

Fig 12: Variation of shrimp pond water Ammonia-nitrogen

4.13 Nitrate-nitrogen

Nitrate-nitrogen is the most oxidized form of nitrogen and is an important plant nutrient. This nitrate is the most stable and perhaps the most important source for autotrophic forms. Variation of nitrate-nitrogen in pond water during the study period are depicted in the Fig. 13. The highest nitrate-nitrogen content of 11.78 µg-at./L was recorded at Hejamadi pond 1 and the lowest of 0.24 µg-at./L at Hejamadi pond 2 and Kundapura pond 2. Considerable variation in the nitrate-nitrogen content was noticed during the study period. The higher value of nitrate in the present study may be due to the nitrification of ammonia, and the lower concentration could be due to the slow mineralization and faster utilization by phytoplankton. The optimum nitrate-nitrogen required for shrimp culture should be less than 0.03 ppm (Anon, 2006) [4]. Mathew (1994) [30] reported the variation of nitrate-nitrogen from trace to 38.66 µg-at./l in the brackish water pond along the Nethravathi estuary. The nitrate content of 0.0001 mg/L was observed before stocking of *Litopenaeus vannamei* and at the end of the culture period, the nitrite content of 0.13966 mg/L was observed at Bonto Bahari Subdistrict (BB) location (Mustafa *et al*., 2022) [35]. Singh (2001) reported a variation of nitrate-nitrogen between 3.88 µg-at./Lto 48.48 µg-at./L in the brackish water ponds along the Nethravathi estuary.

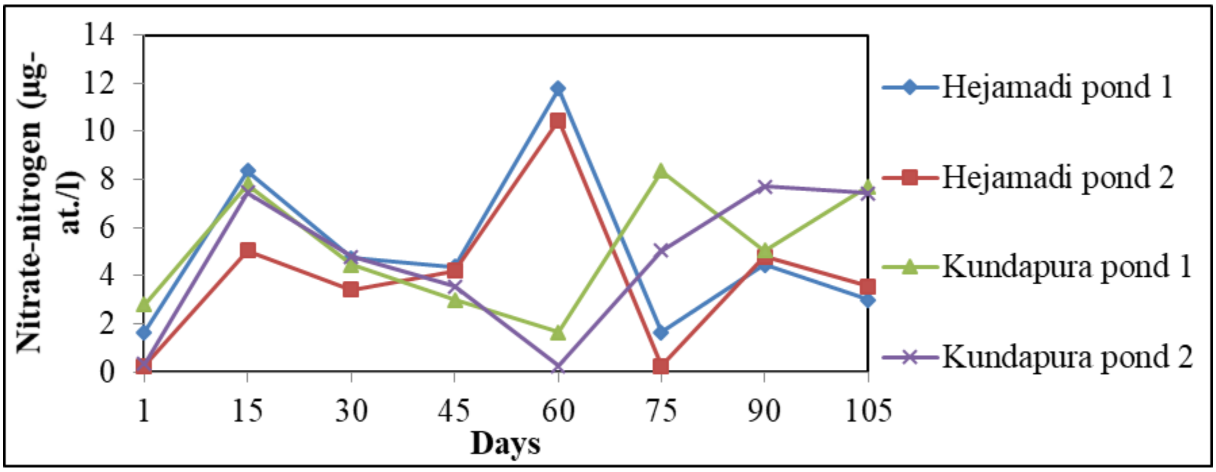

Fig 13: Variation of shrimp pond water Nitrate-nitrogen

4.14 Nitrite-nitrogen

Nitrite is the intermediate state of nitrogen in both the process of oxidation of ammonia to nitrate and in the reduction of nitrate, and hence it is a usable form obtained during oxidation and reduction processes in an environment like brackish water. The desirable form of nitrogen in aquaculture systems is nitrite-nitrogen. It originates from the reduction of nitrate by aerobic bacteria, which are present in mud or water. The nitrite-nitrogen content of pond water is presented in Fig. 14. The highest nitrite-nitrogen concentration of 5.72 µg-at./L was recorded at Hejamadi pond 1 and the lowest of 0.02 µg-at./L at Hejamadi pond 2. The lower concentration of nitrite-nitrogen may be due to the complete utilization of nutrients by the phytoplankton during the later part of the culture period. The nitrite content of 0.02006 mg/L was observed before stocking of *Litopenaeus vannamei* and at the end of the culture period, the nitrite content of 0.00020 mg/L was observed at Bonto Bahari Subdistrict (BB) location (Mustafa *et al*., 2022) [35]. Lao (1998) [26] recommended a nitrite-nitrogen concentration of 1.28 µg-at./L for the better growth and survival of shrimp.

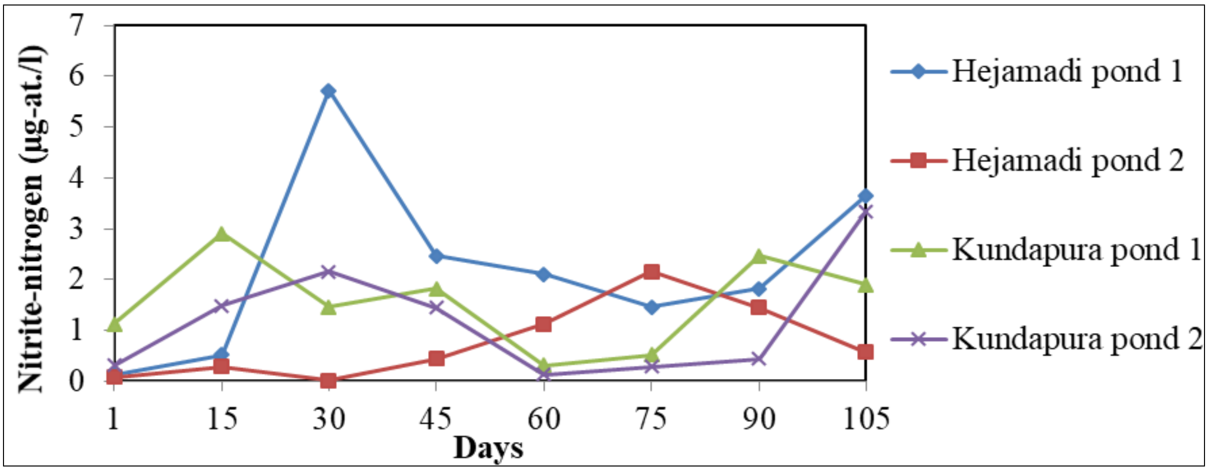

Fig 14: Variation of shrimp pond water Nitrite-nitrogen

4.15 Total dissolved solids

A total dissolved solids (TDS) is a measurement of inorganic salts, organic matter, and other dissolved materials in water. The total dissolved solids values of pond water is presented in the Fig. 15. The values ranged from 0.70 mg/L to 9.99 mg/L. The minimum total dissolved solids concentration was observed on the 30th day at Hejamadi Pond 2 and the maximum on the 90th and 105th days at Hejamadi Pond 1 and also on 45th day at Kundapura pond 1. There was an increasing trend in the total dissolved solids concentration in Hejamadi Pond 1, but there was not much variation in the other ponds during the study period. Total dissolved solids ranging from 15 to 25 ppt are considered slight, 5 to 15 ppt as moderate, and less than 5 ppt as severe for brackish water aquaculture (Hajek and Boyd, 1994) [10]. Total dissolved solids cause toxicity through an increase in salinity, changes in the ionic composition of water, and the toxicity of individual ions (Phyllis *et al.*, 2007) [39].

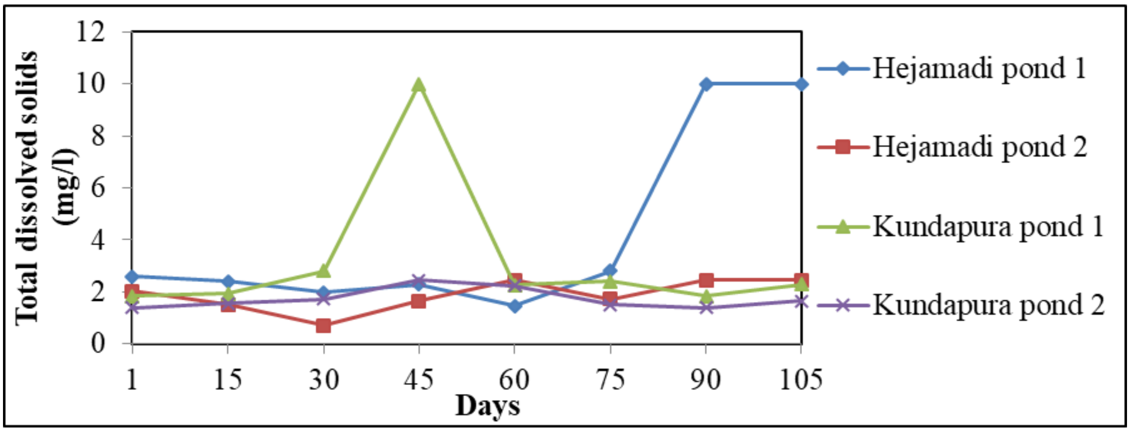

Fig 15: Variation of shrimp pond water Total dissolved solids

4.16 Phosphate-phosphorus

Phosphorus is required in smaller amounts, and it often limits biological productivity. The main nutrient-limiting phytoplankton in brackish water ponds is phosphorus. The phosphate-phosphorus content of water in shrimp culture ponds is presented in the Fig. 16. The highest phosphate-phosphorus concentration of 9.0 µg-at./L was recorded at Kundapura pond 1 and the lowest of 0.15 µg-at./L at Hejamadi pond 2 and Kundapura pond 2. Application of fertilizers and manure at the beginning of culture is the reason for the higher value of phosphate-phosphorus, and utilization of phosphate-phosphorus by phytoplankton may be the reason for the lower concentration. The optimum level of phosphate-phosphorus required for the shrimp culture is 0.10 to 0.20 ppm (Anon, 2006) [4]. It was observed that the concentration of phosphate-phosphorus is within a permissible limit. Pankaj *et al.* (2012) [38] observed that reactive phosphorus in the pond water ranged between 7.40 µg./L to 8.40 µg./L in the shrimp farms in Gujarat. The phosphate of 0.06622 mg/L was observed before stocking of *Litopenaeus vannamei* and at the end of the culture period, the phosphate of 0.03586 mg/L was observed at Bonto Bahari Subdistrict (BB) location (Mustafa *et al.*, 2022) [35]. Singh (2001) [43] found that the phosphate content varied from 0.77 to 7.11 µg-at./L in the brackish water ponds of Mangalore.

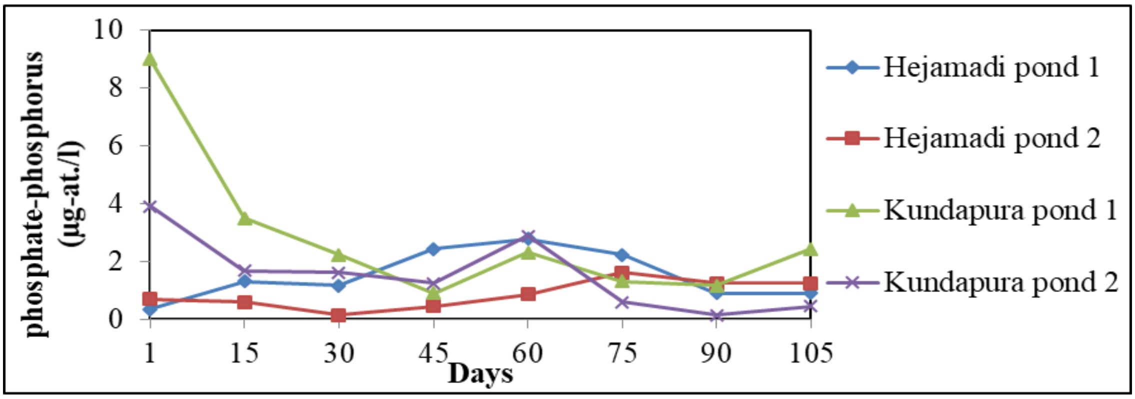

Fig 16: Variation of shrimp pond water Phosphate-phosphorus

4.17 Alkalinity

The amount of acid required to titrate the bases in water is a measure of alkalinity (Boyd, 1978) [6]. The number of bases, like hydroxide, carbonates, bicarbonates, ammonia, silicate, phosphate, *etc.*, may contribute to the alkalinity of water. However, most of these bases usually occur in very small concentrations in water bodies and exhibit considerable influence on water quality. The observed values of alkalinity in the shrimp culture ponds are depicted in the Fig. 17. The minimum alkalinity value of 17 ppm was observed at Kundapura Pond 1 on the 15th day, and the maximum value of 127 ppm was observed at Kundapura Pond 2 on the 1st day of the study period. There was considerable variation in the alkalinity values of the pond water during the study period. The optimal level of alkalinity required for shrimp culture is 200 ppm. The total alkalinity of brackish water farms in Raigad district, Maharashtra, is within the range of 90 to 140 mg/l (Bansode *et al.*, 2020) [5]. According to Van Wyk and Scarpa (1999) [47], *L. vannamei* needs alkalinity values higher than 100 mg $CaCO_3$/L for good development. The absence of bases like hydroxides, carbonates, and bicarbonates in the water may be the reason for the low alkalinity level in the ponds, but it can be improved by applying lime to the pond.

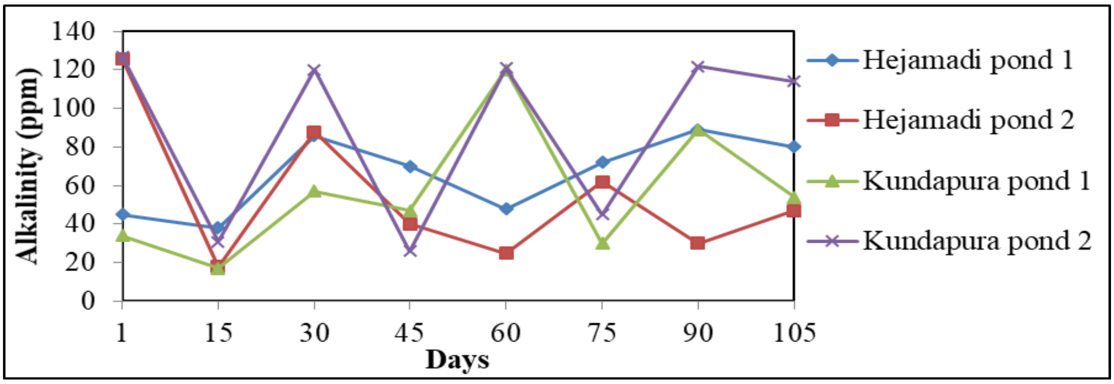

Fig 17: Variation of shrimp pond water Alkalinity

4.18 Properties of Air

Temperature is one of the most important factors that affect the growth of marine shrimp. The growth rate of shrimp is one of the most powerful factors determining economic performance in shrimp farming (Wyban *et al.*, 1987) [50]. The variations in air temperature recorded at different ponds are presented in the Fig. 18. The air temperature ranged from 27.60 °C on the 30th day at Hejamadi Pond 1 to 32.40 °C on the 15th day at Kundapura Pond 1 and on the 105th day at Hejamadi Pond 1. There was no considerable variation in the air temperature in all ponds, and it was within the permissible limit required for shrimp culture. James *et al.* (1993) [25] observed the mean air temperature ranges from 23.60 °C to 27.60 °C in aeutrophic culture pond.

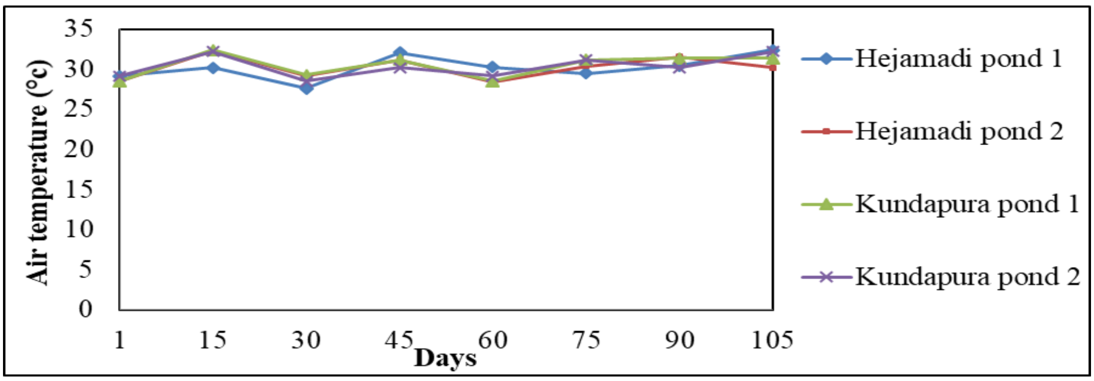

Fig 18: Variation of shrimp pond air Temperature

4.19 Production

The average production of shrimp of 3 tons per hectare per crop was obtained at Hejamadi ponds, and in Kundapura ponds, on average, 7 tons per hectare per crop were harvested. The survival rate observed ranged from 79.00 to 86.0 percent. The individual shrimp weight achieved, varied from 25.32 g to 31.26 g for a culture period of 105 days. The overall observation of all the ponds about the influence of water quality parameters on the growth of the shrimp, it was noticed that temperature, pH, ammonia-nitrogen, alkalinity, and total dissolved solids were found to be significant. It was also noticed that the remaining water quality parameters were not found to be significant. The soil quality parameters analysis with the growth of the shrimp, it was noticed that the electrical conductivity and total nitrogen of the soil were found to be significant in the growth of shrimp. The other soil quality parameters were found to be statistically not significant for the growth of the shrimp. In the present study, the yield of shrimp was good as the culture was carried out during the period of November to March. Usually, higher production is obtained during this period due to the fact that the salinity of the water can be maintained at the optimum level required for shrimp culture, whereas in the rainy season, per unit production may decline due to low salinity. In a farm-intensive cultivation of shrimp in Nayarit with stocking densities of 80 PL/ m^2 survival was obtained at a rate of 80.55% with a yield of 18.04 tons/ha (Olguin-Pineda, 2006). Nammalwar and Kathirvel (1998) [36] obtained 20.6-35.3% survival and 12.8–17.8 g of growth for *P. monodon* after 6 months of culture when *Chanos chanos* was stocked in a polyculture system. Ali *et al.* (1999) [2] stocked 4 pl/m^2, and in another study they obtained 35 g mean weight and 28.76% of survival of *P. monodon* for a culture period of 105 days.

5. Conclusion

The quality of the pond bottom soil and water plays a vital role in shrimp culture. During the culture period, there was not much variation in the water quality parameters recorded, and it was found that these parameters were within the permissible range required for shrimp culture. In the present study, the yield of shrimp was good, as the study was carried out during the period of November to March. Higher production was obtained during this period due to the fact that the salinity of the water can be maintained at the optimum level required for shrimp culture, whereas in the rainy season, production declined due to low salinity. Overall, the study reveals that suitable site selection considering soil and water properties not only helps in better production but also helps in proper land use planning and efficient land management. Frequent testing of soil and water and appropriate treatment make the shrimp culture more eco-friendly and productive. The results are useful for proper land-use planning and management.

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