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Comprehensive Analysis of Environmental and Production Dynamics in Non-Coastal Shrimp Farming in Haryana: Implications for Productivity, Water Quality, and Heavy Metal Contamination

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ABSTRACT:
This study evaluates shrimp farming productivity and environmental conditions in Haryana, India. Key factors like stocking density, survival rate, feed consumption, and farm management were analyzed. Stocking densities ranged from 16 to 116 shrimp per square meter, with higher densities correlating with lower survival rates. The highest net weight gain (33.45 grams) and shrimp harvest (6000 kg/ha) were recorded in Bhiwani and Gurugram, respectively. Water quality varied significantly, with salinity from 8.46 to 36.35 ppt and dissolved oxygen from 4.33 to 8.00 mg/L. Heavy metals were within permissible limits, including nickel (0.307 to 0.540 ppm) and lead (0.060 to 0.812 ppm). The study highlights the need for tailored management strategies to improve shrimp farming productivity and sustainability in non-coastal regions.

Keywords:
Shrimp, Environmental conditions, Productivity, Haryana, Non- Coastal Area

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INTRODUCTION

Shrimp aquaculture has become an essential component of the global seafood industry, significantly contributing to food security and economic growth. According to FAO (2020), global shrimp production has witnessed substantial growth over the past decades, driven by advancements in aquaculture technologies and management practices. In India, shrimp farming is a vital part of the aquaculture sector, particularly in coastal states where the climatic and environmental conditions favor shrimp culture (Kumar et al., 2018). However, non-coastal regions like Haryana have also demonstrated potential for shrimp farming due to improved aquaculture techniques and the availability of suitable water resources. Research by Verma et al. (2021) has highlighted that with appropriate management, inland regions can achieve significant shrimp yields, thereby diversifying and expanding the scope of aquaculture in India. The success of shrimp farming is influenced by several critical factors including stocking density, feed management, and water quality control. These factors directly affect shrimp growth rates, survival, and overall productivity (Hossain et al., 2019). High stocking densities, if not managed properly, can lead to increased competition for resources, higher disease prevalence, and reduced survival rates (Rahman et al., 2020). Effective feed management is crucial for optimizing growth rates and feed conversion ratios, thus ensuring economic efficiency and sustainability (Sharma et al., 2022; Nguyen et al., 2017).Water quality parameters such as pH, salinity, dissolved oxygen, and nutrient levels are vital for maintaining a healthy culture environment. Poor water quality can lead to stress, disease outbreaks, and ultimately lower productivity (Smith et al., 2016; Sharma et al., 2023a). Regular monitoring and management of these parameters are essential for successful shrimp farming operations. Another significant concern in shrimp aquaculture is the presence of heavy metals and other contaminants in the culture ponds. These contaminants can accumulate in shrimp tissues, posing health risks to consumers and affecting the marketability of the product (Chen et al., 2018). Studies have shown that heavy metal contamination can originate from various sources including agricultural runoff, industrial effluents, and the use of contaminated water sources (Sharma et al., 2023b; Liao et al., 2019). The success of shrimp aquaculture is intricately tied to several key factors. Monitoring and managing these factors are essential to ensure sustainable shrimp farming practices and mitigate potential health and environmental risks. By providing a comprehensive analysis of these factors, this study aims to offer practical recommendations for enhancing shrimp farming practices in Haryana. The findings will contribute to the broader knowledge base of sustainable aquaculture management and help optimize shrimp production in non-coastal regions.

MATERIAL METHODS

The study was carried out in eleven districts (Hisar, Fatehabad, Sirsa, Jind, Jhajjar, Faridabad, Rohtak, Bhiwani, Gurugram, Kaithal, and Dadri) of Haryana. A survey of 50 shrimp farms was conducted for data collection.

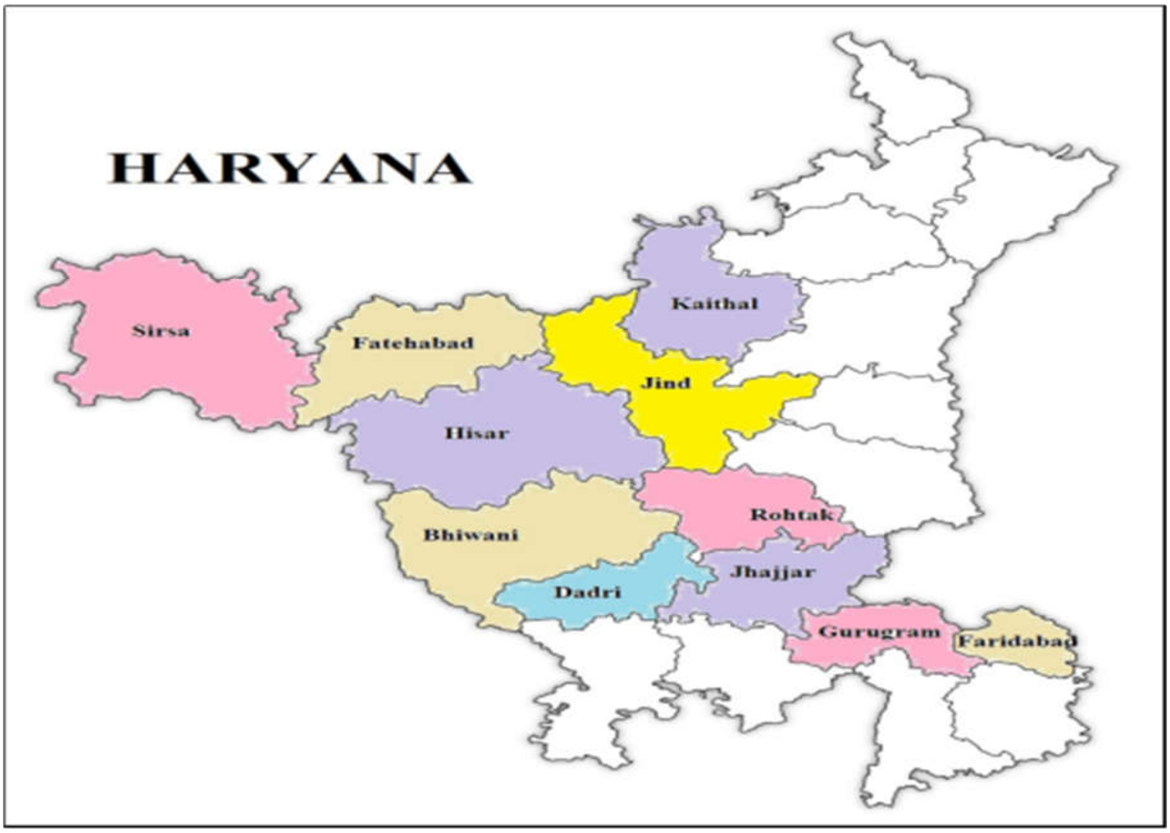

Figure 1: **Study area**

Table 1: Shrimp sampling sites with GPS co-ordinates at different districts of Haryana

S. No	Districts	Village	GPS Co-ordinates
1	Hisar	Mirkan	29.086583N,75.753112E
2	Hisar	Mirkan	29.086583N,75.753112E
3	Hisar	Mangali	29.045384N,75.736814E
4	Hisar	Nalwa	28.942893N,75.828015E
5	Hisar	Balasmand	29.101516N,75.596547E
6	Hisar	Bagla	29.177175N,75.457136E
7	Hisar	Singhwa ragho	29.248130N,75.925335E
8	Hisar	Landhari	29.302095N,75.660097E
9	Fatehabad	Bangaon	29.453311N,75.382462E
10	Fatehabad	Bangaon	29.453311N,75.382462E
11	Fatehabad	Bangaon	29.453311N,75.382462E
12	Fatehabad	Pili mandori	29.387709N,75.252299E
13	Fatehabad	Ban mandori	29.390950N,75286555E
14	Fatehabad	Thuiyan	29.340100N,75.284358E
15	Fatehabad	Ban mandori	29.378094N,75.289862E
16	Fatehabad	Mehuwala	29.356605N,75.288387E
17	Fatehabad	Dhingtania	29.456489N,75.017640E
18	Fatehabad	Dhani bhojraj	29.559550N,75.776569E
19	Fatehabad	Khumber	29.625072N,75.428500E
20	Fatehabad	Kharati kheda	29.501938N,75.362393E
21	Fatehabad	Thuiyan	29.354154N,75.286999E
22	Fatehabad	Kahbra kalan	29.328711N,75.345074E
23	Fatehabad	Sanchla	29.560361N,75.753723E
24	Bhiwani	Syopura	28.763194N,75.492241E
25	Bhiwani	Alampur	28.788920N,75.872534E
26	Bhiwani	Shiwani	28.925485N,75.655639E
27	Bhiwani	Saharwa	28.932056N,75.755641E
28	Bhiwani	Jhumpa	28.811048N,75.506826E
29	Sirsa	Chormar kheda	29.801040N,74.875233E
30	Sirsa	Jhordwali	29.543997N,74.933012E
31	Sirsa	Anandgarh	29.742749N,74.962193E
32	Sirsa	Roharanwali	29.701088N,74.956554E
33	Jind	Frain	29.597386N,76.031650E
34	Jind	Dhrodhi	29.621061N,76.058423E
35	Rohtak	Kharkhara	28.944172N,76.388234E
36	Rohtak	Guroothi	29.034402N,76.534166E
37	Rohtak	Sunderpur	29.328518N,76.399664E
38	Rohtak	Meham	29.022803N,76.558807E
39	Rohtak	Bohar	28.896354N,76.652577E
40	Rohtak	Anwal	28.906463N,76.651772E
41	Jhajjar	Kheri khumar	28.619384N,76.630395E
42	Jhajjar	Kheri khumar	28.619384N,76.630395E
43	Dadri	Jeetpura	29.080678N,76.101860E
44	Dadri	Dadri	28.591202N,76.261347E
45	Faridabad	Faridabad	28.410591N,77.4597692E
46	Gurugram	Jhanjrola	28.489808N,76856153E
47	Gurugram	Sohna	28.246013N,77.056850E
48	Kaithal	Simla	29.633443N,76.215830E
49	Kaithal	Kheri lamba	29.707217N,76.234954E
50	Kaithal	Kalayat	29.678862N,76.249916E

Productivity analysis: During survey, data was collected on shrimp production, stocking size, stocking rate, survival, feed consumed, total harvest, harvesting size, survival rate, average body weight gain, other growth parameters and management differences at farmer's level.

a) Stocking Density: Stocking density was calculated as the total number of post larvae of shrimps stocked per square meter of water spread area.

b) Survival rate: The ratio of the final quantity of shrimp harvested to the total number of shrimp post larvae stocked in each unit of water spread area was calculated as survival rate.

c) Rate of survival (%) = $\frac{Fw \times 100}{Iw}$

Iw is the initial mean weight of shrimp in g, and F_W is the final mean weight of the shrimp in g.

Growth parameters: Before weighing the shrimps, farmers were asked to keep the shrimps starved for whole night. Body length was measured using a measuring scale. The weight (g) of 50 shrimps was taken at each culture pond with the help of portable electronic balance. The weight gain, average daily weight gain, specific growth rate and feed conversion ratio were calculated. The following formulae were used to evaluate growth performance.

a) Weight Gain (WG, g/shrimp) = Fw–Iw

Iw is the initial mean weight of shrimp in g, and Fw is the final mean weight of the shrimp in g.

b) Average Daily Gain (ADG, g/shrimp/day) =

$$\frac{Fw - Iw}{n}$$

Where, n is the duration period;

c) Specific Growth Rate (SGR) =

$$\frac{100 \times (\ln Fw - \ln Iw)}{Days}$$

Where ln is the natural logarithm)

d) Feed Conversion Ratio (FCR) =

$$\frac{\text{Feed given (Dry weight)}}{\text{Body weight gain (wet weight)}}$$

Physico-chemical analysis of water samples: The physico-chemical parameters of water were analyzed in the in the water quality testing laboratory of College of fisheries Sciences of Chaudhary Charan Singh Haryana Agricultural University, Hisar. Total hardness, calcium, magnesium, sodium, potassium, chlorides, phosphate, alkalinity, total dissolved solids, total suspended solids, salinity, electrical conductivity, and biochemical oxygen demand were analyzed in the laboratory. Meanwhile, pH, temperature, dissolved oxygen, turbidity, ammonia, nitrite, and nitrate were determined on-site. The physico-chemical analysis of the water samples was conducted following the standard methods outlined by APHA (1998).

Heavy metal analysis: Heavy metal analysis was done in water collected from shrimp ponds of Haryana by Inductively Coupled Plasma Mass Spectrophotometer IC-PMS by following methodology of Ammann (2002)

RESULTS

Productivity of shrimp farms of Haryana: The productivity of shrimp farms varied significantly across different districts, influenced by factors such as stocking size, stocking rate, survival rate, feed consumption, total harvest, average body weight gain, and farm management practices. Stocking density ranged from 16 to 116 shrimp per square meter. The highest stocking density (116 shrimp/m²) was observed in Alampur of Bhiwani district, which also had the lowest survival rate (31%). Conversely, the lowest stocking density (16 shrimp/m²) and highest survival rate (98%) were recorded in Sohna of Gurugram district. Jhumpa of Bhiwani district reported the maximum net weight gain of 33.45 grams, while Jhanjrola of Gurugram district achieved the highest shrimp harvest at 6000 kg/ha. The highest shrimp count per kilogram (150) was noted in Dhingtania of Fatehabad district. Feed consumption ranged from 1250 to 9000 kg/ha per crop, with feed conversion ratios (FCR) varying between 1.02 and 2.45 across different sites. During sampling, the average weight gain per shrimp ranged from 3 to 20 grams, and the days of culture (DOC) spanned from 60 to 150 days (Table 2).

Growth parameters of *Litopenaeus vannamei* at shrimp farms of Haryana

The correlation matrix between stocking density and shrimp survival indicated a significant negative correlation (r = -0.876), suggesting that an increase in stocking density is associated with a notable decline in shrimp survival (Table 3). The days of culture (DOC) exhibited a significant negative correlation with counts per kilogram (r = -0.410), but showed significant positive correlations with net weight gain (r = 0.355), feed consumed (r = 0.567), feed conversion ratio (FCR) (r = 0.332), and shrimp production (r = 0.295). This indicates that longer culture periods are associated with increases in these parameters. Counts per kilogram were significantly negatively correlated with net weight gain (r = -0.905), shrimp production (r = -0.443), and feed consumed (r = -0.340). Net weight gain demonstrated a positive correlation with feed consumed (r = 0.317). Additionally, feed consumed was positively correlated with shrimp production (r = 0.823), and FCR showed a positive correlation with stocking size (r = 0.289). These correlations indicate that these factors positively influence each other (Table 3).

Table 2: Productivity of shrimp culture ponds in Haryana

Site	Site	Stocking density (m^2)	DOC (days)	Counts/kg	Net weight (g)	Total feed consumed (kg)	FCR	ADWG (g)	Shrimp harvest (kg)	Survival (%)
1	Mirkan	39.00	81.00	100.00	10.00	2000	1.14	3.00	1750	79
2	Mirkan	33.00	90.00	91.00	10.98	5000	1.51	8.00	3300	82
3	Mangali	38.00	90.00	70.00	14.29	5500	1.22	10.00	4500	79
4	Nalwa	41.00	80.00	100.00	10.00	2500	2.08	3.00	1200	60
5	Balasmand	33.00	135.00	50.00	20.00	4500	1.36	18.00	3300	82
6	Bangaon	57.00	90.00	60.00	16.27	4000	1.21	14.00	3300	66
7	Bangaon	36.00	70.00	100.00	10.00	3800	2.11	10.00	1800	81
8	Bangaon	25.00	125.00	30.00	33.33	4400	1.76	8.00	2500	85
9	Pili mandori	80.00	100.00	70.00	14.28	4750	1.18	9.00	4000	40
10	Ban mandori	50.00	97.00	80.00	12.50	3000	1.09	7.00	2750	63
11	Thuiyan	44.00	75.00	62.00	16.12	2500	1.19	10.00	2100	77
12	Syopura	40.00	90.00	63.00	15.87	4000	1.12	8.30	3549	70
13	Roharanwali	50.00	110.00	80.00	12.50	5750	1.15	7.00	5500	66
14	Kharatikheda	100.00	80.00	91.00	11.00	2100	1.25	7.20	1600	34
15	Bagla	31.00	90.00	55.00	18.18	2549	1.10	7.00	2300	86
16	Shiwani	30.00	95.00	40.00	25.36	5500	1.12	7.00	4900	84
17	Simla	50.00	100.00	42.00	24.36	4300	1.30	8.00	3200	68
18	Kherilamba	36.00	80.00	30.00	33.33	5000	1.04	8.00	4800	65
19	Frain	33.00	87.00	50.00	20.00	5200	1.30	18.00	4000	82
20	Dhrodhi	41.00	80.00	80.00	12.50	4800	1.47	10.00	3250	75
21	Kalayat	58.00	120.00	89.00	11.32	5000	1.23	10.00	4050	65
22	Meham	41.00	95.00	64.00	15.60	3250	1.08	3.00	3000	75
23	Bohar	50.00	155.00	80.00	12.50	5000	2.50	10.00	2000	72
24	Rohtak	58.00	88.00	100.00	10.00	3000	1.50	4.00	2500	58
25	Dadri	41.00	75.00	30.00	33.33	4000	1.90	8.00	3600	50

26	Kherikhumar	50.00	88.00	80.00	12.50	2500	1.00	8.00	2500	60
27	Kherikhumar	50.00	120.00	60.00	16.70	4500	1.60	10.00	2800	65
28	Sohna	16.00	62.00	80.00	12.50	2250	1.02	10.00	2200	98
29	Faridabad	33.00	60.00	90.00	11.11	2700	1.68	6.00	1600	72
30	Jhanjrola	33.00	125.00	35.00	28.57	9000	1.50	4.00	6000	92
31	Ban mandori	30.00	90.00	80.00	12.50	3000	1.50	6.00	2000	88
32	Mehuwala	50.00	60.00	140.00	7.14	2166	1.30	7.00	1666	65
33	Dhingtania	42.00	60.00	150.00	6.67	1250	1.78	3.00	700	75
34	Dhanibhojraj	60.00	140.00	30.00	33.32	7000	1.62	8.00	4300	43
35	Khumber	37.00	120.00	50.00	20.12	4000	1.77	7.00	2250	75
36	Chormarkheda	55.00	75.00	30.00	33.33	4100	1.36	3.00	3000	52
37	Jhordwali	28.00	100.00	110.00	9.08	6000	1.62	5.00	3700	86
38	Kharkhara	60.00	75.00	91.00	11.00	4700	1.17	8.67	4000	56
39	Saharwa	37.00	90.00	80.00	20.00	5000	1.11	9.00	4500	76
40	Guroothi	44.00	130.00	30.00	33.00	4000	1.25	4.00	3200	76
41	Landhari	37.00	64.00	110.00	9.00	4000	1.25	3.00	3200	82
42	Thuiyan	37.00	80.00	100.00	10.00	5000	1.38	6.00	3600	83
43	Kahbrakalan	50.00	70.00	50.00	20.00	4000	0.80	7.00	5000	68
44	Jhumpa	25.00	112.00	30.00	33.45	4000	1.33	20.00	3000	84
45	Singhwaragho	100.00	103.00	50.00	21.00	6000	1.25	15.00	4800	32
46	Sanchla	41.00	67.00	84.00	12.00	1750	1.02	3.00	1700	66
47	Anandgarh	40.00	60.00	44.00	23.00	3500	1.04	5.00	3500	68
48	Jeetpura	50.00	80.00	100.00	10.00	4650	1.29	3.00	3600	59
49	Sunderpur	50.00	120.00	100.00	10.00	8000	1.88	9.00	4250	90
50	Alampur	**116.00**	90.00	67.00	15.00	5500	1.17	15.00	4680	31

*ADWG: Average daily weight gain during sampling

Table 3: Correlation matrix of productivity of shrimp culture ponds of Haryana

	Stocking density (m^2)	**DOC (days)**	**Counts/ Kg**	**Net weight (g)**	**Feed consumed (Kg)**	**FCR**	**Shrimp Harvest (Kg)**	**Survival (%)**	**Stock size**
Stocking density (m^2)									
DOC (days)	0.117^{NS}								
Counts/Kg	-0.011^{NS}	-0.410^{**}							
Net weight (g)	0.056	0.355^{*}	-0.905^{**}						
Feed consumed (Kg)	0.229^{NS}	0.567^{**}	-0.340^{*}	0.317^{*}					
FCR	-0.107^{NS}	0.332^{*}	0.178^{NS}	-0.062^{NS}	0.157^{NS}				
Shrimp production(Kg)	0.270^{NS}	0.295^{*}	-0.443^{**}	0.374^{**}	0.823^{**}	-0.342^{*}			
Survival	-0.876^{**}	-0.046^{NS}	0.157^{NS}	-0.152^{NS}	-0.167^{NS}	0.076^{NS}	-0.254^{NS}		
Stock size	-0.050^{NS}	-0.041^{NS}	0.065^{NS}	-0.088	-0.132^{NS}	0.289^{*}	-0.242^{NS}	-0.074	

*Correlationis significant at the0.05level.**.Correlationissignificantatthe0.01level.NS: Not significant.

Physico-chemical analysis of water samples of shrimp farms of Haryana

Significant differences in water quality parameters were observed among surveyed sites (Table 4). Parameters varied across different districts. Salinity ranged from a maximum of 36.35 ppt in Bagla, Hisar district, to a minimum of 8.46 ppt in Sohna, Gurugram district. Electrical conductivity, total suspended solids, total dissolved solids, hardness, alkalinity, ammonia, nitrite, nitrate, and pH in shrimp culture ponds varied as follows: electrical conductivity ranged from 24.48 to 36.78 mS/cm, total suspended solids from 83 to 189 mg/L, total dissolved solids from 4.3 to 18.24 ppt, hardness from 1923.20 to 7250 mg/L , alkalinity from 122 to 382 mg/L, ammonia from 0 to 0.50 ppm, nitrite from 0 to 0.25 ppm, nitrate from 0.13 to 0.38 ppm, and pH from 7 to 8.40. Among these parameters, alkalinity was lowest at Jhordwali (122 mg/L), and ammonia was highest at Mangali and Bangaon (0.50 ppm); however, most places recorded levels below 0.20 ppm. Nitrite concentrations ranged from 0 to 0.20 ppm, and nitrate concentrations ranged from 0 to 0.36 ppm across the 50 sampling sites of shrimp culture ponds. The mineral profiles across the 50 shrimp culture ponds in eleven districts of Haryana showed significant differences (Table 5). Some ponds were well-maintained with optimal mineral ranges, resulting in better yields. Dissolved oxygen (DO), biochemical oxygen demand (BOD), temperature, turbidity, phosphate, chloride, magnesium, sodium, calcium, and potassium ranged as follows: DO from 4.33 to 8.00 mg/L, BOD from 0.57 to 5.11 mg/L, temperature from 24 to 28.50°C, turbidity from 19.42 to 37.32 cm, phosphate from 0.17 to 0.41 mg/L, chloride from 45130.70 to 15422.58 mg/L, magnesium from 1245.97 to 514.01 mg/L, sodium from 11282.67 to 3806.35 mg/L, calcium from 415.32 to 171.48 mg/L, and potassium from 130.32 to 32 mg/L.

The analysis of heavy metals across 50 sampling sites in shrimp culture ponds revealed concentrations within permissible ranges: nickel (0.307 ppm to 0.540 ppm), copper (0.179 ppm to 0.840 ppm), cobalt (0.091 ppm to 0.560 ppm), and lead (0.060 ppm to 0.812 ppm) (Table 6). Maximum concentrations were observed at Guroothi (nickel, 0.307 ppm), Meham (copper, 0.840 ppm), Bangaon (cobalt, 0.560 ppm), and Kalayat (lead, 0.812 ppm). Zinc concentrations ranged from 0.061 ppm to 1.680 ppm, while chromium varied from 0.205 ppm to 3.235 ppm. Most sites showed no significant differences in nickel, copper, lead, and chromium concentrations compared to each other. Overall, heavy metal levels in the shrimp culture ponds generally met permissible limits, with localized higher concentrations observed in specific areas.

Table 4: Water parameters of shrimp culture ponds of Haryana

Site	Salinity (ppt)	EC (Ms/cm)	TSS (mg/L)	TDS (ppt)	Hardness (mg/L)	pH	Alkalinity (mg/L)	Ammonia (ppm)	Nitrite (ppm)	Nitrate (ppm)
Mirkan	16.59	34.63	85.00	8.29	4280.00	7.83	186.00	0.25	0.20	0.31
Mirkan	14.47	31.54	112.00	7.24	4113.25	7.30	172.67	0.25	0.15	0.31
Mangali	21.39	33.32	136.00	10.69	5286.17	7.67	202.00	0.50	0.10	0.28
Nalwa	19.55	29.78	165.00	9.77	4833.13	7.50	192.67	0.38	0.15	0.29
Balasmand	15.30	36.85	102.00	7.65	4253.22	7.33	170.00	0.25	0.15	0.25
Bagla	36.53	29.36	131.00	18.27	9880.00	8.20	382.00	0.00	0.10	0.29
Singhwaragho	17.26	24.48	123.00	8.63	4036.36	7.43	187.33	0.25	0.15	0.38
Landhari	12.85	26.20	116.00	6.43	3486.67	7.70	160.00	0.17	0.20	0.31
Bangaon	20.80	29.54	135.00	10.40	4893.30	7.90	171.33	0.13	0.15	0.36
Bangaon	23.45	33.65	128.00	11.73	5600.00	7.57	200.00	0.42	0.15	0.36
Bangaon	20.17	34.75	166.00	10.08	4846.68	7.47	195.33	0.50	0.10	0.32
Pili mandori	22.86	37.36	135.00	11.43	5633.32	7.60	288.67	0.00	0.20	0.30
Ban mandori	18.65	36.82	83.00	9.33	4243.42	7.37	156.67	0.10	0.25	0.31
Thuiyan	13.47	35.66	152.00	6.74	3783.12	7.23	152.00	0.20	0.15	0.30
Ban mandori	16.93	33.22	112.00	8.47	4733.30	7.70	186.00	0.15	0.25	0.26

Mehuwala	19.13	36.66	185.00	9.57	4743.34	7.50	168.00	0.10	0.10	0.26
Dhingtania	14.46	35.62	136.00	7.23	3900.00	7.33	142.00	0.15	0.20	0.29
Dhanibhojraj	12.61	33.52	135.00	6.30	3213.35	7.30	126.00	0.15	0.25	0.29
Khumber	19.10	36.43	128.00	9.55	4530.00	7.50	173.33	0.25	0.05	0.22
Kharatikheda	12.28	29.52	115.00	6.14	4273.31	7.73	184.00	0.25	0.00	0.22
Thuiyan	10.29	30.78	111.00	5.14	4290.00	7.60	127.33	0.05	0.10	0.27
Kahbrakalan	20.57	29.85	125.00	10.28	4930.00	8.07	156.00	0.01	0.15	0.32
Sanchla	11.36	33.42	164.00	5.68	2236.66	7.43	120.00	0.10	0.20	0.23
Syopura	17.01	32.42	136.00	8.51	4723.25	7.80	154.00	0.20	0.20	0.30
Alampur	14.47	36.25	132.00	7.24	3523.33	7.50	133.33	0.25	0.20	0.34
Shiwani	25.07	35.36	147.00	12.54	7250.00	8.40	278.67	0.10	0.20	0.25
Saharwa	24.38	26.85	105.00	12.19	7133.85	8.20	253.33	0.25	0.15	0.28
Jhumpa	18.29	29.42	107.00	9.15	4653.36	7.17	175.33	0.15	0.00	0.29
Chormarkheda	20.83	36.23	166.00	10.42	4866.52	7.47	182.00	0.15	0.15	0.29
Jhordwali	12.47	35.14	109.00	6.24	2560.00	7.17	122.00	0.00	0.15	0.31
Anandgarh	15.59	35.12	138.00	7.79	4363.25	7.27	132.00	0.15	0.15	0.30
Roharanwali	17.55	36.30	125.00	8.77	4573.12	7.73	182.67	0.10	0.10	0.29
Frain	11.30	35.48	117.00	5.65	3126.67	7.30	134.00	0.20	0.25	0.30
Dhrodhi	13.25	33.87	139.00	6.63	3880.00	7.53	156.67	0.20	0.15	0.27
Kharkhara	15.46	36.52	128.00	7.73	4630.00	7.70	190.00	0.25	0.20	0.33
Guroothi	15.72	35.36	164.00	7.86	3950.00	8.03	216.67	0.25	0.20	0.26
Sunderpur	16.80	33.52	137.00	8.40	4333.33	7.73	193.33	0.15	0.25	0.00
Meham	24.92	36.78	136.00	12.46	7210.00	8.10	267.00	0.15	0.25	0.38
Bohar	24.50	29.49	123.00	12.25	3590.00	7.60	142.00	0.25	0.20	0.50
Anwal	12.80	30.23	167.00	6.40	3310.00	7.40	132.67	0.11	0.15	0.25
Kherikhumar	14.87	29.12	136.00	7.43	3960.00	7.53	143.00	0.15	0.10	0.13
Kherikhumar	8.46	33.43	138.00	4.23	2032.65	7.00	119.33	0.10	0.03	0.00
Jeetpura	10.41	36.45	128.00	5.20	2960.85	7.60	141.67	0.06	0.10	0.38
Dadri	8.96	35.24	166.00	4.48	2236.96	7.30	121.33	0.10	0.15	0.25
Faridabad	10.28	33.40	135.00	5.14	2326.67	7.17	110.00	0.10	0.10	0.13
Jhanjrola	10.96	36.20	189.00	5.48	2113.11	7.13	106.67	0.15	0.25	0.38
Sohna	8.57	35.14	167.00	4.28	1923.20	7.63	99.33	0.10	0.05	0.50
Simla	16.73	33.39	148.00	8.36	5346.30	7.80	191.67	0.07	0.25	0.25
Kherilamba	12.01	36.40	126.00	6.01	3196.25	7.40	140.33	0.10	0.15	0.04
Kalayat	12.47	29.21	135.00	6.24	3860.00	7.77	144.33	0.10	0.10	0.08
C.D. (p=0.05)	**1.33**	**2.08**	**21.46**	**0.66**	**370.18**	**0.50**	**21.95**	**0.15**	**0.10**	**0.14**
SE(m)	**0.47**	**0.74**	**7.64**	**0.24**	**131.74**	**0.18**	**7.81**	**0.05**	**0.04**	**0.05**
SE(d)	**0.67**	**1.05**	**10.80**	**0.33**	**186.30**	**0.25**	**11.05**	**0.08**	**0.05**	**0.07**

Table 5: Mineral profile of shrimp culture ponds of Haryana

Site	DO (mg/L)	BOD (mg/L)	Temp (°C)	Turbidity (cm)	Phosphate (mg/L)	Chloride (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Calcium (mg/L)	Potassium (mg/L)
Mirkan	7.00	0.57	25.32	33.00	0.37	29853.65	829.27	7463.41	276.42	114.92
Mirkan	6.27	1.35	25.45	29.13	0.41	26046.45	723.51	6511.61	241.17	105.57
Mangali	4.33	2.60	24.67	27.67	0.30	38492.72	1069.24	9623.18	356.41	112.54
Nalwa	4.50	1.58	25.00	28.30	0.28	35180.72	977.24	8795.18	325.75	74.88
Balasmand	4.83	1.50	24.22	29.23	0.37	27538.23	764.95	6884.56	254.98	78.53
Bagla	7.17	0.45	24.55	34.00	0.26	31052.22	862.56	7763.06	287.52	122.72
Singhwa ragho	5.17	2.87	25.36	27.67	0.30	31069.57	863.04	7767.39	287.68	125.27
Landhari	6.00	2.19	26.85	24.65	0.37	23130.77	642.52	5782.69	214.17	64.28
Bangaon	6.77	1.81	26.35	26.62	0.30	37433.28	1039.81	9358.32	346.60	64.97
Bangaon	6.03	4.07	27.23	28.66	0.29	42214.92	1172.64	10553.73	390.88	99.73
Bangaon	5.67	5.11	26.12	27.31	0.28	36303.82	1008.44	9075.95	336.15	32.57
Pili mandori	7.00	0.57	24.13	37.32	0.30	41144.84	1142.91	10286.21	380.97	120.73

Ban mandori	6.40	1.25	25.35	29.68	0.41	33571.64	932.55	8392.91	310.85	67.00
Thuiyan	7.15	1.17	25.64	32.39	0.37	24252.63	673.68	6063.16	224.56	63.51
Ban mandori	6.25	1.58	24.00	27.35	0.26	30473.62	846.49	7618.41	282.16	66.43
Mehuwala	5.85	1.73	23.21	27.03	0.37	34436.94	956.58	8609.24	318.86	73.97
Dhingtania	5.95	1.62	27.13	34.22	0.30	26025.40	722.93	6506.35	240.98	54.15
Dhanibhojraj	6.75	1.53	25.12	35.67	0.30	22688.88	630.25	5672.22	210.08	73.73
Khumber	6.25	2.15	26.00	24.33	0.40	34384.28	955.12	8596.07	318.37	65.63
Kharatikheda	7.15	1.81	26.25	27.98	0.30	22104.18	614.01	5526.05	204.67	130.09
Thuiyan	8.15	1.40	26.78	28.67	0.26	18520.19	514.45	4630.05	171.48	130.32
Kahbrakalan	6.60	5.11	27.65	23.85	0.37	37022.58	1028.41	9255.65	342.80	104.48
Sanchla	7.55	1.57	25.34	33.00	0.41	20449.20	568.03	5112.30	189.34	93.12
Syopura	7.25	1.62	26.06	31.12	0.30	30619.20	850.53	7654.80	283.51	73.61
Alampur	6.70	2.60	26.87	30.23	0.28	26049.97	723.61	6512.49	241.20	96.36
Shiwani	7.15	1.58	26.67	30.12	0.37	45130.70	1253.63	11282.67	417.88	64.83
Saharwa	6.75	2.17	27.53	29.33	0.26	43885.45	1219.04	10971.36	406.35	52.54
Jhumpa	7.60	1.12	28.27	34.00	0.30	32926.09	914.61	8231.52	304.87	89.01
Chormar kheda	8.05	1.53	25.43	27.67	0.37	37497.65	1041.60	9374.41	347.20	110.59
Jhordwali	7.45	1.85	28.53	24.33	0.30	22446.45	623.51	5611.61	207.84	95.57
Anandgarh	6.65	1.91	26.30	24.25	0.29	28052.72	779.24	7013.18	259.75	106.21
Roharanwali	6.70	1.40	28.43	28.67	0.28	31580.72	877.24	7895.18	292.41	124.88
Frain	6.85	1.11	25.43	29.37	0.30	20338.24	564.95	5084.56	188.32	88.53
Dhrodhi	7.15	0.84	28.30	33.36	0.41	23852.22	662.56	5963.06	220.85	109.39
Kharkhara	5.70	1.35	25.77	29.35	0.37	27829.57	773.04	6957.39	257.68	84.93
Guroothi	6.65	1.27	28.50	27.65	0.26	28290.77	785.86	7072.69	261.95	112.94
Sunderpur	7.80	1.18	25.67	22.67	0.37	30233.27	839.81	7558.32	279.94	94.97
Meham	8.05	1.15	25.57	29.36	0.30	44854.92	1245.97	11213.73	415.32	103.40
Bohar	7.25	1.45	25.27	24.38	0.30	44103.82	1225.11	11025.95	408.37	73.30
Anwal	6.80	2.87	27.00	21.35	0.40	23033.62	639.82	5758.41	213.27	121.93
Kheri khumar	7.05	2.19	25.10	24.38	0.30	26756.94	743.25	6689.24	247.75	107.94
Kheri khumar	5.90	2.48	25.25	22.09	0.26	15225.40	422.93	3806.35	140.98	64.97
Jeetpura	7.10	1.40	26.14	28.66	0.37	18728.88	520.25	4682.22	173.42	106.06
Dadri	7.95	1.47	26.00	27.36	0.41	16132.28	448.12	4033.07	149.37	63.30
Faridabad	8.05	1.00	25.36	27.63	0.30	18504.18	514.01	4626.05	171.34	92.73
Jhanjrola	7.55	1.81	25.12	24.21	0.28	19720.19	547.78	4930.05	182.59	77.00
Sohna	7.10	4.07	28.25	19.42	0.17	15422.58	428.41	3855.65	142.80	83.51
Simla	7.40	3.44	25.14	26.00	0.23	30109.20	836.37	7527.30	278.79	131.93
Kherilamba	6.65	2.19	27.25	27.13	0.26	21619.20	600.53	5404.80	200.18	120.94
Kalayat	7.10	1.81	28.32	28.67	0.37	22449.97	623.61	5612.49	207.87	103.30
C.D. (p=0.05)	0.58	0.48	N/A	5.61	0.08	2373.06	65.92	593.27	21.97	19.44
SE(m)	0.21	0.17	1.16	2.00	0.03	844.50	23.46	211.12	7.82	6.92
SE(d)	0.29	0.24	1.64	2.82	0.04	1194.30	33.18	298.57	11.06	9.79

DISCUSSION

The physico-chemical parameters of water, such as temperature, pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), total hardness, alkalinity, ammonia nitrogen, nitrate-nitrogen, nitrite-nitrogen, sodium, potassium, calcium, magnesium, chloride, salinity, turbidity, phosphate, total dissolved solids (TDS), and total suspended solids (TSS), were found to be within the optimal ranges suggested for shrimp cultivation by various authors. Temperature is crucial for shrimp growth and survival, with an increase from 20 to 32°C notably improving the development rate of *L. vannamei* juveniles (Khushbu et al., 2022a). The temperature in the study ranged from 24 to 28°C, ideal for shrimp survival and development (Zhang et al., 1998). Similarly, pH levels between 7.00 and 8.40 were observed, aligning with recommendations for shrimp cultivation (Cohen et al., 2005). Alkalinity, which ranged from 99 to 382 mg/L in the study, also fell within optimal ranges suggested by Van Wyk and Scarpa (1999) for penaeid culture. Dissolved oxygen (DO) ranged from 7.8 to 8.9 mg/L, a critical factor in aquatic environments affecting shrimp metabolism and health (Boyd, 1982). Salinity, ranging from 10 to 35 ppt in the study, is known to influence shrimp physiology and osmoregulation (Liu et al., 2006). Phosphate concentrations ranged from 0.07 to 0.41 mg/L, with levels typically increasing during the culture period, influenced by factors like salinity and silt load (Das and Saksena, 2001). Ammonia levels, ranging from 0.04 to 0.10 mg/L, were within the safe range for shrimp aquaculture (Jhingran, 1991). Nitrite concentrations (0.00-0.25 mg/L) and nitrate levels (below 0.04 mg/L) were also observed to be within acceptable limits for pond aquaculture (Boyd and Tucker, 1998). The presence of heavy metals such as nickel, copper, cobalt, and lead within permissible ranges (<1.000, <2.000, <0.795, and <0.900 ppm, respectively) indicated that the study area was free of heavy metal toxicity (Khushbu et al., 2022b). This aligns with similar findings in other aquaculture studies (Venkatesh and Kiran, 2016). Overall, the findings from this study provide significant insights into the factors influencing shrimp farm productivity and water quality in Haryana. The variation in stocking density, survival rates, and growth parameters across different districts underscores the importance of effective farm management practices and environmental conditions (APHA, 1998). The observed negative correlation between stocking density and shrimp survival highlights the need for optimal stocking practices to maintain favorable conditions for growth (Boyd and Tucker, 2012). Additionally, the positive correlations between days of culture and growth parameters suggest that longer culture periods can lead to higher yields, with careful attention to factors such as feed consumption and stocking size (New, 2002).The significant differences in water quality parameters among surveyed sites emphasize the complex interplay of various factors affecting shrimp culture ponds. Salinity, electrical conductivity, and mineral profiles varied widely across districts, indicating diverse environmental conditions that may impact shrimp health and growth (Boyd, 2012). While heavy metal concentrations were within permissible limits, continuous monitoring and mitigation efforts are necessary to prevent localized instances of elevated concentrations (EPA, 2009).

CONCLUSION

The study provides valuable insights into the productivity and environmental conditions of shrimp farming in Haryana, India. It highlights significant variations in stocking density, survival rates, feed consumption, and water quality parameters across different districts. The findings underscore the importance of optimized farm management practices tailored to local conditions to enhance shrimp farming productivity and sustainability in non-coastal regions. Additionally, the study confirms that heavy metal concentrations in shrimp culture ponds generally adhere to permissible limits. Future research should focus on further improving stocking strategies and water quality management to maximize shrimp yield and minimize environmental impact in these inland farming systems.

Declaration of Competing Interest:
The authors declare that they have no known competing financial interests.

Ethical Approval:
This study did not require any ethical approval.

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