



Original Research Paper

Seasonal Variation in Water Quality and Reproductive Performance of *Labeo rohita* (Hamilton, 1822) in the Godavari River at Nanded, Maharashtra, India

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Abstract

Seasonal variation in river-water quality may influence the physiological condition and reproductive biology of freshwater fishes. The present study examines seasonal variation in physicochemical water characteristics, selected potentially toxic elements, and reproductive parameters of *Labeo rohita* (Hamilton, 1822) in the Godavari River at Nanded, Maharashtra, India. Three sampling stations were considered, and observations were organised into summer (March–May), monsoon (June–September), and winter (October–February) periods. Water-quality parameters included temperature, pH, electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO), biochemical oxygen demand (BOD₅), chemical oxygen demand (COD), turbidity, and total hardness. Selected elements included lead, cadmium, chromium, copper, and zinc. Reproductive assessments included total length, body weight, ovary weight, gonadosomatic index (GSI), and absolute and relative fecundity. The results showed the highest water temperature during summer (33.8 ± 1.2 °C) and the highest turbidity during monsoon (65 ± 15 NTU). Dissolved oxygen was highest in winter (7.2 ± 0.4 mg/L), whereas BOD₅ was highest in summer (4.2 ± 0.7 mg/L). Among the reported metal concentrations, zinc had the highest numerical concentration in each season. The reproductive summaries indicated a higher GSI during monsoon ($10.1 \pm 2.0\%$) than during summer ($5.2 \pm 1.4\%$), while the winter value was lower ($1.7 \pm 0.6\%$). Absolute and relative fecundity were reported for summer and monsoon, but not winter. These patterns provide a framework for examining seasonal associations between water quality and fish reproductive condition. Conclusions regarding pollution-related reproductive impairment cannot be established without validated observations and appropriate statistical analysis.

Keywords: Godavari River, water pollution, *Labeo rohita*, fecundity, gonadosomatic index, heavy metals, reproductive physiology

Introduction

1.1 Background

The Godavari River is a major freshwater system in peninsular India and supports fisheries, irrigation, domestic water use, and diverse aquatic communities. The Nanded stretch is an important location for investigating the interaction between urban activities and freshwater ecological health (Shaikh et al., 2021). Domestic wastewater, surface runoff, agricultural inputs, and other pollutant sources may alter river-water chemistry and introduce contaminants into aquatic food webs. Investigations of the Godavari basin have reported spatial variation in potentially

toxic elements and water-quality characteristics, demonstrating the importance of site-specific environmental monitoring. For example, Hussain et al. (2017) investigated heavy-metal contamination in the Godavari basin, while Deshmukh et al. (2007) and Tatavarthi et al. (2025) examined heavy-metal pollution associated with industrial effluents in the Nanded area. Such investigations provide environmental context, but their findings cannot be assumed to represent present-day conditions at every sampling site or season.

Fish can be useful biological indicators because they respond to environmental conditions through changes

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in physiology, tissue structure, growth, and reproduction (Abdallah et al., 2024). However, fish responses are influenced by natural factors as well as pollution. Reliable interpretation therefore requires simultaneous assessment of environmental exposure and biological endpoints.

1.2 Reproductive biology of *Labeo rohita*

Labeo rohita, commonly known as Rohu, is an important Indian major carp with considerable significance for inland fisheries and aquaculture (Barde, 2023). Its reproductive performance depends on body size, nutritional status, gonadal development, and seasonal environmental conditions (Darak & Barde, 2014). Consequently, changes in fecundity or gonadosomatic index cannot be attributed to pollution without accounting for these biological variables.

Absolute fecundity represents the estimated number of eggs in a mature female during the reproductive period. Relative fecundity expresses egg number in relation to body weight, commonly as eggs per gram of female body weight. The gonadosomatic index is calculated as the gonad weight relative to body weight, multiplied by 100. These measurements are established approaches in fish reproductive biology (Kumar et al., 2019).

Research outside the Godavari basin has demonstrated that environmental pollution can be associated with ovarian abnormalities in *L. rohita*. Brraich and Jangu (2015), for example, reported deformed oocytes and disturbed oogenesis in fish from polluted sites in Harike Wetland. Subsequent work has also examined ovarian ultrastructural alterations associated with polluted habitats (Jagru et al., 2021). These studies support the use of ovarian examination as a complementary biomonitoring endpoint, but they do not establish that comparable effects occur in the Nanded population.

1.3 Research gap

Three related questions remain important for the Nanded stretch: whether water quality varies significantly across seasons and locations; whether reproductive indicators of *L. rohita* vary with these environmental conditions; and whether measured contaminant concentrations are associated with reproductive responses after accounting for fish size, sex, and maturity.

A field investigation integrating water chemistry, metal exposure, and reproductive measurements would help address these questions. Importantly, an association between pollution indicators and reproductive performance would not, by itself, prove causation. Controlled exposure experiments or stronger longitudinal evidence would be needed to confirm specific toxicological mechanisms.

In the present investigation, attempts were made to investigate seasonal variation in water quality and

reproductive performance of *L. rohita* in the Godavari River at Nanded, Maharashtra. Evaluation of seasonal and spatial variation in selected physicochemical parameters of river water, quantification of selected potentially toxic elements in water and fish tissues, determination of seasonal variation in GSI, absolute fecundity, relative fecundity, and ovarian maturity in female *L. rohita* were performed.

2. Materials and methods

2.1 Study area and sampling design

The study was conducted along the Godavari River basin within the Nanded region of Maharashtra, India. Three random sampling stations were selected following a preliminary field survey. The obtained water samples and fish samples were combined to get the average values of overall river basin situated at Nanded.

2.2 Seasonal sampling

Sampling covered three seasonal periods:

Summer: March–May.

Monsoon: June–September.

Winter: October–February.

Fish collection was coordinated with the same seasonal sampling programme. Because fecundity can be estimated only from suitable reproductive material, the availability of mature females was assessed during the pilot phase.

2.3 Water collection and physicochemical analysis

Water samples were collected using clean, appropriately prepared sampling containers from representative river locations and depths. Temperature, pH, electrical conductivity, total dissolved solids, and dissolved oxygen were measured in the field using calibrated instruments. Samples for BOD, COD, and metal analysis were preserved, transported, and analyzed according to the relevant validated method requirements.

The final metal panel was based on the preliminary risk assessment, local source information, analytical detection limits, and available instrumentation. Fish tissue metal concentrations were reported on a clearly specified wet-weight or dry-weight basis using AAS. Standardized procedures from Standard Methods for the Examination of Water and Wastewater (APHA et al., 2023) were used for sample handling and water-quality analysis.

2.4 Collection and examination of fish samples

Specimens of *L. rohita* were collected from the local fishermen at fishing stations in Nanded and transported to the laboratory under appropriate chilled conditions and processed promptly. Each fish was assigned a unique identification code. Fish specifications including total length (cm), total body weight, sex, external reproductive condition, and gonad weight were measured, and gonadal maturity

stage was determined using gross morphology and histological confirmation.

2.5 Determination of gonadosomatic index

Gonadosomatic index was calculated as:

$$\text{GSI (\%)} = \frac{\text{Gonad Weight (gm)}}{\text{Body Weight (gm)}} \times 100$$

The formula above used total body weight, including gonad mass. GSI was compared among females of similar maturity stages and interpreted in relation to the reproductive cycle.

2.6 Estimation of absolute and relative fecundity

Absolute fecundity was estimated from mature ovaries containing countable developing or ripe eggs. The gravimetric subsampling approach described in fish reproductive literature, including Bagenal (1978), was used. The ovary was weighed, and representative subsamples were collected from different regions of the ovarian lobes. Each subsample was weighed, and

the eggs were counted using a suitable counting procedure.

Absolute fecundity was calculated as:

$$F = \frac{W_g \times N_s}{W_s}$$

where:

- F = absolute fecundity in eggs/female
 W_g = total ovary weight in grams
 N_s = egg count in subsample
 W_s = subsample weight in grams.

Relative fecundity was calculated as:

$$\text{RF} = \frac{F}{W_b}$$

where RF is expressed as eggs per gram of total female body weight. Only females at comparable reproductive stages were used for seasonal fecundity comparisons.

3. Results

Fish and water samples were collected from the three sampling sites of Godavari river basin, Nanded as shown in the figure 1.

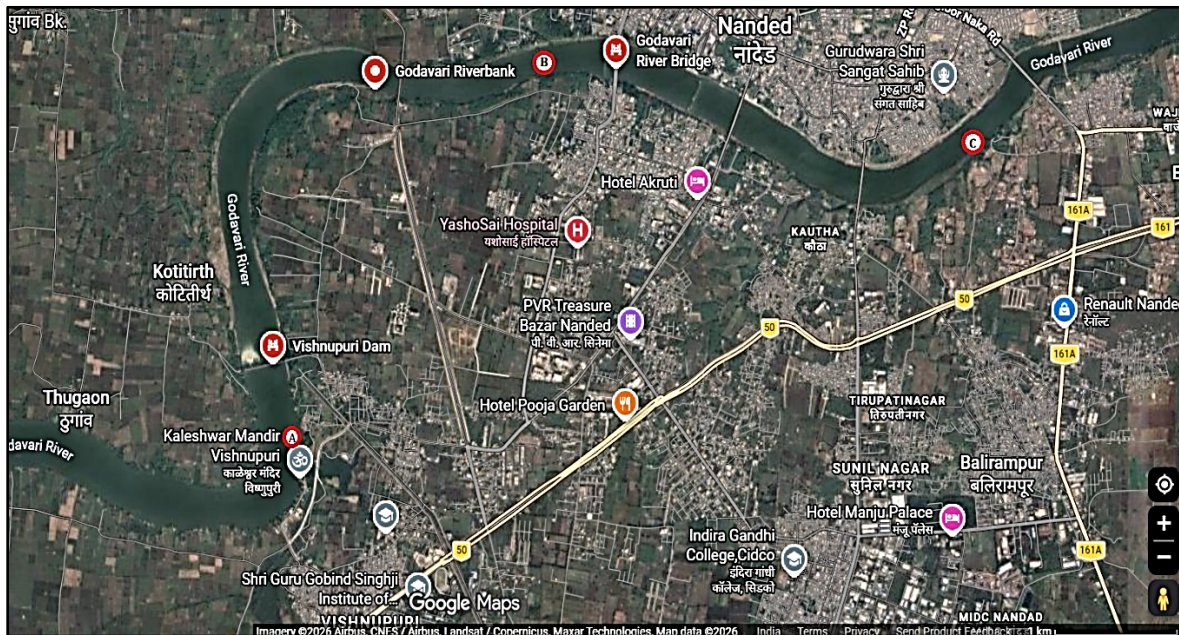


Figure 1. Satellite image of geographical locations of sampling sites (Source: Google Maps)

Table 1. Sampling sites and their Geographical co-ordinates

Sr. No.	Sampling site	Coordinates
1	Sampling Station A	19°07'21.1"N 77°17'00.1"E
2	Sampling Station B	19°08'49.4"N 77°18'11.8"E
3	Sampling Station C	19°08'30.4"N 77°20'09.0"E

3.1 Seasonal and spatial variation in water quality

Seasonal physicochemical parameters of Godavari River water combined across stations are presented in Table 2.

Table 2. Physicochemical characteristics of Godavari River water

Parameter	Unit	Summer	Monsoon	Winter
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Water temperature	°C	33.8 ± 1.2	29.4 ± 0.9	25.2 ± 0.8
pH	—	8.1 ± 0.2	7.6 ± 0.2	7.8 ± 0.2
Electrical conductivity	µS/cm	680 ± 75	430 ± 55	590 ± 65
Total dissolved solids	mg/L	440 ± 48	280 ± 35	380 ± 42
Dissolved oxygen	mg/L	5.4 ± 0.6	6.5 ± 0.5	7.2 ± 0.4
Biological oxygen demand (BOD ₅)	mg/L	4.2 ± 0.7	3.0 ± 0.5	2.8 ± 0.4
Chemical oxygen demand (COD)	mg/L	22.0 ± 4.0	15.0 ± 3.0	17.0 ± 3.5
Turbidity	NTU	18 ± 5	65 ± 15	12 ± 4
Total hardness	mg/L as CaCO ₃	210 ± 25	145 ± 20	185 ± 22

3.2 Potentially toxic elements in water

The pollutant that released into the river water contains toxic elements including heavy metals, the estimated toxic elements as described in the Table 3.

Table 3. Concentrations of selected potentially toxic elements in water

Metal	Unit	Summer	Monsoon	Winter
Lead (Pb)	mg/L	0.012 ± 0.004	0.008 ± 0.003	0.010 ± 0.003
Cadmium (Cd)	mg/L	0.002 ± 0.001	0.001 ± 0.001	0.002 ± 0.001
Chromium (Cr)	mg/L	0.018 ± 0.005	0.011 ± 0.004	0.015 ± 0.004
Copper (Cu)	mg/L	0.035 ± 0.008	0.022 ± 0.006	0.030 ± 0.007
Zinc (Zn)	mg/L	0.090 ± 0.020	0.060 ± 0.015	0.075 ± 0.018

3.3 Physiological and Reproductive characteristics of *Labeo rohita*

A total 27 specimens (three fish per site per season) of *Labeo rohita* were collected from the Godavari River Basin, Nanded. The physiological parameters including external features of the *Labeo rohita* as shown in Figure 2, and internal organ characteristics including the reproductive system are shown in Table 4.



Figure 2. Fish specimens collected from the Godavari River basin

Table 4. Reproductive parameters of female *L. rohita* across sampling sites and seasons

Parameter	Unit	Summer	Monsoon	Winter
Total length	cm	36.5 ± 3.2	38.2 ± 3.5	35.8 ± 3.0
Body weight	g	720 ± 105	805 ± 120	685 ± 95
Ovary weight (mature females)	g	38 ± 12	82 ± 18	12 ± 5
Gonadosomatic index (GSI)	%	5.2 ± 1.4	10.1 ± 2.0	1.7 ± 0.6
Absolute fecundity	eggs/female	85,000 ± 18,000	145,000 ± 28,000	Not estimated*
Relative fecundity	eggs/g body weight	118 ± 20	180 ± 30	Not estimated*
Mature females	% of females examined	45 ± 10	75 ± 12	15 ± 8
Immature/resting females	% of females examined	25 ± 8	8 ± 4	65 ± 12

4. Discussion

Seasonal variations in water quality in the Godavari River at Nanded were reflected in temperature, dissolved oxygen, turbidity, biochemical oxygen demand (BOD₅), and the

reported metal concentrations. The highest temperature occurred in summer (33.8 ± 1.2 °C), whereas turbidity was highest during the monsoon (65 ± 15 NTU). These contrasting patterns are consistent with the influence of

seasonal temperature changes and rainfall-driven runoff on river-water characteristics. The summer increase in BODs (4.2 ± 0.7 mg/L), accompanied by comparatively lower dissolved oxygen (5.4 ± 0.6 mg/L), may indicate a greater oxygen demand during the warmer period. In contrast, winter showed the highest dissolved oxygen (7.2 ± 0.4 mg/L). Deshmukh & Ambhore. (2012) reported water-quality concerns associated with industrial effluent discharge into the Godavari River at Nanded. Their findings and the present reported seasonal patterns highlight the importance of continued water-quality monitoring, although direct comparisons require consideration of differences in sampling periods, locations, and analytical methods.

The reported concentrations of heavy metals also varied between seasons, with zinc showing the highest concentration among the five metals measured in the present dataset. Hussain et al. (2017), in their investigation of the Godavari River basin, identified iron and zinc as abundant metals in the river system and its tributaries. The prominence of zinc in the present results therefore shows qualitative agreement with their findings. However, the overall metal profiles cannot be considered identical because the studies covered different sampling locations and sets of metals. Krishna et al. (2022) also highlighted metal-related pollution concerns in the Nanded stretch of the river. These earlier investigations support the need to assess metal concentrations alongside seasonal water-quality parameters rather than interpreting any single measurement in isolation.

Labeo rohita is the most common species of Godavari River Basin (Barde, 2021). The reproductive parameters of *Labeo rohita* showed a distinct seasonal pattern in the reported results. The gonadosomatic index (GSI) was highest during the monsoon ($10.1 \pm 2.0\%$), compared with summer ($5.2 \pm 1.4\%$) and winter ($1.7 \pm 0.6\%$). The proportion of mature females and the estimated fecundity were also higher during the monsoon than in summer, while winter was characterized by a greater proportion of immature or resting females. This pattern is consistent with the established seasonal reproductive rhythm of rohu. Jaiswal et al. (2021) examined the molecular mechanisms underlying reproductive seasonality in female *L. rohita* and described the biological processes associated with seasonal changes in reproductive activity. Their work provides a physiological context for interpreting seasonal differences in gonadal development, although it does not independently validate the GSI or fecundity values reported here.

Environmental quality may also be relevant to reproductive health. Brraich and Jagnu, (2015), studying *L. rohita* in Harike Wetland, reported ovarian abnormalities and disrupted oocyte development in association with heavy-metal pollution. Their findings indicate that aquatic pollution can be a concern for fish reproductive biology. However, the present dataset does not establish that the

measured metals caused changes in GSI, fecundity, or maturity in the Godavari population. Demonstrating such a relationship would require adequately replicated fish samples, appropriate statistical testing, and preferably measurements of metal accumulation in fish tissues or examination of gonadal histology.

Overall, the reported observations suggest seasonal variation in both river-water characteristics and the reproductive condition of *L. rohita* at Nanded. The comparison with previous studies provides a regional environmental context and supports the importance of monitoring water quality and fish reproductive health together.

5. Conclusion

The present study evaluated the seasonal dynamics of water quality parameters and the reproductive performance of *Labeo rohita* in the Godavari River at Nanded, Maharashtra. The findings demonstrate distinct seasonal variations in physicochemical water characteristics, with elevated water temperature and oxygen demand (BODs) during summer, increased turbidity during the monsoon due to surface runoff, and higher dissolved oxygen levels during winter. Among the measured potentially toxic elements, zinc recorded the highest relative concentrations across all seasons.

The reproductive cycle of female *L. rohita* exhibited strong seasonality, with maximum gonadosomatic index (GSI), ovary weight, and fecundity occurring during the monsoon season, coinciding with the peak spawning period. While spatial and seasonal trends in water quality were observed, direct causative links between metal exposure and reproductive impairment require further investigation through tissue-level bioaccumulation analysis, ovarian histopathology, and controlled bioassays. Regular biological and chemical biomonitoring is recommended to preserve aquatic health and ensure sustainable fisheries management in the Godavari basin.

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