Impact of Climatic Factors on Population Dynamics of *Hoplobatrachus tigerinus* in North 24 Parganas district, West Bengal, India

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ABSTRACT

The present study investigates the influence of climatic and ecological factors on the population dynamics of *Hoplobatrachus tigerinus* in selected ecological habitats of North 24 Parganas district, West Bengal, during 2023–2025. Amphibians are highly sensitive to environmental fluctuations because of their permeable skin and biphasic life cycle (Blaustein and Wake, 1990). Seasonal population variation was analyzed in relation to climatic factors, aquatic physicochemical characteristics, and soil parameters. Results revealed that rainfall, humidity, dissolved oxygen, aquatic pH, and habitat quality significantly influenced abundance and breeding activity. Monsoon periods supported maximum population density, whereas lower abundance occurred during pre-monsoon months. Agricultural wetlands exhibited comparatively higher abundance because of favorable hydro-ecological conditions and prey availability, while urban habitats showed reduced populations because of pollution, habitat fragmentation, and anthropogenic disturbances. The findings indicate that climatic instability and ecological degradation strongly regulate long-term population stability of *H. tigerinus*.

Keywords: Amphibia, climate variability, Indian Bullfrog, wetland ecology, population dynamics, amphibian conservation

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INTRODUCTION

Amphibians are among the most environmentally sensitive vertebrates and are considered important biological indicators of ecosystem health (Wake, 1991). During the past few decades, global amphibian populations have experienced substantial declines because of habitat destruction, climatic variability, environmental pollution, invasive species, and infectious diseases (Stuart et al., 2004). Climatic factors such as rainfall, humidity, and temperature strongly influence amphibian breeding behavior, larval survival, and seasonal migration (Carey and Alexander, 2003). The Indian Bullfrog, *Hoplobatrachus tigerinus*, is one of the largest amphibian species distributed throughout South Asia. The species inhabits wetlands, marshes, ponds, paddy fields, and temporary aquatic habitats (Daniels, 2002). Breeding activity of *H. tigerinus* is highly associated with monsoon rainfall and temporary wetland formation (Padhye et al., 2008). Climate-induced habitat alteration and irregular monsoon patterns may therefore significantly influence population dynamics and reproductive success.

Several studies have reported that amphibian abundance positively correlates with rainfall and wetland hydroperiod stability (Reading, 2007). Prolonged droughts and habitat fragmentation negatively affect juvenile recruitment and adult survivorship (Semlitsch et al., 1996). Despite ecological importance, detailed investigations correlating climatic variables with population dynamics of *H. tigerinus* remain limited in West Bengal. Therefore, the present investigation was undertaken to evaluate the impact of climatic and environmental factors on population fluctuations of *H. tigerinus* across different ecological habitats during 2023–2025.

MATERIALS AND METHODS

Study Area

The present investigation was conducted in selected ecological regions of North 24 Parganas district, West Bengal, India, namely Naihati, Bira, Duttapukur, and Barasat. These regions comprise heterogeneous ecological habitats including agricultural fields, wetlands, marshy areas, temporary water bodies, peri-urban habitats, and urban ecosystems. The selected sites were chosen based on the occurrence and abundance of *Hoplobatrachus tigerinus* as recorded during preliminary field observations and previous regional amphibian studies.

Study Duration

Field investigations were carried out seasonally from April 2023 to September 2025 covering two major climatic periods:

- Pre-monsoon season (April–June)
- Monsoon season (July–September)

Seasonal observations were conducted to assess temporal fluctuations in the population dynamics of *H. tigerinus* in relation to climatic and environmental variables.

Population Sampling and Habitat Survey

Population assessment of *Hoplobatrachus tigerinus* was performed using standard amphibian ecological survey methods following Heyer et al. (1994). Visual Encounter Survey (VES) techniques were employed during morning and evening hours within representative habitats of each study site. Individuals were identified based on external morphological characters described by Daniels (2002) and Chanda (2002).

Direct hand collection and habitat-based observations were conducted in wetlands, paddy fields, marshes, temporary ponds, and adjacent terrestrial habitats. Sex-wise population distribution was determined on the basis of secondary sexual characteristics including body size, vocal sac development, and nuptial pad presence. Population abundance was recorded seasonally and site-wise during the study period.

Environmental and Physicochemical Analysis

Aquatic physicochemical parameters were analyzed from representative water bodies of each study site. Water samples were collected seasonally and analyzed using standard limnological procedures. The following parameters were evaluated:

- Aquatic pH
- Dissolved Oxygen (DO)
- Free Carbon Dioxide (Free CO_2)
- Hardness
- Salinity

Aquatic pH was measured using a digital pH meter, whereas dissolved oxygen was estimated following standard Winkler's method. Free CO_2, hardness, and salinity were determined using standard analytical procedures described for freshwater ecological investigations.

Soil Analysis

Soil samples were collected from frog-inhabited terrestrial zones adjacent to breeding habitats. Soil parameters analyzed included:

- Soil Organic Carbon
- Specific Gravity
- Soil pH

Soil organic carbon was determined following standard soil analytical methods, whereas soil pH was measured using a digital soil pH meter. Specific gravity was estimated through standard gravimetric procedures. These parameters were evaluated to understand the influence of soil characteristics on habitat suitability and population distribution of *H. tigerinus*.

DATA ANALYSIS

Population data were analyzed seasonally and site-wise to evaluate temporal variation in abundance. Relationships between environmental variables and frog population were assessed using comparative ecological analysis. Graphical representations were prepared using Microsoft Excel 2019 to illustrate the association between physicochemical parameters and population dynamics.

Ethical Considerations

Field observations and specimen handling were carried out with minimal habitat disturbance. No specimens were sacrificed during the investigation. Amphibian handling and observational procedures were conducted following standard ethical guidelines for ecological and biodiversity studies.

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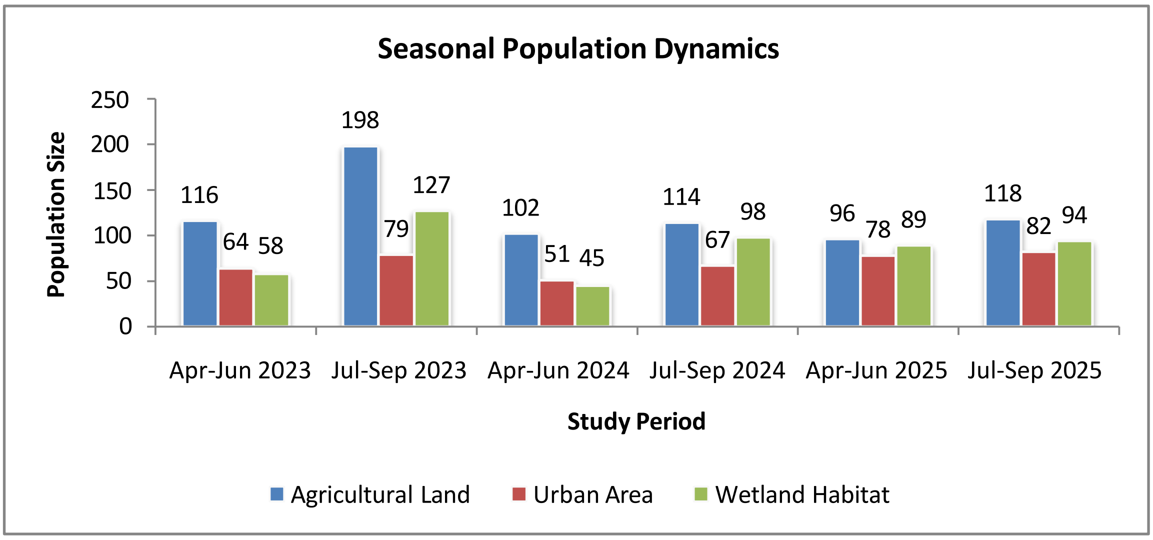
RESULTS

1. Population Dynamics of *Hoplobatrachus tigerinus*

Seasonal Population Dynamics of *Hoplobatrachus tigerinus* (2023–2025)

Study Period	Agricultural Land	Urban Area	Wetland Habitat
Apr-Jun 2023	116	64	58
Jul-Sep 2023	198	79	127
Apr-Jun 2024	102	51	45
Jul-Sep 2024	114	67	98
Apr-Jun 2025	96	78	89
Jul-Sep 2025	118	82	94



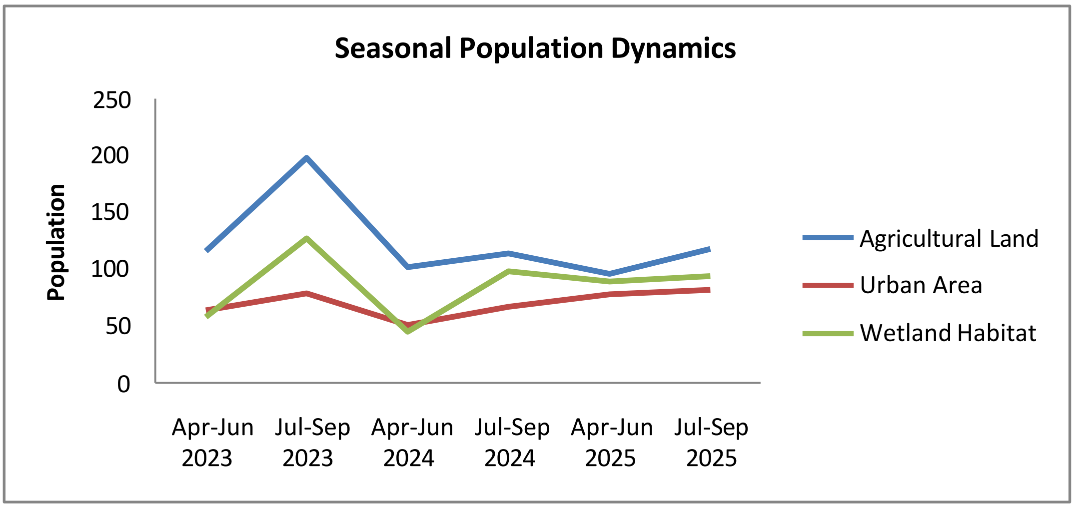


Fig-1: Illustration of the population dynamics of *Hoplobatrachus tigerinus* across different habitats and study periods from 2023 to 2025

Figure-1 illustrates the population dynamics of *Hoplobatrachus tigerinus* across different habitats and study periods from 2023 to 2025. The population showed noticeable seasonal and annual fluctuations throughout the study.
The graph demonstrates a substantial increase in population during monsoon periods, especially in agricultural wetlands. Rainfall and increased humidity positively influenced breeding activity and larval survival (Reading et al., 2007).

The highest population was recorded during the 2023 monsoon season, where the species exhibited a sharp increase compared to the pre-monsoon period. Following this peak, the population declined considerably during the 2024 pre-monsoon season. A moderate rise was again observed during the 2024 monsoon period, followed by slight fluctuations during 2025.

Among all study periods, monsoon seasons consistently supported higher frog populations than pre-monsoon seasons. The population values during 2025 remained relatively stable, indicating gradual recovery after the decline observed in early 2024.

Overall, the graph demonstrates clear temporal variation in the abundance of *Hoplobatrachus tigerinus*, with population peaks occurring during monsoon periods.

Study Site-wise Population Distribution

Table 4. Study Site-wise Population Distribution of *Hoplobatrachus tigerinus*

Year	Study Site	Male	Female	Total Population
2023	Naihati	68	27	95
2023	Bira	185	69	254
2023	Duttapukur	109	58	167
2023	Barasat	79	47	126
2024	Naihati	49	18	67
2024	Bira	105	87	192
2024	Duttapukur	76	61	137
2024	Barasat	49	32	81
2025	Naihati	52	37	89
2025	Bira	103	79	182
2025	Duttapukur	94	71	165
2025	Barasat	73	48	121

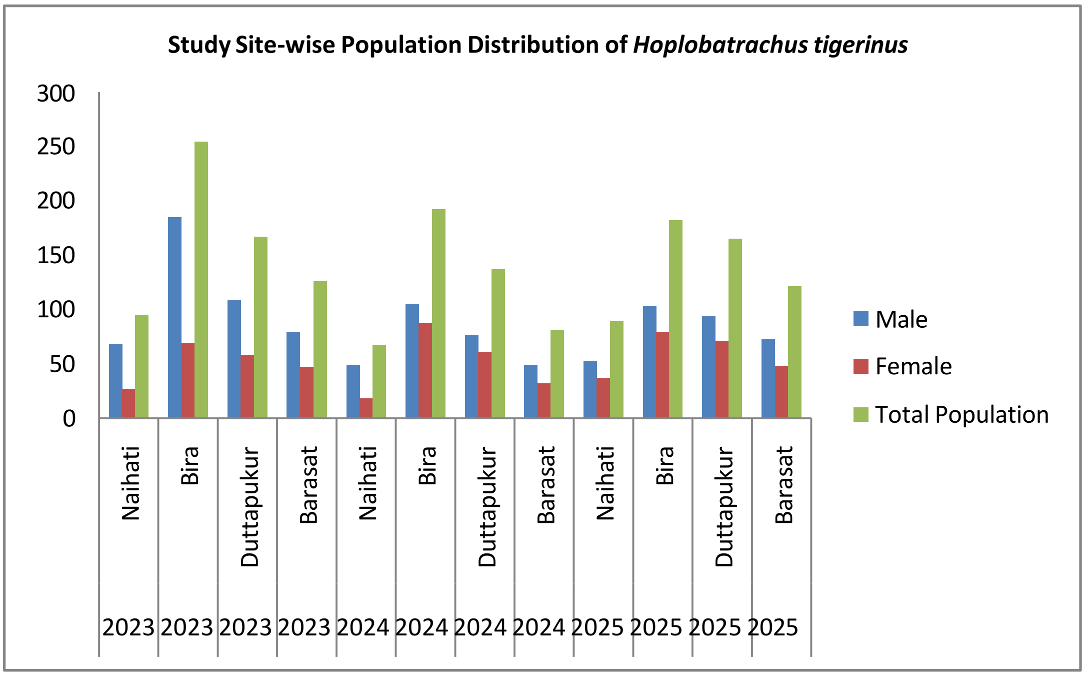


Fig-2: Illustration of the site wise Population Distribution of *Hoplobatrachus tigerinus* across different habitats and study periods from 2023 to 2025

The population of *Hoplobatrachus tigerinus* showed clear site-wise and annual variation during 2023–2025. Bira recorded the highest population throughout the study, with a peak of 254 individuals in 2023, followed by 192 in 2024 and 182 in 2025. Naihati consistently showed the lowest population, ranging from 67 to 95 individuals. Overall population declined during 2024 and showed partial recovery in 2025.

Male frogs were consistently more abundant than females at all study sites. For example, in Bira during 2023, males constituted 185 individuals compared to 69 females. Similar male-biased population structures are common in amphibian breeding assemblages (Duellman and Trueb, 1994).

The higher population in Bira may be associated with favorable habitat and physicochemical conditions observed in previous analyses. Population fluctuations across years may be influenced by climatic variation, habitat quality, and breeding success, which are important regulators of amphibian population dynamics (Wells, 2007; Blaustein et al., 2010).

2. Aquatic Physicochemical Characteristics

Table 1. Aquatic Physicochemical Parameters of Study Areas

Study Area	Aquatic pH	lved Oxygen (mg/L)	Free CO_2 (mg/L)	Hardness (mg/L)	Salinity
Naihati	6.33 ± 0.25	9.04 ± 0.25	9.55 ± 0.09	124.69 ± 0.08	0.33 ± 0.04
Bira	6.37 ± 0.12	9.68 ± 0.04	10.17 ± 0.04	130.04 ± 0.46	0.28 ± 0.02
Duttapukur	6.14 ± 0.03	9.22 ± 0.24	10.46 ± 0.04	128.04 ± 0.48	0.27 ± 0.05
Barasat	6.68 ± 0.11	9.49 ± 0.06	9.79 ± 0.05	128.86 ± 0.12	0.32 ± 0.03

Relationship Between Aquatic pH and Population Density

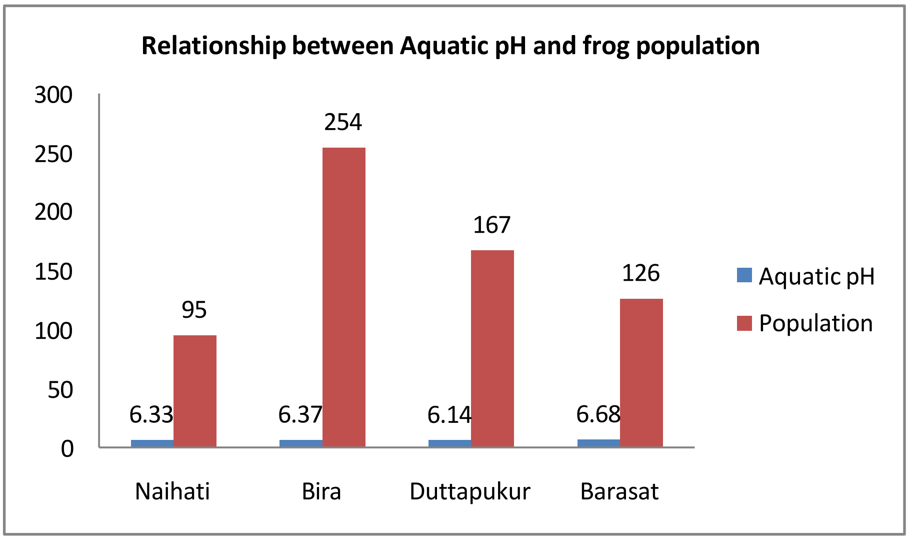


Fig-3. Relationship Between Aquatic pH and Population Density

The graph represents the relationship between aquatic pH and the population of *Hoplobatrachus tigerinus* in four study areas namely Naihati, Bira, Duttapukur, and Barasat. The aquatic pH values ranged from 6.14 to 6.68, while frog population varied between 95 and 254 individuals.

Among the study areas, Bira recorded the highest frog population (254) with an aquatic pH of 6.37. Duttapukur showed a population of 167 at pH 6.14, whereas Barasat exhibited a population of 126 at pH 6.68. The lowest frog population (95) was observed in Naihati where the aquatic pH was 6.33.

The data indicate that *Hoplobatrachus tigerinus* populations were comparatively higher in slightly acidic to near-neutral aquatic conditions

Relationship Between Dissolved Oxygen and Population Density

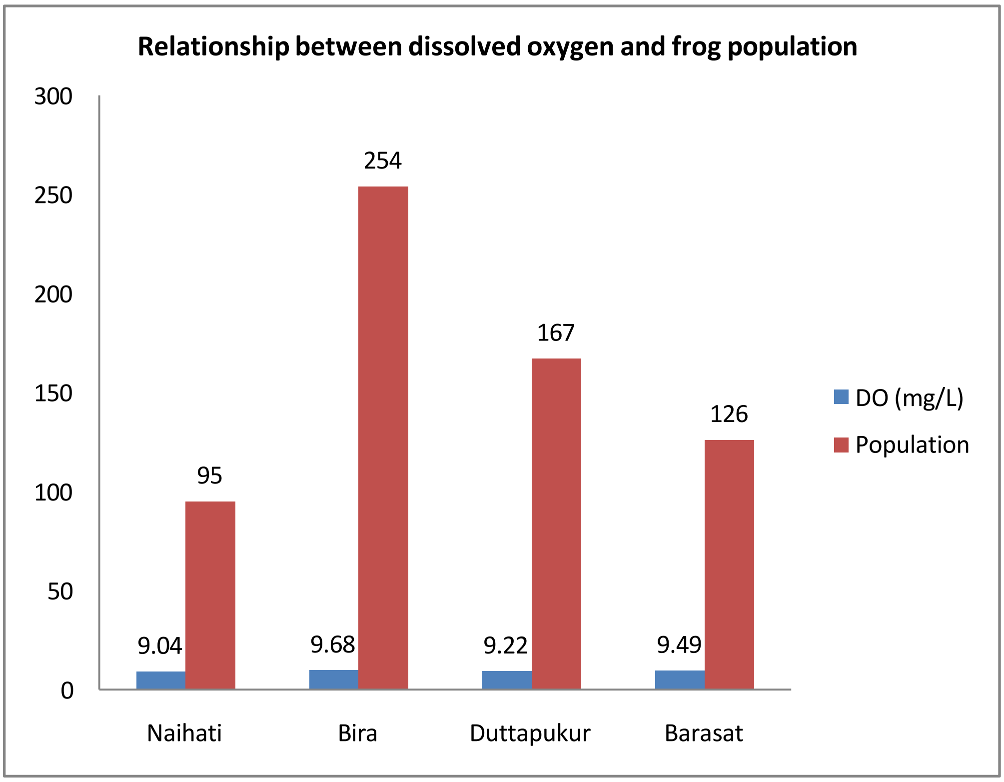


Fig-3. Relationship Between Dissolved Oxygen and Population Density

The graph shows the relationship between dissolved oxygen (DO) concentration and *H. tigerinus* population in four different study areas namely Naihati, Bira, Duttapukur, and Barasat. The dissolved oxygen values ranged from 9.04 mg/L to 9.68 mg/L, while frog population varied from 95 to 254 individuals.

Among the study areas, Bira recorded the highest dissolved oxygen concentration (9.68 mg/L) and also showed the maximum frog population (254). In contrast, Naihati exhibited the lowest dissolved oxygen level (9.04 mg/L) along with the lowest frog population (95). Duttapukur and Barasat showed intermediate dissolved oxygen levels of 9.22 mg/L and 9.49 mg/L with frog populations of 167 and 126 respectively.

The graph indicates that areas with higher dissolved oxygen concentrations generally supported greater *H. tigerinus* abundance.

Relationship between Free CO2 and *H. tigerinus* population

The graph illustrates the relationship between free carbon dioxide (Free CO_2) concentration and the population of *Hoplobatrachus tigerinus* across four study areas. Free CO_2 values ranged from 9.55 to 10.46, while frog population varied from 95 to 254 individuals.

Bira recorded the highest frog population (254) at a Free CO_2 concentration of 10.17, whereas Duttapukur showed a moderate population (167) with the highest CO_2 level (10.46). Naihati exhibited the lowest frog population (95) with the lowest Free CO_2 concentration (9.55), while Barasat showed intermediate values for both parameters.

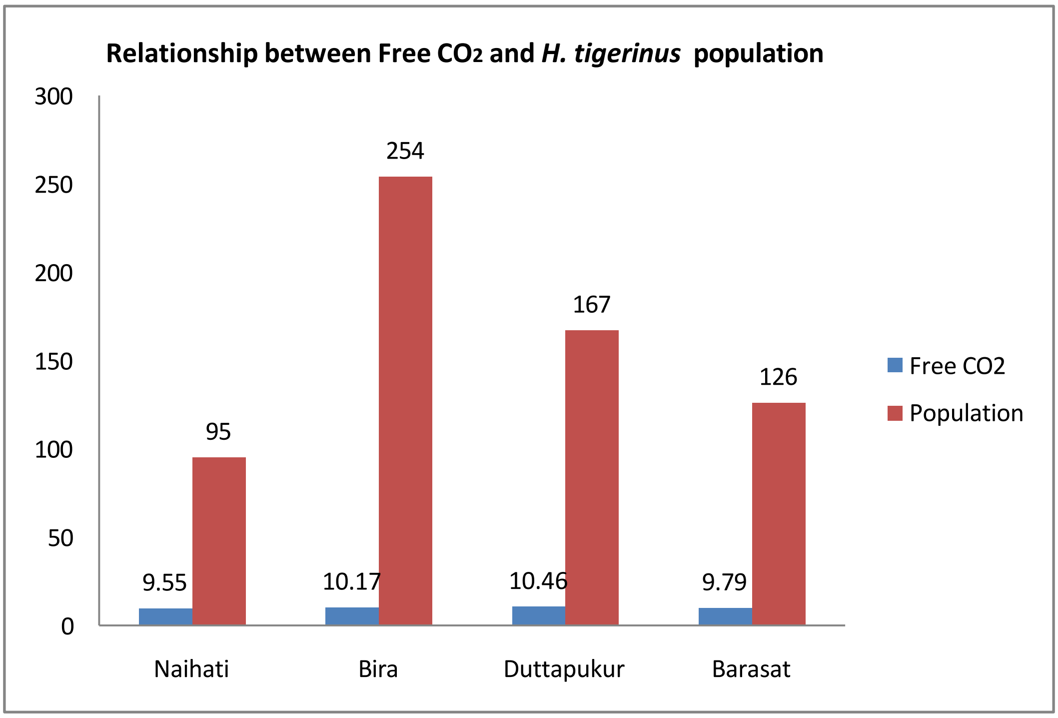
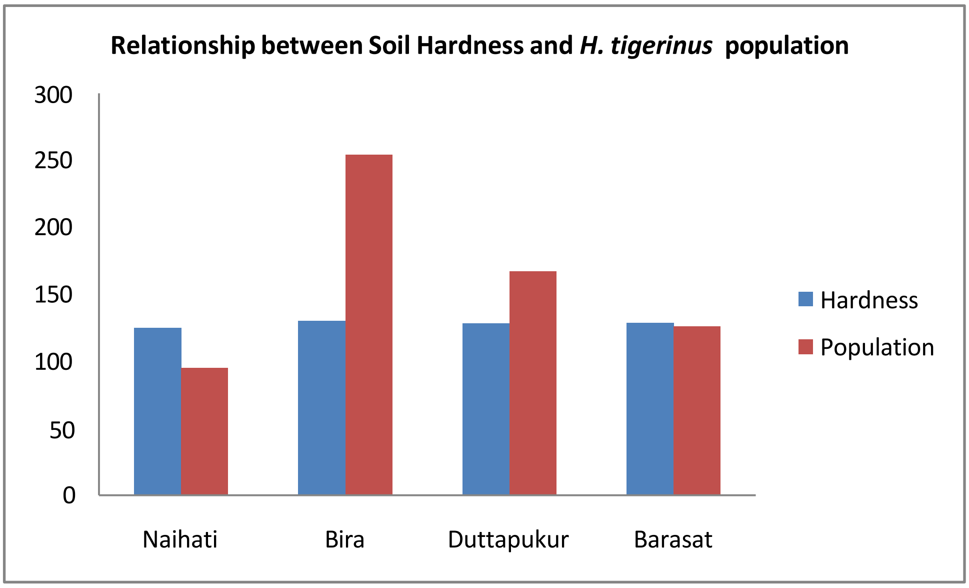


Fig-4. Relationship between Free CO2 and *H. tigerinus* population

The graph suggests a moderate positive relationship between Free CO_2 concentration and frog abundance up to an optimum range. Aquatic free CO_2 is closely linked with primary productivity, microbial decomposition, and nutrient cycling in freshwater ecosystems. Moderate CO_2 levels may enhance aquatic plant growth and productivity, indirectly supporting amphibian populations through improved food availability and habitat quality (Wetzel, 2001). However, excessively high CO_2 concentrations can adversely affect aquatic organisms by reducing dissolved oxygen availability and altering acid–base balance in water bodies (Haslam, 1990). Amphibians are highly sensitive to changes in aquatic physicochemical conditions because of their permeable skin and aquatic larval stages (Duellman and Trueb, 1994). The comparatively high population observed in Bira may therefore reflect a balanced ecological condition where Free CO_2, dissolved oxygen, pH, and habitat quality collectively remained favorable for *H. tigerinus* survival and breeding. Previous ecological studies have shown that amphibian abundance is strongly influenced by water quality parameters including dissolved gases, pH, salinity, and nutrient status (Wells, 2007). The present findings indicate that moderate Free CO_2 concentrations may support productive wetland conditions favorable for sustaining healthy populations of *Hoplobatrachus tigerinus*.

Relationship between Soil Hardness, Salinitys and *H. tigerinus Population*



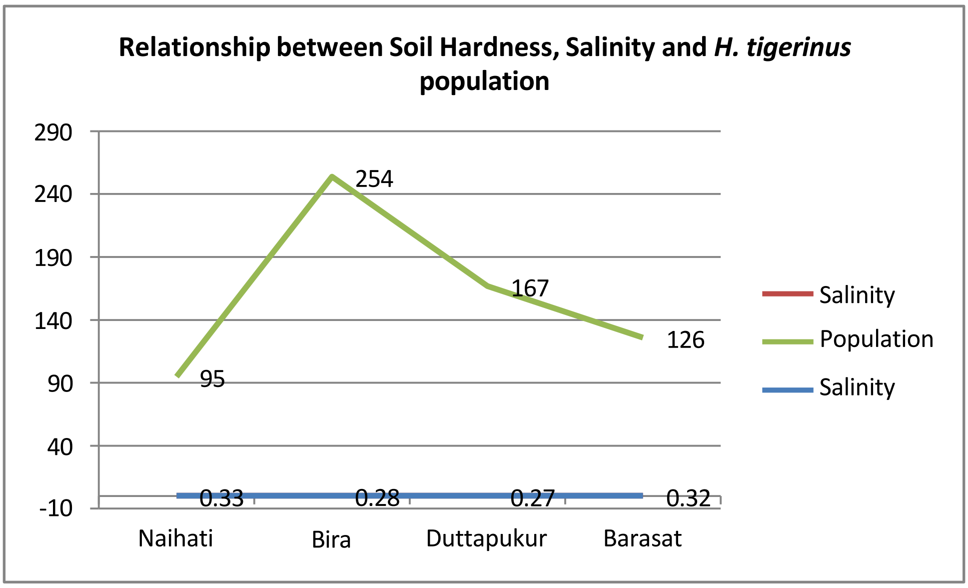


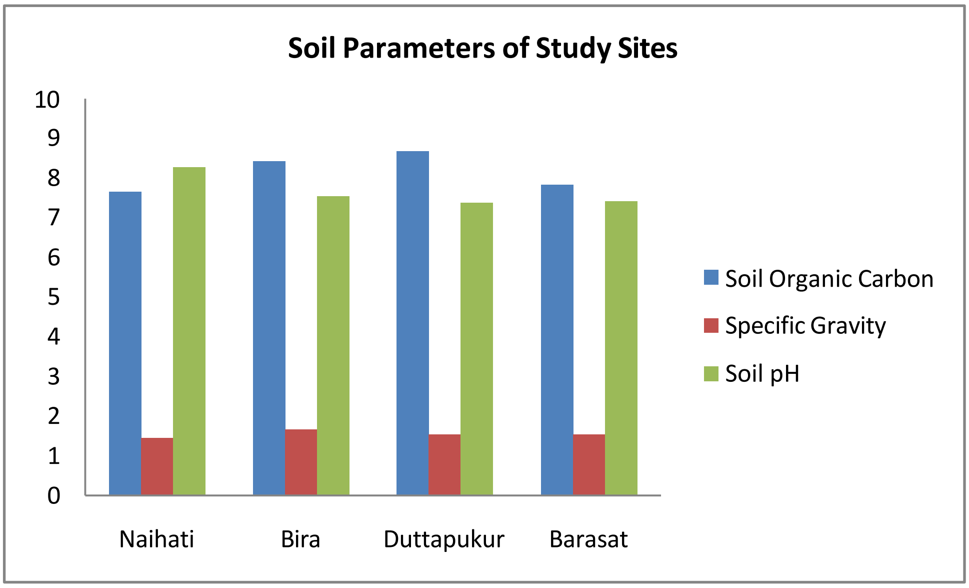
Fig-4:Relationship between Soil Hardness, Salinity and *H. tigerinus Population*

The graph demonstrates the relationship between soil hardness, salinity, and the population dynamics of *Hoplobatrachus tigerinus*. Soil hardness ranged from 124.69 to 130.04, while salinity varied between 0.27 and 0.33. Frog population ranged from 95 individuals in Naihati to 254 individuals in Bira. Bira recorded the highest population with higher soil hardness (130.04) and lower salinity (0.28), whereas Naihati showed the lowest population with lower hardness (124.69) and higher salinity (0.33). The results indicate a positive association between soil hardness and frog abundance, while salinity showed a negative relationship with population density. These findings suggest that moderate soil hardness and lower salinity provide favorable habitat conditions for *H. tigerinus*. Similar observations have been reported in previous amphibian ecological studies (Ahmed et al., 2014; Hopkins and Brodie, 2015).

3. Soil Characteristics

Table 2. Soil Parameters of Study Areas

Study Area	Soil Organic Carbon	Specific Gravity	Soil pH	Population
Naihati	7.65	1.45	8.27	95
Bira	8.42	1.66	7.54	254
Duttapukur	8.68	1.53	7.38	167
Barasat	7.83	1.54	7.42	126



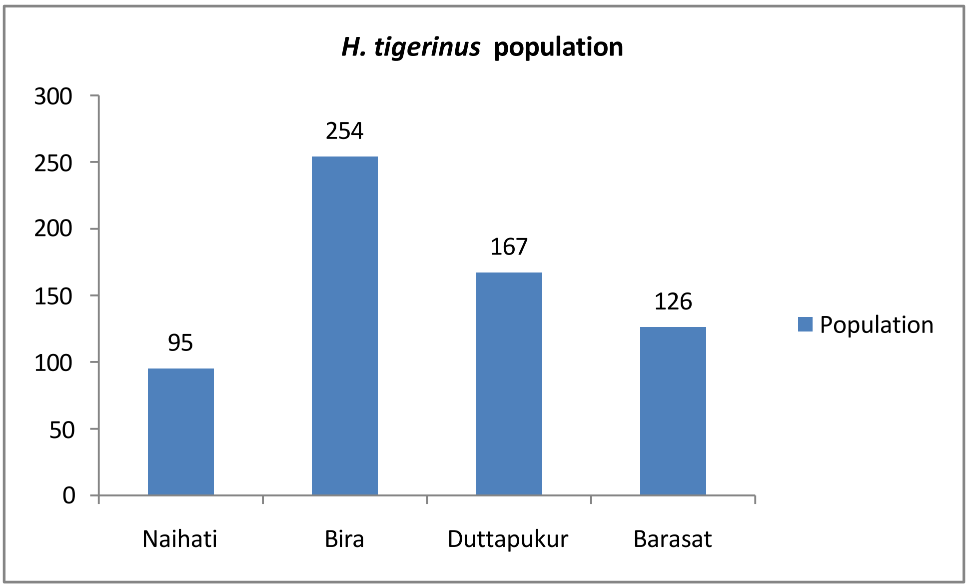


Fig-5: Soil Parameters of Study Sites and Population of *H. tigerinus Population*

The study showed that *Hoplobatrachus tigerinus* population was higher in areas with greater soil organic carbon, moderate specific gravity, and near-neutral soil pH. Bira recorded the highest population (254) with relatively high soil organic carbon (8.42), highest specific gravity (1.66), and near-neutral pH (7.54), whereas Naihati showed the lowest population (95) with lower organic carbon and comparatively alkaline pH (8.27).

The graph suggests that favorable soil conditions enhance habitat suitability for *H. tigerinus*. Higher soil organic carbon improves soil fertility, moisture retention, and prey availability (Brady and Weil, 2016). Near-neutral pH conditions are also known to support amphibian survival, breeding, and larval development, whereas extreme pH may negatively affect amphibian physiology (Duellman and Trueb, 1994). Similar studies have reported that amphibian abundance is strongly influenced by soil quality and physicochemical habitat parameters (Wells, 2007; Sparling et al., 2000). Soil organic carbon positively influenced prey abundance and moisture retention, thereby supporting amphibian habitat suitability (Duellman and Trueb, 1994).

DISCUSSION

The present study demonstrated that climatic and environmental factors significantly influenced the population dynamics of *Hoplobatrachus tigerinus* in different habitats of North 24 Parganas, West Bengal. Monsoon seasons supported higher population abundance compared to pre-monsoon periods, indicating the importance of rainfall and moisture availability for breeding and survival. Similar observations were reported by Reading (2007) and Wells (2007).

Agricultural wetlands supported the highest population density because of favorable hydro-ecological conditions, vegetation cover, and prey availability, whereas urban habitats showed comparatively lower abundance due to habitat fragmentation and anthropogenic disturbances (Cushman, 2006).

Aquatic physicochemical parameters including dissolved oxygen, aquatic pH, free CO_2, soil hardness, and salinity also influenced frog abundance. Higher dissolved oxygen and lower salinity were associated with greater population density, while moderate soil hardness and near-neutral pH favored habitat suitability. Similar findings have been reported in earlier amphibian ecological studies (Ahmed et al., 2014; Hopkins and Brodie, 2015).

Overall, the findings indicate that *H. tigerinus* populations are highly sensitive to climatic variability and habitat quality, emphasizing the ecological importance of wetland conservation.

CONCLUSION

The study concludes that climatic and environmental factors strongly regulate the population dynamics of *Hoplobatrachus tigerinus*. Monsoon rainfall, dissolved oxygen, aquatic pH, soil quality, and habitat characteristics significantly influenced population abundance and breeding activity. Agricultural wetlands provided the most favorable habitats for sustaining healthy populations, whereas urban ecosystems showed reduced abundance because of habitat degradation and anthropogenic disturbances. The study highlights the need for wetland conservation, pollution control, and sustainable habitat management for long-term amphibian conservation in West Bengal.

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