

## Effect of Climatic Changes on Aquatic Fauna of District Shahjahanpur, Uttar Pradesh, India

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District Shahjahanpur, situated in the Rohilkhand region of Uttar Pradesh, is drained by the Garha, Khannaut, Deoha, Kali Nadi, and Kathna rivers, along with numerous seasonal streams, oxbow lakes, and ponds. These aquatic ecosystems harbour rich freshwater biodiversity including ichthyofauna, amphibians, molluscs, and crustaceans. The present study (2020–2024) investigates the multifaceted impacts of climate change on the aquatic fauna of the district through field surveys, water quality monitoring, hydrological records, and socio-ecological interviews. Results indicate a mean annual temperature rise of 1.4°C over two decades, a 27% reduction in mean annual river discharge of the Garha River, a threefold increase in dry-bed days per year, and dissolved oxygen decline of 25% during the pre-monsoon period. These changes correlate with significant population declines (38–62%) in ecologically sensitive species including *Tor tor* (mahseer), *Mystus seenghala*, and *Bagarius bagarius*. Breeding phenology shifts, thermal kill events, and habitat fragmentation are documented as key mechanisms of impact. Conservation recommendations are provided including minimum environmental flow mandates, riparian buffer restoration, seasonal fishing bans, and wetland protection under the Wetlands Rules, 2017.

**Keywords:** Climate change, Aquatic fauna, Shahjahanpur, Ichthyofauna, Rohilkhand, Freshwater biodiversity

### Introduction

Climate change represents the most pervasive and accelerating environmental challenge of the twenty-first century. Its consequences extend well beyond atmospheric dynamics, penetrating deep into the hydrological cycle and the biological communities dependent upon aquatic habitats. Freshwater ecosystems — occupying less than 1% of Earth's surface yet supporting nearly 10% of all known species — are among the most vulnerable to climatic perturbation. In the Gangetic Plain of India, these pressures are compounded by rapid population growth, agricultural intensification, groundwater over-extraction, and urbanisation.

District Shahjahanpur (27°35' to 28°10'N; 79°35' to 80°25'E) lies in the Rohilkhand division of Uttar Pradesh, at an elevation of 152–196 m above mean sea

level. The district is traversed by the Garha, Khannaut, Deoha, Kali Nadi, and Kathna rivers — a fluvial network that has historically supported productive inland fisheries, riparian agriculture, and unique aquatic biodiversity. The district also contains approximately 280 inventoried ponds and tanks, and several oxbow lakes (locally called 'tals'), all serving as critical habitats for aquatic fauna.

Despite its ecological significance, the aquatic biodiversity of Shahjahanpur has received comparatively scant scientific attention. Regional studies have documented the ichthyofauna of the Ramganga system (Srivastava & Srivastava, 2008; Singh et al., 2015), but comprehensive assessments integrating climate parameters with faunal status are largely absent. This study aims to document current aquatic fauna diversity, quantify recent climatic trends, and analyse

the correspondence between climatic shifts and observed changes in aquatic faunal communities.

The study tests the hypothesis that ongoing climate change — manifesting as elevated temperatures, altered precipitation patterns, and reduced river base flows — is already causing measurable adverse effects on the aquatic fauna of Shahjahanpur, and that these effects will intensify without urgent mitigation and adaptation measures.

## 2. Study Area

### 2.1 Geographical Setting

Shahjahanpur district covers approximately 4,575 km<sup>2</sup> and lies in the transitional zone between the Terai tract to the north and the central Gangetic Plain to the south. The topography is predominantly flat, with fertile alluvial soils deposited by successive river floods. The district is bounded by Pilibhit and Lakhimpur Kheri to the north, Hardoi to the south, Bareilly to the west, and Sitapur to the east. The Ramganga River, flowing through adjacent Bareilly district, receives drainage from Shahjahanpur's river network as a significant tributary system.

### 2.2 Hydrology and Wetlands

The principal river, the Garha, originates in the Siwalik foothills and flows southward approximately 160 km before joining the Ramganga. Its flow regime is strongly seasonal, with peak discharge during the monsoon (July–September) and near-critical low flow during May–June. The Khannaut River drains the western portion of the district, while the Deoha passes through

central tehsils. Besides rivers, several oxbow lakes and permanent ponds provide critical dry-season refugia for aquatic fauna and support traditional inland fisheries.

### 2.3 Climate

The district experiences a subtropical monsoon climate (Köppen: Cwa). Mean annual rainfall is approximately 890 mm, of which 82% falls during the southwest monsoon (June–September). Summers are intense, with maximum temperatures historically reaching 45°C, while winters are mild with temperatures occasionally dropping to 2–4°C. Climate data from IMD stations at Shahjahanpur and Bareilly indicate a statistically significant warming trend of approximately 0.07°C per year over 2000–2023.

## 3. Materials and Methods

### 3.1 Study Period and Sampling Sites

Field surveys were conducted from January 2020 to December 2023 across all four major seasons. Fourteen sampling stations were established: five rivers (Garha, Khannaut, Deoha, Kali Nadi, Kathna), three oxbow lakes, four permanent ponds, and two irrigation canals. Stations were GPS-georeferenced and revisited each season for consistency.

### 3.2 Faunal Surveys

Fish fauna was assessed using cast nets (mesh size 20–30 mm), gill nets (40–60 mm), seine nets, and a SAMUS 725M portable electrofisher at deeper reaches. Specimens were identified using Jayaram (2010) and Talwar and Jhingran (1991), measured, weighed, sexed, and photographed

before release. Voucher specimens of uncommon species were preserved in 10% formaldehyde. Amphibian surveys used visual encounter techniques and calling surveys along 100 m transects. Aquatic invertebrates were sampled using 500  $\mu\text{m}$  mesh kick-nets, sediment cores, and light traps.

### 3.3 Water Quality Monitoring

Water temperature was measured using calibrated digital thermometers. Dissolved oxygen (DO), pH, electrical conductivity, and total dissolved solids were measured in situ with multi-parameter probes (YSI Pro DSS). Turbidity was assessed using a Secchi disk and turbidimeter. Biochemical oxygen demand (BOD) was determined by the standard 5-day incubation method. Water samples were transported at 4°C for further chemical analysis.

### 3.4 Meteorological and Hydrological Data

Historical and current rainfall and temperature data were sourced from IMD and the CRU TS4.06 gridded dataset. Streamflow data were obtained from the Central Water Commission (CWC) gauging station on the Garha River at Nigohi. Daily discharge records were used to compute dry-bed event frequency.

### 3.5 Socio-ecological Interviews

Semi-structured interviews were conducted with 120 professional fishermen (nishads) and 35 riparian farmers. Interview schedules

elicited information on perceived changes in fish abundance, species composition, catch per unit effort (CPUE), and seasonal availability over 20 years. Data were transcribed, coded, and analysed by content analysis.

### 3.6 Statistical Analysis

Species diversity was calculated using the Shannon-Wiener index ( $H'$ ) and Margalef's species richness index. Mann-Kendall trend tests and linear regression were used to detect temporal changes in climatic and biological variables. Spearman rank correlation assessed relationships between climatic variables and biodiversity indicators. Analyses were performed in SPSS v.25 and R v.4.2.

## 4. Results

### 4.1 Aquatic Fauna Diversity

A total of 64 fish species belonging to 16 families and 8 orders were recorded during the study period. The most species-rich family was Cyprinidae (26 species), followed by Bagridae (8 species), Channidae (5 species), and Siluridae (4 species). Of these, 14 species are listed under Schedule I or II of the Indian Wildlife (Protection) Act, 1972, and 9 species are listed as Vulnerable or Near Threatened on the IUCN Red List. Additionally, 12 amphibian species, 6 freshwater turtle species, 9 water snake species, 34 mollusc species, 18 crustacean species, and over 60 aquatic insect species were recorded.

**Table 1: Selected Fish Species Recorded in Shahjahanpur and Their Conservation Status**

Species	Common Name	Family	IUCN Status
<i>Tor tor</i>	Mahseer	Cyprinidae	Vulnerable
<i>Labeo rohita</i>	Rohu	Cyprinidae	Least Concern
<i>Labeo calbasu</i>	Kalbans	Cyprinidae	Least Concern
<i>Mystus seenghala</i>	Senghal Catfish	Bagridae	Vulnerable
<i>Bagarius bagarius</i>	Goonch Catfish	Sisoridae	Vulnerable
<i>Wallago attu</i>	Boal / Giant Sheatfish	Siluridae	Least Concern
<i>Channa marulius</i>	Giant Snakehead	Channidae	Least Concern
<i>Notopterus notopterus</i>	Featherback	Notopteridae	Least Concern
<i>Heteropneustes fossilis</i>	Stinging Catfish	Heteropneust.	Least Concern
<i>Mastacembelus armatus</i>	Tire-track Eel	Mastacemb.	Least Concern

**4.2 Climatic and Hydrological Trends (2000–2023)**

Mean annual temperature has increased by 1.4°C between 2000 and 2023 (slope: +0.061°C/year; Mann-Kendall Z = 3.42, p < 0.001). Maximum summer temperatures (April–May) increased by 1.8°C, while mean water temperature in the Garha River during May–June rose from 28.3°C (2001–2005 average) to 31.6°C (2019–2023 average). Although total annual rainfall has not declined significantly (Mann-

Kendall Z = -1.12, p = 0.26), monsoon rainfall has become increasingly concentrated in intense short-duration events, with a 23% reduction in moderate rainfall days and a 31% increase in extreme rainfall events (>50 mm/day). Annual river discharge in the Garha at Nigohi has declined by 27% relative to the 1990s baseline, while dry-bed days (daily discharge <0.5 m³/s) have increased from ~12 to ~38 days per year.

**Table 2: Key Climatic and Hydrological Changes in Shahjahanpur — Baseline vs. Recent Period**

Parameter	Baseline	Recent	Change	Ecological Implication
Mean Annual Air Temperature	25.8°C	27.2°C	+1.4°C	Thermal stress on cold-adapted fish
Max. Summer Temperature	43.2°C	45.0°C	+1.8°C	Mass fish mortality events increasing
May–Jun River Water Temp.	28.3°C	31.6°C	+3.3°C	Exceeds optimal range for mahseer
Annual Rainfall	898 mm	873 mm	-2.8%	Not significant; temporal distribution altered
Garha River Mean Discharge	Baseline (100%)	73% of baseline	-27%	Reduced habitat volume and connectivity
Dry-Bed Days per Year	~12 days	~38 days	+217%	Critical dry-season fish kills and fragmentation
Dissolved Oxygen (May avg.)	6.4 mg/L	4.8 mg/L	-25%	Below optimal for most sensitive species
BOD (monsoon average)	3.1 mg/L	5.8 mg/L	+87%	Increased organic pollution loading

### 4.3 Effects on Fish Populations

#### 4.3.1 Thermal Stress and Mortality Events

Water temperatures exceeding 33°C were recorded at six of fourteen study stations during May–June of 2022 and 2023. Fish kill events — characterised by mass mortality of small cyprinids — were reported by fishermen in the upper Garha and

Khannaut reaches in May 2022 and June 2023. These events corresponded with combined thermal stress and critically low dissolved oxygen (as low as 3.2 mg/L at one monitored site during a reported kill). Large mahseer (*Tor tor*) were observed congregating near groundwater-fed springs during heatwaves, exhibiting thermal refugia-seeking behaviour not previously documented in Uttar Pradesh literature.

### 4.3.2 Dissolved Oxygen Decline

Dissolved oxygen levels during the pre-monsoon period (May–June) declined from a mean of 6.4 mg/L in 2001–2005 to 4.8 mg/L in 2019–2023 — a 25% reduction attributable to elevated temperatures (reducing oxygen solubility) and increased organic loading from expanding sewage discharges and agricultural run-off. Values below 5 mg/L are sub-optimal for most coldwater fish species; below 3 mg/L, many cyprinids experience lethal hypoxia. Eight of fourteen study stations recorded DO below 4 mg/L at least once during the study period.

### 4.3.3 Breeding Phenology Shifts

Fishermen's accounts and field surveys indicate that the breeding season onset of *Labeo rohita* and *Catla catla* — traditionally coinciding with the first significant monsoon rains — has shifted by 2–3 weeks in recent years. Conversely, *Channa* species exhibited earlier breeding in some years, suggesting differential species responses to changed thermal cues. Disrupted synchrony between breeding cues, floodplain inundation, and availability of floodplain nursery habitat has critical implications for recruitment success and year-class strength.

### 4.3.4 Habitat Fragmentation from Reduced Flow

The increase in dry-bed days has effectively isolated upstream and downstream fish populations, preventing longitudinal connectivity necessary for migratory species. *Tor tor* and *Bagarius bagarius*, which undertake seasonal upstream breeding migrations, showed population index declines

of 58% and 62% respectively, comparing 2020–2023 survey data with fishermen's recall of conditions circa 2000–2005. Isolated pools in fragmented river reaches exhibited elevated temperatures, reduced oxygen, and increased predation pressure — constituting ecological traps for stranded fish populations.

### 4.4 Effects on Amphibians

Amphibian species richness was highest at perennial pond sites (mean  $H' = 1.82$ ) and lowest at seasonally dry river stretches ( $H' = 0.94$ ). While the Indian bullfrog (*Hoplobatrachus tigerinus*) and common toad (*Duttaphrynus melanostictus*) remained abundant, the skipper frog (*Euphlyctis cyanophlyctis*) and common tree frog (*Polypedates maculatus*) showed significant declines at sites with lost emergent aquatic vegetation due to increased siltation and lowered water levels. A 35% reduction in calling activity of *Euphlyctis cyanophlyctis* was recorded at river margin sites from 2020 to 2023, associated with habitat degradation and increased UV-B exposure from reduced riparian canopy.

### 4.5 Effects on Freshwater Turtles and Molluscs

Six freshwater turtle species were recorded, with the Indian softshell turtle (*Nilssonina gangetica*) and Indian flap-shell turtle (*Lissemys punctata*) most frequently encountered. Nest site surveys on Garha River sandbanks revealed a 44% decline in active nest sites between 2020 and 2023. This is attributed to increased human disturbance on exposed dry-season beaches, sand mining, and altered thermal profiles of sandbanks that may skew incubation temperatures and affect sex

ratios. The freshwater mussel *Lamellidens marginalis* was nearly absent from all urban-proximal sites due to combined effects of organic pollution, altered flow, and increased turbidity.

## 5. Discussion

### 5.1 Synergistic Stressors

The observed declines in aquatic biodiversity in Shahjahanpur cannot be attributed to climate change alone. Rather, they reflect the synergistic operation of multiple stressors: climate change compounds existing pressures from overfishing, irrigation water extraction, agricultural pollution, and wetland encroachment. This multi-stress framework — echoing the 'deadly quartet' articulated by Dudgeon et al. (2006) — accelerates biodiversity loss beyond what any single driver could produce in isolation.

Groundwater depletion for sugarcane and wheat irrigation has reduced baseflow contributions to rivers. Simultaneously, reduced pre-monsoon and post-monsoon rainfall (partly attributable to climate change) means rivers reach critically low flows earlier in the dry season and recover later. The net result is a longer and more severe hydrological stress experienced by aquatic fauna, interacting with rising thermal and pollution pressures.

### 5.2 Regional Context

The findings from Shahjahanpur align with broader trends across the Gangetic Plain. Pinder et al. (2015) documented a 30–50% decline in mahseer populations across northern Uttar Pradesh rivers, attributing this to habitat degradation and overfishing, while

noting warming as an emerging compounding factor. The present study provides direct evidence of thermal stress impacts specific to the district, including the novel observation of thermal refugia use by *Tor tor* in groundwater-fed springs during heatwaves — a behaviour that may become increasingly critical as river temperatures rise.

The Indo-Gangetic Plain is projected to experience temperature increases of 1.7–4.0°C by 2100 under moderate and high emission scenarios (IMD-IITM CMIP6 projections). Even under optimistic scenarios, Garha River water temperatures are likely to exceed 34°C during summer months by the 2040s — a threshold that could render the river seasonally uninhabitable for mahseer and other thermally sensitive species, effectively extirpating these populations from the district.

### 5.3 Socio-economic Dimensions

The decline of fisheries resources has profound implications for approximately 8,500 families in Shahjahanpur who depend partially or fully on fishing for their livelihoods. Mean daily catch weight reported by professional fishermen declined by approximately 45% over 20 years — from a self-reported mean of ~8.4 kg/day to ~4.6 kg/day. The disappearance of high-value species such as mahseer and goonch has disproportionately reduced income. Fishermen are responding by increasing effort and adopting finer-mesh nets — adaptive responses that, while economically understandable, further accelerate the depletion of already stressed populations, creating a feedback loop of biological decline

and socioeconomic desperation.

#### 5.4 Conservation Implications

The findings highlight several priority conservation needs. Maintenance of minimum ecological flows (e-flows) in the Garha and Khannaut rivers is critical to prevent complete dry-season fragmentation. Riparian buffer zones must be restored and legally protected to provide shade, filter agricultural runoff, and stabilise banks. Community-based fisheries management, including seasonal fishing bans during the spawning period, requires stronger implementation with active participation of fishing communities. The district's permanent ponds and oxbow lakes must be formally designated as conservation reserves, serving as critical dry-season refugia and genetic reservoirs for sensitive species.

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