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BEFORE THE HON'BLE NATIONAL GREEN TRIBUNAL
PRINCIPAL BENCH, NEW DELHI

ORIGINAL APPLICATION No. 361 OF 2018

IN THE MATTER OF

Narmada Pradushan Nivaran Samiti & Ors.

.....Applicants

Verses

Ministry of Environment, Forest and Climate Change & Ors.Respondents

ADDITIONAL REPLY AFFIDAVIT/FURTHER PROGRESS REPORT ON

BEHALF OF RESPONDENT NO.4/ SARDAR SAROVAR NARMADA

NIGAM

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Filed Through,

Parth H. Bhatt Advocate

For Respondent No. 4


Superintending Engineer
Narmada Project Head Works Circle
S.S.N.L., Ekta Nagar

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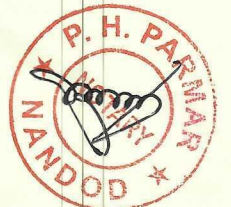
Ministry of Environment, Forest and Climate Change & Ors.Respondents

**ADDITIONAL REPLY AFFIDAVIT/FURTHER PROGRESS REPORT ON
BEHALF OF RESPONDENT NO. 4/ SARDAR SAROVAR NARMADA
NIGAM**

I, Shubham S. Goyal, age- 31, serving as Superintending Engineer being authorised signatory and representative of Narmada Project Head Work Circle, Sardar Sarovar Narmada Nigam Ltd., having communication address at 406, 4th floor, New Administrative Building, Ekta Nagar, District Narmada, Gujarat – 393151, the authorised signatory of the respondent No. 4, do hereby state on solemn oath and make this affidavit as under:

1. I am filing the present affidavit in compliance of the order dated 23.02.2026 passed by this Hon'ble Tribunal, whereby this Hon'ble Tribunal was pleased to direct the answering respondent to submit the report prepared by Central Inland Fisheries Research Institute (hereinafter referred to as 'CIFRI') before this Hon'ble Tribunal. The paragraph 3 of the order is reproduced herein for ready reference of the Hon'ble Tribunal.


Superintending Engineer
Narmada Project Head Works Circle
S.S.N.N.L., Ekta Nagar





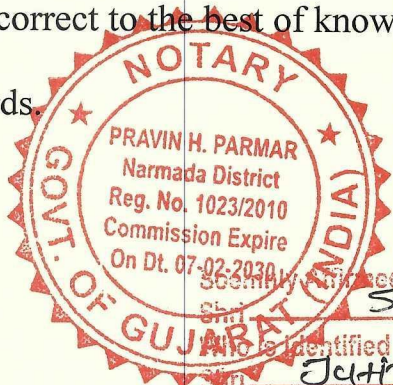
Para 3 of the order dated 23.02.2026, "Respondent no. 4 is directed to ensure that report from the CIFRI, Kolkata is received within the time limit as disclosed today. He is directed to place on record the report before the next date of hearing."

2. In compliance whereof, the answering respondent hereby submits the report received from CIFRI on 06.05.2026 for the consideration of this Hon'ble Tribunal. Annexed hereto and marked as Annexure - R1 is the copy of report dated 25.04.2026 which is received by the answering respondent on 06.05.2026.
3. Further, in compliance of the directions contained in 97th meeting of the Narmada Control Authority (NCA) convened on 28.01.2026, whereby the answering respondent was directed to submit a copy of the report obtained from CIFRI before this Hon'ble Tribunal for its consideration and also to the Executive Member (NCA) and Chairman of the E-Flow Committee, the answering respondent has in due compliance thereof also submitted a copy of the report to the concerned authority for their consideration, deliberation and further action.

Verification

Verified at Gandeshwar on 12/05/2026 that the contents of above affidavit are true and correct to the best of knowledge and belief and derived from the official records.

[Signature]
I Know the Person who Signed the Document. He Signed this Document in my Presence.



[Signature]
DEPONENT

NOTARY

Regd. No.:- 371
Date:- 12/05/2026

Subscribed / Declared before me
Shri Subham S. Goyal
Who is identified by
Shri Jitimbhai B. Dhimu
Whom I Know Personally

Superintending Engineer
Narmada Project Head Works Circle
S.S.N.N.L., Ekta Nagar

[Signature]
PRAVIN H. PARMAR (ADVOCATE,
NOTARY Public (Govt. Of Gujarat)
NANDOD Dist. Narmada

FINAL REPORT
ON
ASSESSMENT OF ENVIRONMENTAL FLOW TOWARDS RIVER
HABITAT AND ECOLOGICAL REQUIREMENT WITH A FOCUS ON
DOWNSTREAM FISH SPECIES OF SARDAR SAROVAR DAM (SSD) IN
NARMADA RIVER



Submitted to:

SARDAR SAROVAR NARMADA NIGAM LTD, Govt. of Gujarat



ICAR – CENTRAL INLAND FISHERIES RESEARCH INSTITUTE
BARRACKPORE, KOLKATA-700120

1315

PROJECT TEAM

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Sponsored By:

Sardar Sarovar Narmada Nigam Limited, Govt. Of Gujarat

Submitted By:

ICAR – Central Inland Fisheries Research Institute

Barrackpore, Kolkata-700120



भा.कृ.अनु.प. - केंद्रीय अन्तर्स्थलीय मात्स्यिकी अनुसंधान संस्थान

AN ISO 9001 : 2015 Certified Organization

ICAR - CENTRAL INLAND FISHERIES RESEARCH INSTITUTE

Barrackpore Kolkata, West Bengal - 700 120

Foreword

Sardar Sarovar Narmada Nigam Limited (SSNNL), vide letter No. SSNNL/Env/CIFRI/e-flow/119 dated 15 March, 2025, entrusted ICAR-Central Inland Fisheries Research Institute (CIFRI) with a consultancy assignment on "Assessment of Environmental Flow towards River Habitat and Ecological Requirement, with a focus on downstream fish species of the Sardar Sarovar Dam in the Narmada River." This initiative reflects the increasing national priority on defining scientifically robust environmental flow regimes to sustain riverine ecosystems alongside developmental interventions.

An expert multidisciplinary team from ICAR-CIFRI carried out comprehensive field investigations during both pre-monsoon and post-monsoon periods, capturing seasonal variability in river dynamics. The study examined key biotic and abiotic parameters governing river health, including fish diversity, migratory species, habitat characteristics, planktonic productivity, and benthic communities. Hydrological assessment using Acoustic Doppler Current Profiler (ADCP) enabled precise estimation of discharge and flow velocity across nine strategically selected sampling sites during the post-monsoon phase.

To estimate environmental flows, hydraulic simulations were undertaken using the HEC-RAS model, integrating physical habitat conditions with ecological requirements of key fish species. Based on habitat characteristics and species composition, the river stretch between the dam and Bhadbhut was classified into three distinct ecological zones: Zone I, represented by Mahseer; Zone II, characterized by major carps; and Zone III, represented by Hilsa. Habitat suitability assessments for these representative species provided the scientific basis for recommending optimal environmental flow regimes supporting balanced ecological function in the selected stretches.

I place on record my sincere appreciation for the dedicated efforts of the scientists, technical officers, administrative personnel, and supporting staff of ICAR-CIFRI for their rigorous field investigations, data analysis, and report preparation. I also acknowledge the valuable cooperation extended by officials of SSNNL and the Narmada Control Authority during field visits and coordination, which was instrumental in the successful completion of this study. The findings of this study are expected to serve as a scientific reference for policy formulation, and regulatory decision-making, aimed at balancing ecological sustainability with water resource development.

Date: 25 April 2026
Place: Barrackpore


(Pradip Dey)
DIRECTOR

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Executive Summary

An investigation on “**Assessment of Environmental Flow Towards River Habitat and Ecological Requirements With a Focus on Downstream Fish Species of Sardar Sarovar Dam (SSD) in Narmada River**” was carried out during June 2025 and November 2025 covering pre-monsoon and post-monsoon with the following objectives 1) to assess the seasonal hydrological and hydraulic dynamics in the study area 2) to assess the seasonal habitat requirement (ecology) of the key stone fish species and major fish diversity 3) to estimate E-flow for fish diversity employing the hydraulic cum habitat simulation method. Based on fish abundance, water quality, varying substrate/habitat, water requirement in terms of environmental flows in the downstream of SSD was determined. Nine sampling sites were identified in the downstream of SSD between SSD to Bhadbhut covering about 130 km longitudinally.

The habitat profile of the river Narmada was assessed during the study period. The habitat factors that influence fish to complete their lifecycle are substrate type, deep pools, scar pools, riparian vegetation, water depth, water flow, river gradient, width of the wetted channel, flood plains, etc. The values of the habitat profile obtained during the study period showed no significant variations in habitat profile in both seasons, except for depth and water velocity. In pre-monsoon sampling average depth in the sampling sites varied from 3.26 m. to 10.3 m, whereas it was between 0.97 and 6.85 m. during the post-monsoon period, which showed slightly less value than the pre-monsoon season. Water velocity recorded ranged from 0.25 to 1.30 m./sec. in the pre-monsoon season and 0.17 to 1.06 m./sec in post-monsoon sampling, which is again a slightly higher value during the pre-monsoon season than post monsoon. The remaining parameters were almost the same in both the seasons, which is acceptable for aquatic life.

During the post-monsoon season, Acoustic Doppler Current Profiler (ADCP) survey was conducted along the lower stretch of the Narmada River. Width of the channel, water discharge, depth, mean depth, and water velocity were the key parameters recorded by the ADCP survey. Downstream variations of river width towards the estuarine zone were recorded, which gradually increased. Width ranged from 213.7 m at Garudeshwar to 965.95 m at Bhadbhut, with notable widening at Bharuch (785.55 m) and Sakkarpura (589.9 m). Maximum water velocity (3.03 m/s) was recorded from Bhadbhut, and the minimum water velocity (0.85

m/s) was recorded from Jhanor. Other parameters, like depth and water discharge data, were also recorded during the survey.

A total of 3352 fish belonging to 12 orders, 20 families, 36 genera, and 47 fish species have been documented from the sampling sites of the river Narmada during pre-monsoon (June' 25) and post-monsoon (November'25) sampling. During pre-monsoon sampling 36 no. fish species have been documented, and 42 species have been recorded during the post-monsoon period. *Labeo bata*, *Labeo gonius*, *Protonibea diacanthus*, *Osteochilus vittatus*, *Channa punctatus*, *Channa striatus*, *Rhinomugil corsula* and *Cynoglossus cynoglossus* were recorded during the post-monsoon season, whereas *Labeo dyocheilus*, *Channa marulius* and *Parambassis ranga* were documented in the pre-monsoon season, and the remaining species were recorded in both seasons. Fish species dominance obtained from the above study, showed cyprinid was the major group (36.07%), followed by Bagridae (8.51%), Channidae (6.38%), and Sciaenidae (4.25%) respectively. Maximum species richness in both seasons was recorded at Garudeshwar (n=30, 63.82%), followed by Sisodra (n= 29, 61.70%), Poicha (n=24, 51.06%), and Jhanor (n=21, 44.68%), respectively. Significantly, it has been found that species richness gradually decreased with the decrease in river elevation.

The Index of Biotic Integrity (IBI) was calculated in all the sampling stations, and the calculated score showed acceptable and moderately acceptable, which are favourable for freshwater habitats.

As far as water quality is concerned, no such significant differences were found in pH, Hardness, Total Alkalinity, Conductivity, Salinity, TDS, Free CO₂, Dissolve oxygen (D.O), Total Hardness, Nitrate, Silicate, Chlorinity, BOD, Chlorophyll, Available Phosphate, Total Nitrogen, and nutrient parameters except water temperature and dissolved oxygen. During the pre-monsoon period, water temperature across the sampling stations remained relatively high, ranging from about 25.5°C to 28.03 °C. In contrast, during the post-monsoon period, water temperature declined at all stations, ranging between 23°C and 27 °C.

A total of six phytoplankton taxa were observed from the downstream of the Sardar Sarovar Dam (SSD) on the Narmada River during the pre-monsoon study from 9 different sampling stations. Among all the recorded phytoplankton groups, *Pediastrum simplex* was found to be the most abundant. During the post-monsoon period, a total of five phytoplankton taxa were recorded during this period. Among the recorded taxa, *Pediastrum* sp. exhibited the highest cell density (1300 cells/ml), indicating its dominance and strong adaptability under

post-monsoon environmental conditions. During the pre-monsoon season, the zooplankton community was dominated by copepods, with *Mesocyclops* being the most abundant. In contrast, the post-monsoon season showed a slight variation in species composition, with the occurrence of *Keratella* sp. (Rotifera) and *Cyclops* sp. The less abundance and limited diversity of zooplankton during both the seasons indicates a sparse zooplankton community structure in the study area.

A total of thirteen macro and meiobenthic taxa were recorded from the downstream stretch of the Sardar Sarovar Dam (SSD) on the Narmada River during the pre-monsoon season. During the post-monsoon season, six benthic macroinvertebrate species, all belonging to Mollusca, were recorded from the same study area. The gastropod assemblage comprised *Tarebia granifera*, *Bellamya crassa*, *Thiara tuberculata*, and *Bellamya dissimilis*, while the bivalve fauna included *Corbicula striatella* and *Parreysia favidens*. The occurrence of both gastropod and bivalve species during the post-monsoon period reflects a moderately diverse molluscan assemblage in the downstream stretch of the SSD.

In the present investigation, environmental flows (E-flows) was estimated between SSD and Bhadbhut based on river habitat and key fish species hydrological requirement. The entire stretch was classified into three zones (Zone-I; the habitat is suitable for Mahseer fish; Zone II: habitat suitable for large bodied Carp species; Zone III: habitat suitable for commercial important Hilsa and Seabass fish species). All species are migratory in nature either long or short migrants. Mahseer migrates within the freshwater stretch and is of high importance from native conservation point of view. While, Hilsa is an anadromous which migrates from Sea to River. Keeping these criteria, e-flows was estimated by habitat cum hydraulic rating curve using HEC-RAS model. The simulation was done at Poicha, Sisorda and Shuklatirth. These three sites are the representation of the key fish species habitat suitability. Poicha as Mahseer species, Sisorda as large bodied Carps and Shuklatirth as Hilsa habitat suitability. Based on the habitat suitability of fish species depth and velocity, the HEC-RAS model was set. As the zones are varied with river habitat and key fish species, the environmental flows requirement also varied. **Based on the habitat requirement for selected key stone fish species, environmental flows between SSD and Bhadbhut was estimated and recommended as discharge of 35 to 40 cumec is optimum.** This discharge was found as most suitable for the Mahseer, Carp and Hilsa. As Hilsa migrates in a shoal, water requirement becomes a critical factor. **Therefore, specific environmental flows of 40 cumec is suitable for Hilsa in the downstream mostly at Shuklatirth and down. This discharge will support the**

downstream river ecology and fish species during the lean/pre-monsoon/post-monsoon period (excluding July to September). While, simulation results showed a discharge of 450 to 500 cumec is suitable for Monsoon period (July to September) to maintain the suitable depth and velocity for fish migration. Based on the previous time series hydrological data at SSD, higher discharge, than the recommendation as above is recorded during monsoon in normal year. Therefore, the recommended monsoon flows will be the regular flows discharge from the SSD as spillover during monsoon.

This pattern of flow release (lean/pre-monsoon/post monsoon and monsoon) is critical for both vertical and horizontal migration and breeding of the Masheer, Hilsa and indigenous fish species in the river Narmada below SSD. Flow release during July to September triggers the reproductive behaviour resulting in upstream migration. In addition, this timing of flow supports the life stages e.g spawning, hatching, rearing and movement of fish species. Hence, it is vital to ensure the above recommended flow release from the Dam site during pre-monsoon/post monsoon/lean and monsoon seasons.

Introduction

Environmental flow:

Environmental flow is described as the quantity, timing, and quality of water flows required to sustain freshwater and estuarine ecosystems and human livelihood and well-being that depend on these ecosystems. Environmental flow within a river plays a pivotal role for provides important goods and ecological services to society, including fisheries. It is supporting habitat, maintaining water tables, and facilitating fish species movement. Water provides in the river supports ecological integrity, reduces aquatic weeds, improves river health, sustenance of native fish species, river dependence plants and animals that rely on different flows to trigger migration and breeding. It is evident that due to the overall environmental degradation, like diminishing water flow and manmade interferences in the catchment area of the river basin, there has been a perceptible decline in both fish productivity and diversity. Therefore, it is necessary to give added emphasis to fisheries as well as the changed environmental conditions for eco-restoration and development of norms for management towards the sustenance of the necessary environmental flow in the river. With this backdrop, the present investigation was designed to address the following objectives

Objectives of the study:

- To assess the seasonal hydrological and hydraulic dynamics in the study area
- To assess the seasonal habitat requirement (ecology) of the key stone fish species and major fish diversity
- To estimate environmental flow for fish diversity employing the hydraulic cum habitat simulation method

River Narmada

Large rivers and their floodplains support a significant proportion of the world's biodiversity and provide economic upliftment, drinking water, agriculture through irrigation, facilitate transport, and serve as habitats for diverse ecosystems, including fisheries. From time immemorial, the river Narmada has been India's river of faith, devotion, and worship. The Narmada, a Sanskrit word meaning 'the Giver of Pleasure', is one of the most sacred rivers in India. It is the longest West-flowing river rising from a spring at a height of 1057 m above MSL on the summit of Amarkantak hill in Shadol district of Madhya Pradesh. The total length of the Narmada from the source of its outfall into the Gulf of Cambay in the Bharuch district of Gujarat is 1312 kms.

The Narmada basin lies between east longitudes 72° 32' to 81° 45' and north latitude 21° 20' to 23° 45', lying on the northern extremity of the Deccan plateau and extending over an area of 98796 km² (38,145.3 sq. mi.). The basin covers large areas in the states of Madhya Pradesh (86%), Gujarat (14%), and a comparatively smaller area (2%) in Maharashtra. In the river course of 1,312 km (815.2 mi.), there are 41 tributaries, out of which 22 are from the Satpura range and the rest on the right bank are from the Vindhya range.

The river serves as an important source of livelihood for the artisanal fishermen. However, over the years, various anthropogenic activities have altered the aquatic environment (environmental flow) of the river. Of late, it is assumed that the production process at different trophic levels of fish has been impeded, resulting in a decline in fish production and diversity. With this belief, an investigation was undertaken to assess the present status of the environmental flow with respect to the fish diversity and other aquatic ecological integrity in the limited stretches of the river Narmada.

Significance of sampling in limited stretches

The present study concentrated on a limited stretch of the river Narmada to estimate environmental flows (e-flows) for fish diversity employing the hydraulic cum habitat simulation method from downstream of SSD to Bhadbhut. Sampling in limited stretches of the river focuses on gathering representative data within a defined area of a river, often in response to comprehensive information on the ecological integrity of the river Narmada about water quality status. To assess the likely changes in the fish species in rivers due to environmental stress and any deviation from the environmental flow.

Study area and sampling sites

The stretch from downstream of SSD to Bhadbhut is a critical stretch for indigenous fish species, including the migratory fish species. Therefore, focus was given to those sites important for fish diversity and suitable habitat for these fish. Sampling undertaken in the rivers at regular intervals (Seasonal) to obtain information about population density of fish, their abundance, species-wise occurrence, often in relation to the habitat they occupy and other biotic and abiotic factors. Any interruption in seasonal sampling may lead to a missing link in obtaining accurate statistical data. Therefore, it is mandatory to adopt a sampling approach logistically. Keeping the above aspects in view, the study was carried out in the river Narmada, covering the pre-monsoon (Lean period) and post-monsoon season. Pre-monsoon field campaign was carried out during June 23rd to 27th, 2025, and post-monsoon sampling

undertaken during November 7th to 14th, 2025, to collect fish and other hydrological data from different selected sites in the river Narmada at Garudeshwar, Poicha, Sisodra, Lilod, Jhanor, Shuklatirth, Bharuch, Sakkarpara, and Bhadbhut of Gujarat (Table.1). Nine sampling sites were selected covering about 130 km. downstream of the Sardar Sarovar Dam (SSD) of the river Narmada. The positional coordinates ranged from N 21.807099, E 73.656058 to N 21.680952, E 72.845297 at an elevation between 60.57 and 25.47 m. of msl (Table.1 & Fig. 1). Sampling sites were selected based on fish abundance, varying substrate, and possible impact of downstream of SSD. The distance between the sampling sites is almost equal at all the sites except for Sakkarpara to Bhadbhut (Table 2).

Table 1: Details of sampling sites

| Sampling sites | River basin | District | GPS Coordinates | Elevation (m. MSL) |
|-------------------------|-------------|----------|----------------------------|--------------------|
| Site-I (Garudeshwar) | Narmada | Narmada | N 21.887099 E 73.656058 | 60.57 |
| Site-II (Poicha) | Narmada | Narmada | N 21.975716 E 73.458628 | 36 |
| Site-III (Sisodra) | Narmada | Navsari | N 21.913903 E 73.347048 | 37.3 |
| Site –IV (Lilod) | Narmada | Vadodara | N 21.878093 E 73.233343 | 29.0 |
| Site –V (Jhanor) | Narmada | Bharuch | N 21.8388 E 73.134 | 20.0 |
| Site- VI (Shuklatirth) | Narmada | Bharuch | N 21.747727 E 73.123398 | 36.9 |
| Site- VII (Bharuch) | Narmada | Bharuch | N 21.690182 E 73.00644 | 15.9 |
| Site- VIII (Sakkarpara) | Narmada | Bharuch | N 21.682 E 73.907 | 14.8 |
| Site- IX (Bhadbhut) | Narmada | Bharuch | N 21.680952 E 73.845297 | 17.47 |

Table 2. Distance between the sampling sites

| Sampling sites | | Distance (km.) |
|----------------|-------------|----------------|
| From | To | |
| Garudeshwar | Poicha | 25.18 |
| Poicha | Sisodra | 19.28 |
| Sisodra | Lilod | 23.52 |
| Lilod | Jhanor | 19.12 |
| Jhanor | Shuklatirth | 10.78 |
| Shuklatirth | Bharuch | 15.46 |
| Bharuch | Sakkarpura | 10.84 |
| Sakkarpura | Bhadbhut | 6.65 |

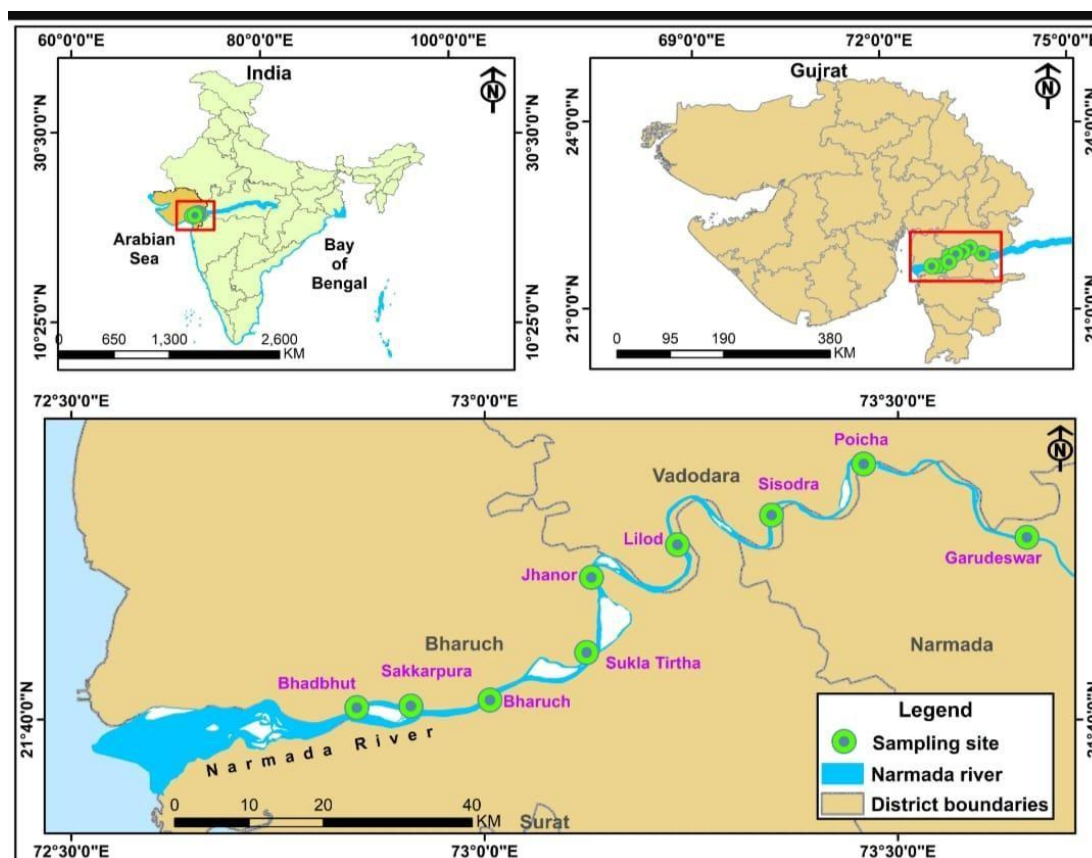


Fig 1. GIS map depicting sampling sites along the river Narmada

Sampling and Methodology

Water quality parameters

Water samples from different stations were collected across the river as well as both banks, and also from the sub-surface layer of the middle of the river to obtain composite water from each centre. Water quality characteristics, including temperature, pH, electrical conductivity, salinity, dissolved oxygen (DO), free carbon dioxide, alkalinity, total hardness, total phosphorus, available phosphorus, nitrate-nitrogen, total nitrogen, silicate, chloride, and biological oxygen demand (BOD), were monitored throughout the experiment according to methods of APHA (2017).

Hydrological parameters

Shoreline depth of left and right bank, mid-channel depth was measured by using Eco sounder (PS-7, LCD Digital sounder), ADCP, and wetted perimeter, water flow was measured by using digital flow meter (Make - Global Water Instrument: model FP 111, USA), and ADCP. Transparency of the water at each sampling stations was measured by the Secchi Disk.

Sediment parameters

Sediment samples were collected by an Ekman dredge across the river as well as two banks, and also from the bottom of the middle of the river to obtain a composite sediment sample from each centre. The sediment characteristics, including pH, conductivity, organic carbon, texture, free calcium carbonate (CaCO_3), total nitrogen and total phosphorus, were monitored throughout the experiment according to methods of APHA (2017).

Planktonic status in the river Narmada

To explore the planktonic communities of the Narmada River downstream of the Sardar Sarovar Dam (SSD), 100 liters of water were filtered using a plankton net with a mesh size of $50\mu\text{m}$. The concentrated 10 ml sample was preserved in 5% formalin. Numerical enumeration was carried out following the method described by Welch (1948). Identification of plankton was performed using standard taxonomic keys and literature, including those by Pennak (1978), Davis (1955), Ward & Whipple (1959), Cox (1966), and Needham & Needham (1972).

Benthic communities

Benthos samples were collected by using Petersen Grab having area of 19.0 x 19.5 cm² from each site. Three random hauls constituted one sample which was preserved in 10% formalin after sieving through Sieve No. 40. The qualitative and quantitative enumerations have been carried out by following Welch (1948), Subba Rao (1989), Ramakrishna & Anirudha Day (2007) and APHA (2017).

Habitat profile

In the present investigation, the habitat profile of each site was recorded based on types of substrates, bedrocks, riparian vegetations, deep pools, refill, etc. Water velocity, depth, and width of the river were measured using a flow meter and an Acoustic Doppler Current Profiler (ADCP) system. However, deep pools were measured using an echo sounder at the shoreline and mid-channel. Agriculture practices on the river banks, if any, were recorded based on interaction with local people and visualized in the sampling site. The width of the river (bank to bank) channel was measured physically.

Fish sample collection and analysis

Fish samples were collected from the main channel as well as the adjacent area. Though the river was bank full due to heavy rain during the pre-monsoon season, fish were collected from the river using gill nets, hook and lines, and drag nets of assorted mesh sizes from all possible habitat niches along the sampling sites, assuming that the existing species and their abundance would be reflected in the sample. The fish samples were collected mainly through experimental fishing and from adjoining landing centres. The experimental fishing was carried out along the longitudinal gradient of the river within 5 km. up and downstream. A sampling effort of 6 hours for the gill net was carried out. Further, the abundance of species indicated in the observations is the total number of fish of the individual species collected. Fish catch data and samples were also collected from fish landing stations at all the sampling sites. Representative specimens (n=5) of all fish species were identified and preserved in 10% formalin and brought to the laboratory for analysis.

The identification of the fish specimen from various sites of river Narmada was conducted using the keys as per Francis Day (1889), Mishra (1962), Talwar and Jhingran (1991), Jayaram (1981 & 2006), Nath and Dey (2000).

Observations

Aquatic habitat assessment

Aquatic habitat plays a significant role in the successful colonization of fish and other aquatic organisms. It is well known that water alone will not ensure the survival of fish. Along with quality water, fishes need an ideal and suitable aquatic habitat for their growth, breeding, migration, etc. In general, freshwater can be categorized into lentic (standing) and lotic (flowing) water habitats. Habitat diversity can vary tremendously within these two broad categories, and few fish taxa can be found in both habitats. The habitat factors that influenced fish to complete their lifecycle are substrate type, deep pools, scar pools, riparian vegetation, water depth, water flow, river gradient, the width of the wetted channel, flood plains, etc. Some indigenous fish also have to move between different habitats as they mature and breed. Different fish species have different habitat requirements, and these may change as they grow older. Significantly, it has been found that there are not many seasonal variations in the habitat profile over the short period of time, except for the width of the wetted channel, average depth, and water velocity.

Habitat profile during pre-monsoon period

During pre-monsoon period habitat profile of each sampling site of the river Narmada is shown in Table 3. Some significant variations were recorded in each sampling site. The mean depth of the studied stretches varied from 3.26 m. to 10.3 m. Depth was recorded from the shoreline (L and R banks) and mid-channel. The substrate type was dominated by boulders, coarse sand, gravels, and sandy clay at upper stretches of the river (Garudeshwar to Sisodra) and sandy clay and sand in all remaining sites (Lilod to Bhadbhut), which are considered to be ideal habitats for the freshwater ecosystem. In the site Garudeshwar to Sisodra, substrates were predominant with boulders, gravels, cobbles, and coarse sand, which are an ideal habitat for catfish. Water velocity recorded ranged from 25 to 130 cm/sec, which is supposed to be acceptable for freshwater rivers. This is common features in a lean period. Deep pools were recorded from the sampling sites, which are significant for aquatic fauna for their shelter and breeding ground, especially in the lean period. A significant observation was that agricultural practices were observed in catchment areas in the sampling sites, which is a serious concern as the pesticides used for agricultural practices may be deposited into the river through runoff. Good riparian vegetation on the catchment area and riverbanks is considered to be an important part of the river habitat.

Habitat profile during post-monsoon period

Habitat profile during post monsoon period (Nov. 2025) at each sampling site of river Narmada has been portrayed (Table 4.), and data were recorded in a printed proforma prepared for this purpose. Some significant habitat variations were recorded in each sampling site. The mean depth of the studied area varied from 0.97 to 6.85 m as per ADCP data. Minimum depth (0.97 m) recorded from Garudeshwar and maximum depth (6.85 m) recorded from Jhanor, which are acceptable for a lotic water body. Depth was recorded by the ADCP system from the shoreline (L and R banks) and mid-channel. Width of wetted channel varied from 198.0 m to 965.95 m. It is evident from the present study that the width of the river Narmada (wetted channel) increased as the river gradient goes further towards downstream. In general, heavy rainfall over the year, afforestation of bank vegetation, and the resistance of river banks to erosion plays a crucial role in determining the channel's width. The substrate type was dominated by boulders, coarse sand, gravels, and sandy clay at upper stretches of the river (Garudeshwar, Poicha and Sisodra) sandy clay and sandy in all remaining sites (Lilod, Jhanor, Shuklatirth, Bharuch, Sakkarapura and Bhadbhut), which are considered to be ideal habitats for the freshwater ecosystem. In sites, Garudeshwar, Poicha and Sisodra substrates were predominant with boulders, gravels, cobbles and coarse sand which are ideal habitat for cat fishes. Water velocity recorded ranged from 0.17 to 1.06 m/sec (ADCP data). Minimum water velocity (0.17 m/sec) recorded from Lilod site, whereas maximum (1.06 m/sec) was recorded from Sakkarapura site which are supposed to be acceptable for freshwater rivers. This is common features in late post-monsoon season. Deep pools were recorded from the sampling sites which are significant for aquatic fauna for their shelter and breeding ground, especially in the lean period. Significant observation was that agricultural practices were not observed in catchment areas in the sampling sites, which is favourable for aquatic habitat. As it is evident that use of pesticides for agricultural practices may be deposited into the river through runoff and make the river polluted. Good riparian vegetation on the catchment area and riverbanks is considered to be an important part of the river habitat.

Remarks

In pre-monsoon sampling, average depth in the sampling sites varied from 3.26 m to 10.3 m whereas it was between 0.97 and 6.85 m during the post-monsoon period, which showed slightly less value than the pre-monsoon season. The possible reason was that heavy rain during the pre-monsoon sampling made the river deeper. Water velocity recorded ranged from 0.25 to

1.30 m/sec in the pre-monsoon season and 0.17 to 1.06 m/sec in post-monsoon sampling, which is again a slightly higher value during the pre-monsoon season than post monsoon sampling due to heavy downpour and added additional rain water into the main channel from catchment area which enhanced the water velocity. The water velocity in both seasons is supposed to be acceptable for freshwater rivers. Remaining habitat parameters like substrate type, deep pools, and meandering nature remained almost the same in both seasons. Width of wetted channel, width of bank to bank was slightly varied due to a sudden increase in water level due to heavy rain during the pre-monsoon season.

Riparian vegetation growing on the catchment area and river banks of the stream is considered to be an important part of the river habitat. In the present investigation, fairly good bank vegetation was observed in all the sampling sites, both in pre- and post-monsoon seasons. Good, diverse bank vegetation in the sampling sites, which, as a whole act as a filter for runoff from the surrounding land, partly purifying the water before it enters the stream. The more or less meandering nature of the stream was observed in the studied area.

Table 3. Habitat profile of sampling stations (pre-monsoon)

| | Garudeshwar | Poicha | Sisodra | Lilod | Jhanor | Shuklatirth | Bharuch | Sakkarpura | Bhadbhut |
|----------------------------------|---|--|---|--|---|--|--|---|---|
| Width of channel (wetted) | 300 m | 300 m | 200 m | 500 m | 450 m | 400 m | 700 m | 500 m | 900 m |
| Bank to bank width | 800 m | 800 m | 800 m | 700 m | 700 m | 700 m | 1000 m | 700 m | 1200 m |
| Depth (Avg.) | 3.5 m | 3.26 m | 3.9 m | 9.6 m | 5.46 m | 4.7 m | 11.46 m | 5.2 m | 7.76 m |
| Water velocity | 1.30 m/sec | 1.10 m/sec | 0.75 m/sec | 0.42 m/sec | 0.32 m/sec | 0.36 m/sec | 0.25 m/sec | 0.61 m/sec | 0.56 m/sec |
| Substrate composition | Boulders 25%, coarse sand 45%, gravels 10%, clay and others 20%. | Coarse sand 25%, gravels 15%, cobbles 10% clay and others 50%. | Small gravels 15%, sand 35%, clay and others 50% | Sandy clay and others 100% | Sandy clay | Sandy clay | Clay and organic materials | Sandy clay | Sandy clay |
| Deep pools | 2 nos. identified with average depth of 18.5 ft | 1 no (depth 12 m) | Not recorded | Recorded (1 no. with 30 m depth) | Not recorded | Not recorded | Not recorded | Not recorded | Not recorded |
| Riparian vegetation | Trees 45%, Herbs 15%, Shrubs 25%, grass land 15% | Trees 40%, Herbs 20%, Shrubs 25%, grass land 15% | Trees 35%, shrubs 15%, herbs 15%, grass land 25% | Trees 40%, shrubs 10%, herbs 15%, grass land 35% | Trees 20%, shrubs 25%, herbs 15%, grass land 40% | Trees 15%, shrubs 25%, herbs 20%, grass land and others 40% | Trees 20%, shrubs 25%, herbs 20%, grass land and others 35% | Trees 25%, shrubs 15%, herbs 10%, grass land and others 50% | Rich riparian vegetation (Trees, shrubs, herbs, grass land and others) |
| Other information | Check dam constructed, ritual activities by the local people were visualized, temple exist. No pollution sources were observed. | Pollution source not recorded, bank soil erosion observed, instream cover not found. | Ritual activities visualized, sources of pollution not found. | Temple exists, no significant pollution discharge source identified. | Water lifting pump installed in the bank of the river, no pollution sources were found. | Ritual activities observed as the site considered as one of the holiest shrines. | Urban area, city sewage being discharged into the river, railway and road bridge constructed over the river. | Water lifting pump installed in the shoreline of the river, no instream cover was recorded. | Island formed in the middle of the river, Temples are located on the bank of the river, barrage under construction. |

Table 4. Habitat profile of selected sampling stations (post-monsoon)

| <i>Parameters</i> | Sampling sites | | | | | | | | |
|---|--|--|--|--|--|---|---|---|--|
| | Garudeshwar | Poicha | Sisodra | Lilod | Jhanor | Shuklatirth | Bharuch | Sakkarpura | Badbhut |
| Width of wetted channel (m.) | 213.70 | 271.30 | 198.00 | 242.50 | 461.70 | 300.90 | 785.55 | 589.90 | 965.95 |
| Width of the bank to bank of the river (m.) | 800.00 | 300.00 | 800.00 | 500.00 | 700.00 | 650.00 | 900.00 | 750.00 | 1200.00 |
| Av. Depth (m.) | 0.97 | 3.85 | 6.71 | 6.84 | 6.85 | 3.30 | 4.40 | 3.28 | 4.66 |
| Deep pools | Present (2 nos.) | Present (1 no.) | Not recorded | Present (1 no.) | Not recorded | Not recorded | Not recorded | Not recorded | Not recorded |
| Scar pools | Present | Not recorded | Present | Present | Present | Not recorded | Present | Present | Not recorded |
| Substrate type | Boulders 25%, coarse sand 45%, gravels 10%, clay and others 20%. | Coarse sand 25%, gravels 15%, cobbles 10% clay and others 50%. | Small gravels 15%, sand 35%, clay and others 50% | Sandy clay (| Sandy clay & others (| Sandy clay & others (40%, 50%, 10%) | Clay and organic materials | Sandy clay (55%, 40%, 5% others)) | Sandy clay & others (40%, 50%, 10%) |
| Elevation (m.) | 6.57 | 36.0 | 37.3 | 29.0 | 20.0 | 36.9 | 15.9 | 14.8 | 17.47 |
| Riparian vegetation | Trees 40%, Herbs 15%, Shrubs 25%, grass land 20% | Trees 35%, Herbs 25%, Shrubs 25%, grass land 15% | Trees 35%, shrubs 20%, herbs 25%, grass land 20% | Trees 35%, shrubs 15%, herbs 15%, grass land 35% | Trees 20%, shrubs 20%, herbs 15%, grass land 45% | Trees 15%, shrubs 20%, herbs 20%, grass land and others 40% | Trees 15%, shrubs 30%, herbs 15%, grass land and others 35% | Trees 20%, shrubs 15%, herbs 15%, grass land and others 50% | Rich riparian vegetation (Trees, shrubs, herbs, grass land and others) |
| Water velocity (m/sec) | 0.39 | 0.80 | 0.38 | 0.17 | 0.18 | 0.26 | 0.44 | 1.06 | 0.47 |
| In-stream cover | Present | Not found | Present | Present | Not found | Present | Present | Not found | Not found |
| Meandering nature | Less meandering | Observed | Observed | Less meandering | Observed | Observed | Observed | Less meandering | Observed |

| | | | | | | | | | |
|-----------------------|---|---|-------------------------------|--|---|--|---|---|---|
| Source of pollution | Not found. | Not recorded, | Not found. | No significant pollution discharge source identified | No pollution sources were found. | Not found. | City sewage being discharged into the river | Not found. | Not found. |
| Agriculture practices | Not found | Not found | Not found | Not found | Not found | Not found | Not found | Not found | Not found |
| Other observations | Check dam constructed, Ritual activities by the local people were visualized, temple exist. | bank soil erosion observed, instream cover not found. | Ritual activities visualized. | Temple exists | Water lifting pump installed in the bank of the river | Ritual activities observed as the site considered as one of the holiest shrines. | Urban area, railway and road bridge constructed over the river. | Water lifting pump installed in the shoreline of the river, | Island formed in the middle of the river, Temples are located on the bank of the river, barrage under construction. |

Physico-chemical parameters of water in river Narmada

Water Temperature

During the pre-monsoon period, water temperature across the sampling stations (S₁–S₉) remained relatively moderate, ranging from about 25.5 to 28.03 °C. The high temperatures were recorded at S₈ and S₉, while comparatively lower values were observed at S₁ and S₆. In contrast, during the post-monsoon period, temperatures declined at all stations, varying approximately between 23°C and 27°C, with the lowest temperature at S₅ (Fig. 2). This seasonal reduction in temperature reflects the cooling effect of monsoonal rainfall and enhanced water mixing across the study area.

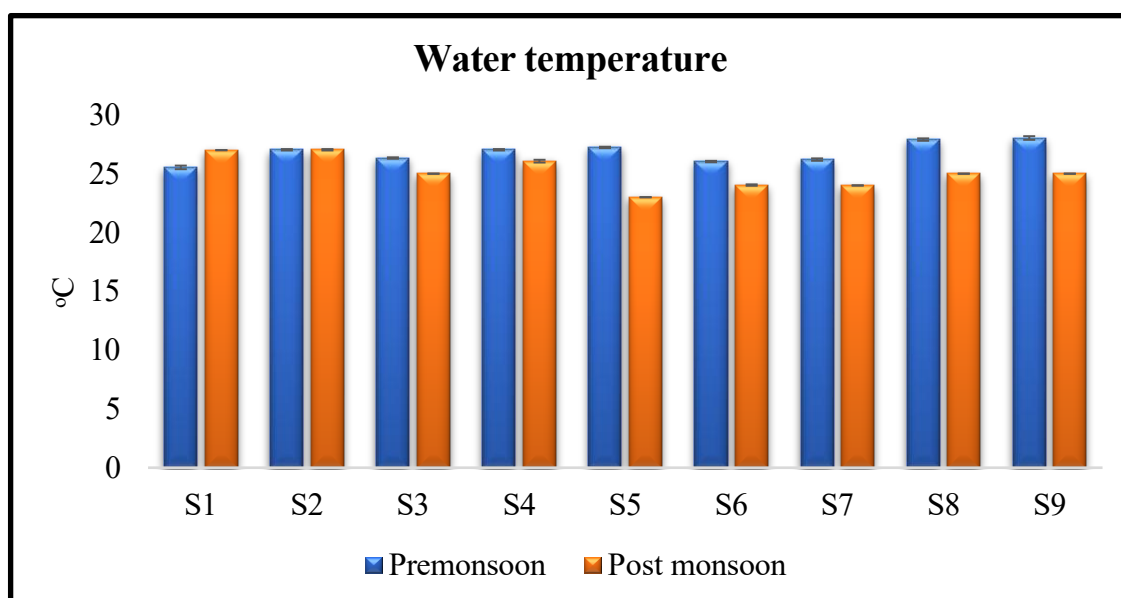


Fig 2. Diagram representing comparative water temperature in pre- and post-monsoon season

Water Flow

During the pre-monsoon period, water flow showed pronounced spatial variation across the sampling sites, with the highest velocity recorded at S₁ (1.296 m/sec), followed by S₂ (1.103 m/sec). Moderate flow conditions were observed at S₃ (0.756 m/sec), S₈ (0.616 m/sec), and S₉ (0.55 m/sec), whereas relatively lower velocities were recorded at S₄ (0.42 m/sec), S₆ (0.3633 m/sec), and S₅ (0.32 m/sec). The lowest pre-monsoon flow occurred at S₇ (0.246 m/sec). In contrast, during the post-monsoon period, water flow decreased sharply across all sites, with velocities remaining very low throughout the stretch. Slight increases were noted at downstream locations such as at S₈ and S₉, where at S₈ it was found to be maximum among the study sites (Fig. 3). Though these values were still substantially lower than pre-monsoon levels.

During the pre-monsoon sampling, due to heavy rain, a higher value of water flow was recorded across the sampling sites. There was a significant reduction in flow during the post-monsoon season, the possible reason was due to less influx of water into the main channel from the catchment area which stabilized hydrological conditions. m/sec

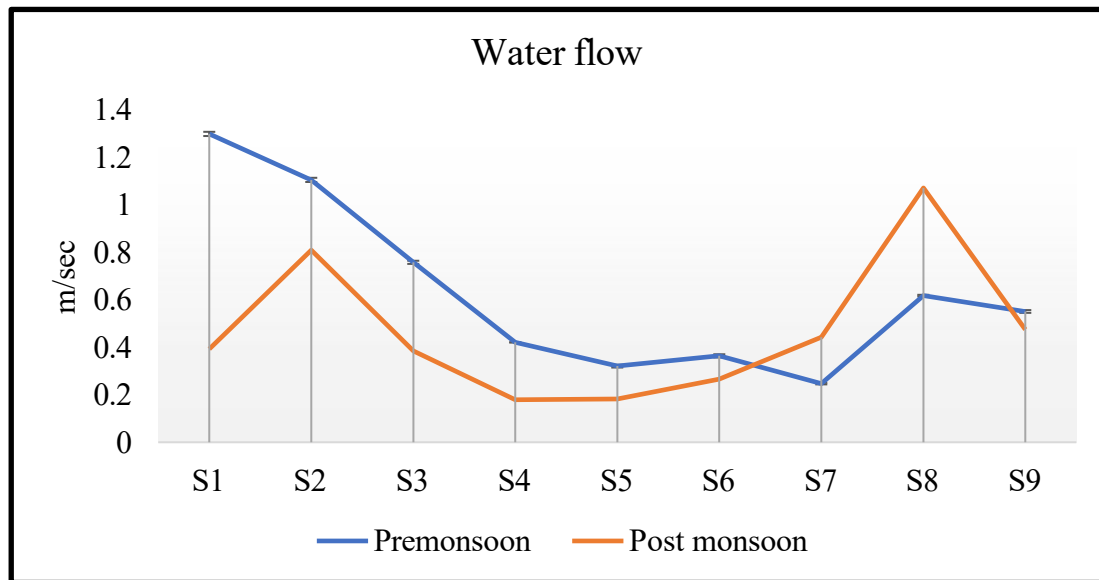


Fig. 3 Diagram showing comparative water flow pattern in both the seasons

Water pH

During the pre-monsoon period, the pH of the Narmada River remained slightly alkaline across all sampling stations (S₁–S₉), ranging approximately from 8.1 to 8.37, indicating stable buffering conditions and limited spatial variation. In the post-monsoon period, pH values increased at all stations, reaching about 8.3–8.7, with the highest values observed at downstream locations such as S₇, S₈, and S₉, reflecting the strong buffering capacity of the river system (Fig. 4). The consistently alkaline nature of the Narmada River during both seasons indicates stable hydrochemical conditions, while the relatively higher pH observed during the post-monsoon period suggests the influence of monsoon runoff, enhanced water mixing, and increased photosynthetic activity, particularly in the downstream stretches.

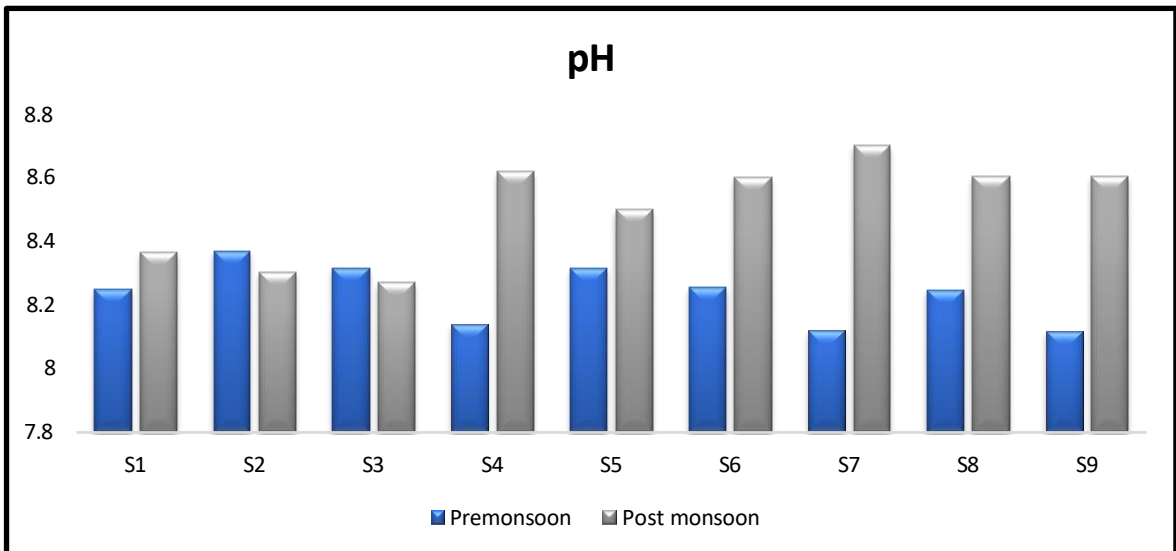


Fig. 4 Sidewise pH value in pre-monsoon and post-monsoon season

Electrical Conductivity of water

Electrical conductivity (EC) of the Narmada River exhibited clear seasonal variation across the sampling stations. During the pre-monsoon period, EC values were comparatively lower, ranging from about 186.6 to 386 $\mu\text{S}/\text{cm}$, with reduced values at midstream sites and relatively higher values toward the downstream reaches due to heavy rainfall during sampling. In the post-monsoon period, EC increased across all stations, varying approximately between 304 and 424.3 $\mu\text{S}/\text{cm}$, with pronounced elevation at downstream locations (S7–S9) because these are comes under estuarine zone (Fig. 5). This post-monsoon rise in EC may be attributed to increased ionic input from catchment runoff and reduce in water volume.

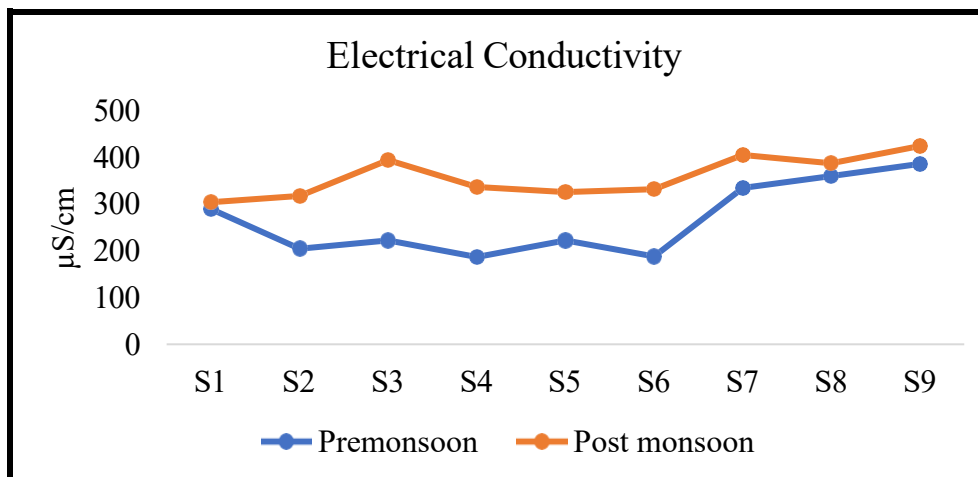


Fig. 5 Conductivity recorded during the study period

Total Dissolved Solids

Total dissolved solids (TDS) exhibited clear seasonal variation across the sampling sites. Pre-monsoon values were comparatively lower and showed moderate spatial fluctuations, with a gradual rise toward downstream sites and a peak around S₇. Post-monsoon TDS was consistently higher at all sites, indicating enhanced inputs from surface runoff. The elevated post-monsoon values found maximum at sites S₃, S₇, S₈ and S₉ reflects cumulative downstream enrichment of dissolved solids (Fig. 6).

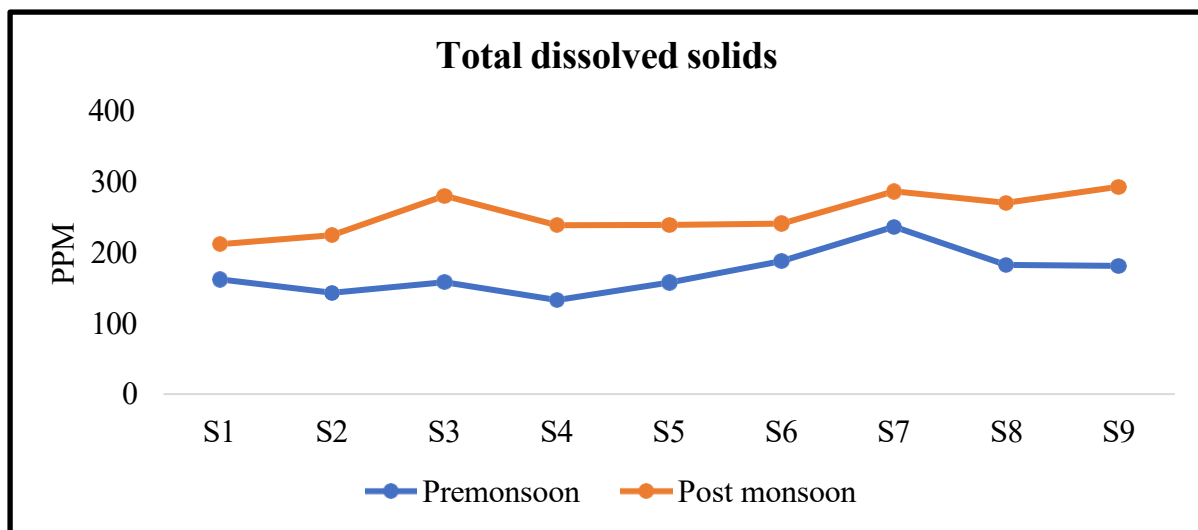


Fig. 6 Linear diagram representing comparative TDS value in pre and post-monsoon period

Salinity

During the pre-monsoon season, salinity values were relatively low and ranged from about 0.081 to 0.268 ppt, with a gradual increase toward the downstream sites and a sharp rise at S₇, S₈, and S₉. In contrast, post-monsoon salinity ranged from nearly 0.01 to 0.17 ppt and was generally lower than pre-monsoon values at the downstream stations. At upstream sites (S₂ and S₃), post-monsoon salinity was slightly higher than pre-monsoon. However, from S₆ onward, pre-monsoon salinity exceeded post-monsoon values, particularly at S₇–S₉. Overall, the graph indicates dilution of salinity during the post-monsoon season and concentrated volume during the pre-monsoon period, especially in the lower river stretch (Fig. 7).

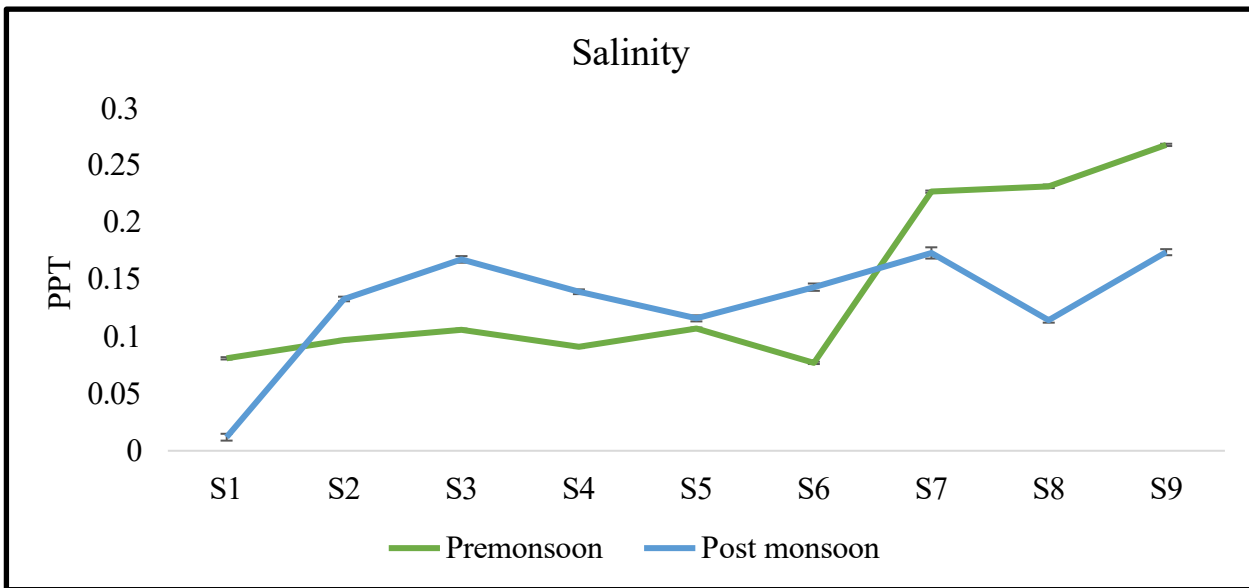


Fig. 7 Diagram represent salinity range recorded during pre-monsoon and post-monsoon period

Free Carbon Dioxide

Free CO₂ showed very limited spatial and seasonal occurrence along the river stretch. During the pre-monsoon period, free CO₂ was absent at all the sampling sites (S₁–S₉), indicating well-aerated conditions. In the post-monsoon season, free CO₂ was detected only at S₆ and S₇, with a volume of about 7.4 mg L⁻¹ at S₆ and 6.1 mg L⁻¹ at S₇ (Fig. 8). The appearance of free CO₂ at these two sites after the monsoon suggests the presence of organic matter pollution.

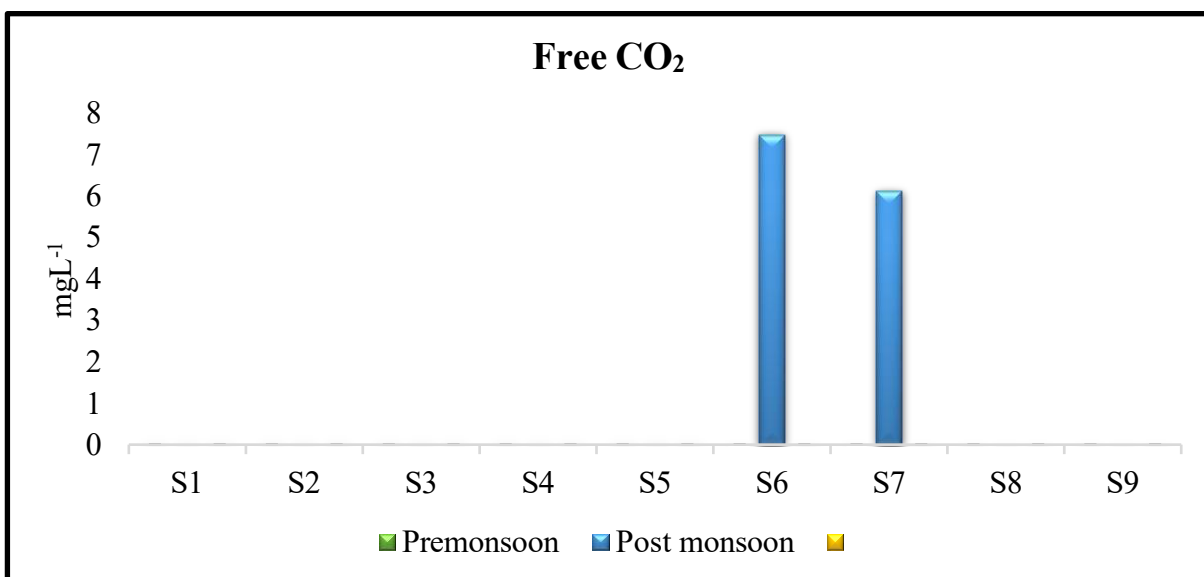


Fig. 8 Diagram showing free CO₂ value in both the seasons

Total Alkalinity

Alkalinity showed a clear difference between the two seasons across all sampling sites. In the pre-monsoon period, alkalinity values were comparatively lower, ranging roughly from 77 and 177.6 mg L⁻¹. Low values were found at S₂, S₄, S₅, S₆, and S₈, whereas S₁, S₃, S₇, and S₉ recorded relatively higher concentrations, indicating site-specific influences under low-flow conditions. During the post-monsoon season, alkalinity increased uniformly at all stations, with values lying in the range of about 133 to 152.6 mg L⁻¹ (Fig. 9). Higher at S₇ and S₈ highlight

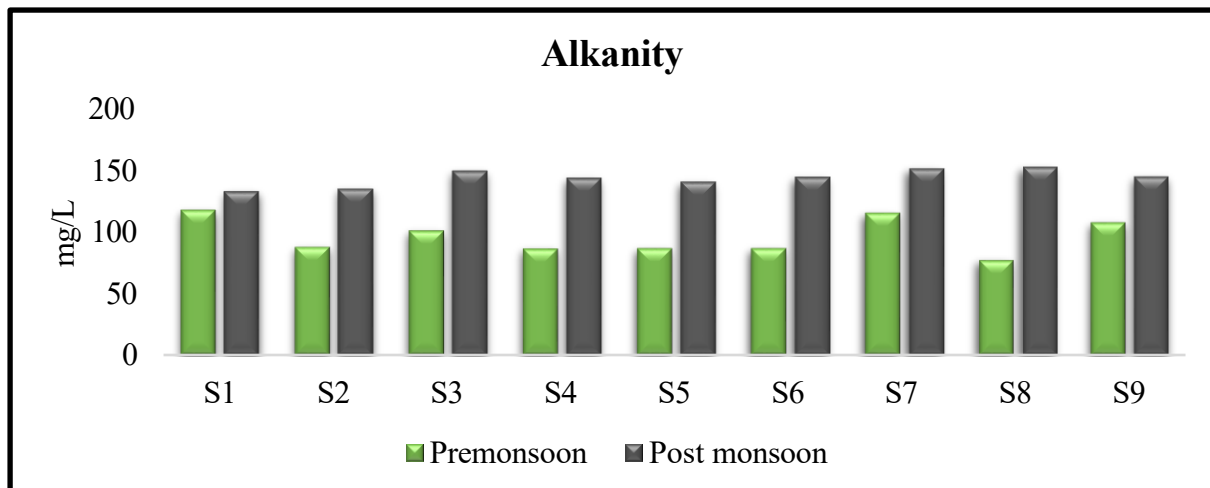


Fig. 9 Site-wise total Alkalinity value recorded in both the seasons

stronger buffering conditions in the downstream stretch. This seasonal rise in alkalinity reflects the contribution of bicarbonates and carbonates through monsoon runoff. Overall, the post-monsoon period exhibits enhanced and more stable alkalinity compared to the pre-monsoon pattern.

Dissolved Oxygen (DO)

During the pre-monsoon period, DO concentrations were relatively higher at most stations, ranging from about 4.96 to 7.1 mg L⁻¹, with maximum values observed at S₁ (7.12 mg L⁻¹) and S₂ (7.12 mg L⁻¹). Slightly lower DO value during pre-monsoon season was recorded at S₃, S₇, and S₉ (Fig. 10). While during the post-monsoon season, DO values ranged from 5.16 to 7.19 mg L⁻¹ and exhibited a mixed pattern. Higher post-monsoon DO was found at S₃ and S₇. Conversely, at stations such as S₁, S₂, S₆, and S₈, post-monsoon DO was marginally lower than pre-monsoon levels, likely reflecting enhanced organic load and microbial respiration. Overall,

the dissolved oxygen remained within a favourable range at all sites, with seasonal shifts influenced by flow conditions and organic inputs.

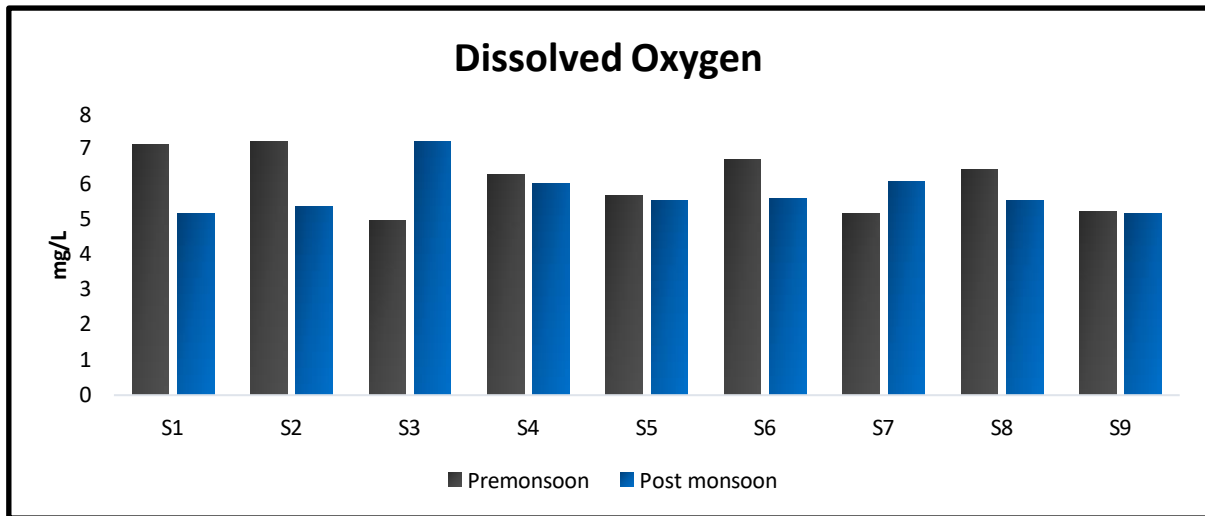


Fig. 10 Dissolved Oxygen (DO) variation during the study period

Total Hardness

Water hardness is an important water quality parameter influencing fish growth and is determined mainly by the concentration of divalent cations, particularly calcium and magnesium. Spatial and seasonal analysis of the Narmada River showed moderate variation in total hardness. During the pre-monsoon period, hardness ranged from about 68.26 to 108 mg L⁻¹, with lower values at S₂ and S₆ and relatively higher values at S₁, S₇, and S₉. During post-monsoon season hardness increased across all sites, ranging from approximately 115.33 to 148.66 mg L⁻¹, with peak values observed at S₃ and S₇ (Fig. 11).

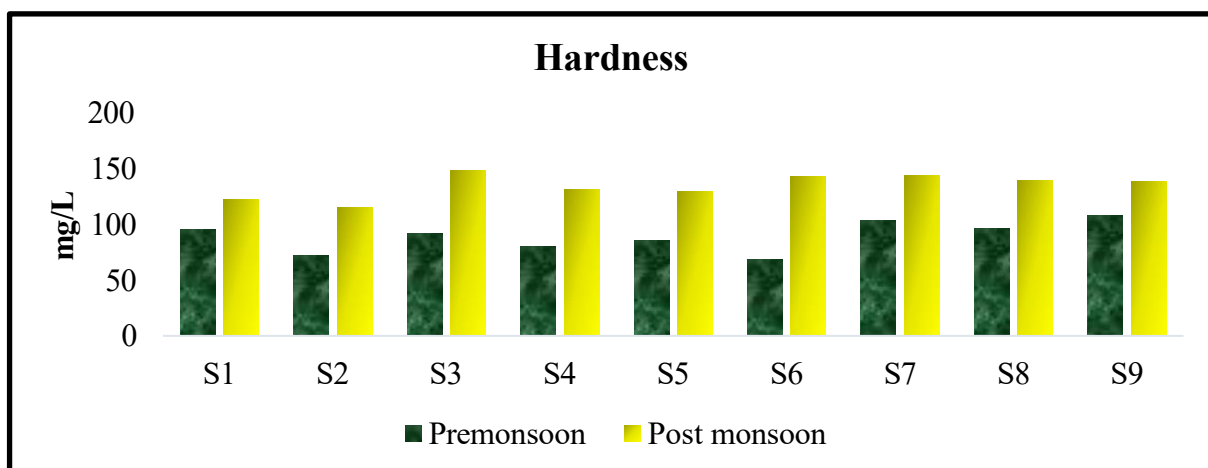


Fig. 11 Comparative total hardness during the study period

Nitrate -N

Nitrate ($\text{NO}_3\text{-N}$) is the most prevalent form of nitrogen present in soils and freshwater systems. It is naturally generated through nitrification process, and is readily used by phytoplankton. However, excessive concentrations of nitrate-N, can lead to eutrophication which can have adverse effects on water quality and aquatic organisms. Nitrate concentrations exhibited clear seasonal variation along the Narmada River. During the pre-monsoon period, nitrate levels were generally low, ranging from about 0.05 to 0.25 mg L^{-1} , with slightly higher values observed at S₂ and S₉. In contrast, during post-monsoon season nitrate-N content increased markedly at all sampling sites, varying from approximately 0.55 to 1.60 mg L^{-1} . The highest post-monsoon nitrate-N levels were recorded at S₃ and S₅ (Fig. 12)

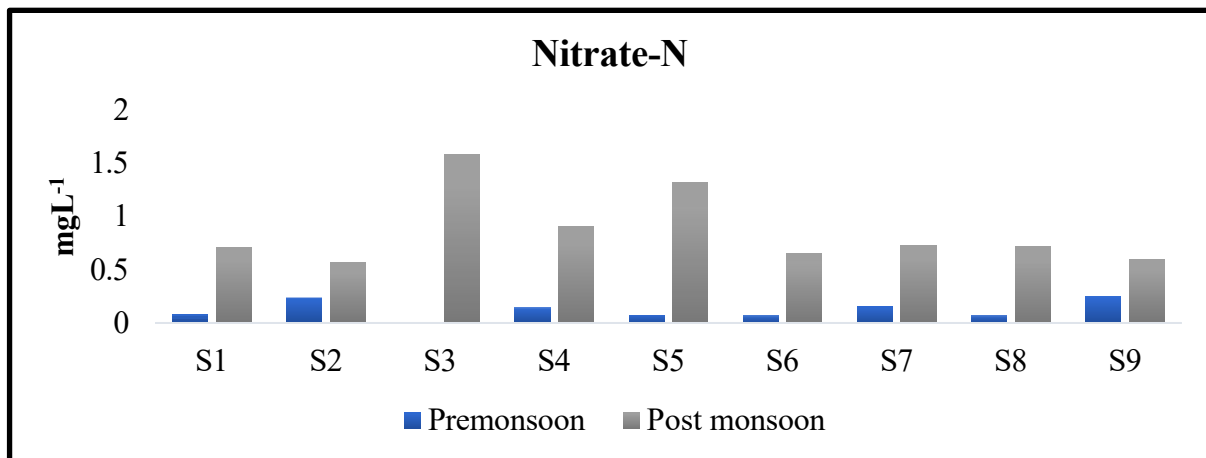


Fig. 12 Site-wise representation of Nitrate value recorded during the study

Silicate The silicate concentration in the Narmada River showed clear spatial and seasonal variation. silicate levels during the pre-monsoon period ranged approximately from

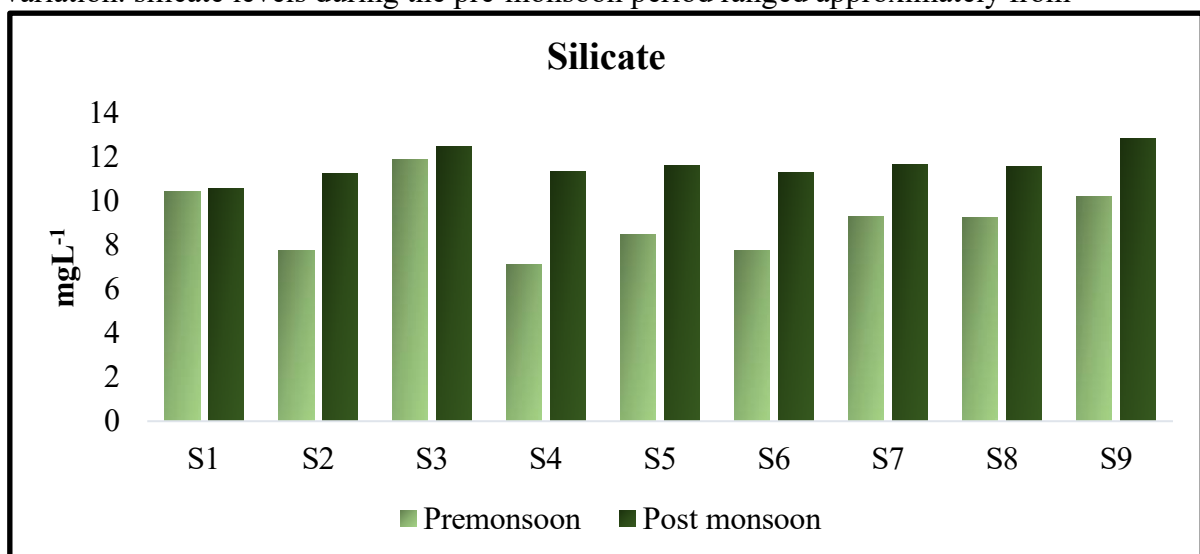


Fig.13 Silicate concentration during the study period.

7.7 to 11.8 mg L⁻¹, with lower values observed at sites such as S₄ and S₆ and higher concentrations at S₃ and S₉. In the post-monsoon season, silicate concentrations were consistently higher, ranging from about 10.53 to 12.82 mg L⁻¹ across the sampling sites (Fig. 13). Relatively higher values at downstream sites indicate cumulative enrichment along the river stretch, while lower volume was recorded during pre-monsoon season which reflects less water flow and dilution.

Chlorinity

Chlorinity levels (mgL⁻¹) measured across nine sampling stations (S₁ to S₉) during the pre-monsoon and post monsoon periods. Post monsoon chlorinity is generally higher than pre-monsoon chlorinity across most stations (S₂ to S₉), with levels ranging from about 17.33 mgL⁻¹ to 49.73 mgL⁻¹ (Fig. 14). In pre-monsoon found maximum 22.99 mgL⁻¹ at Station S₉. Station S₁, where the Post monsoon level (6.46 mgL⁻¹) is notably lower than its Pre-monsoon level (16 mgL⁻¹).

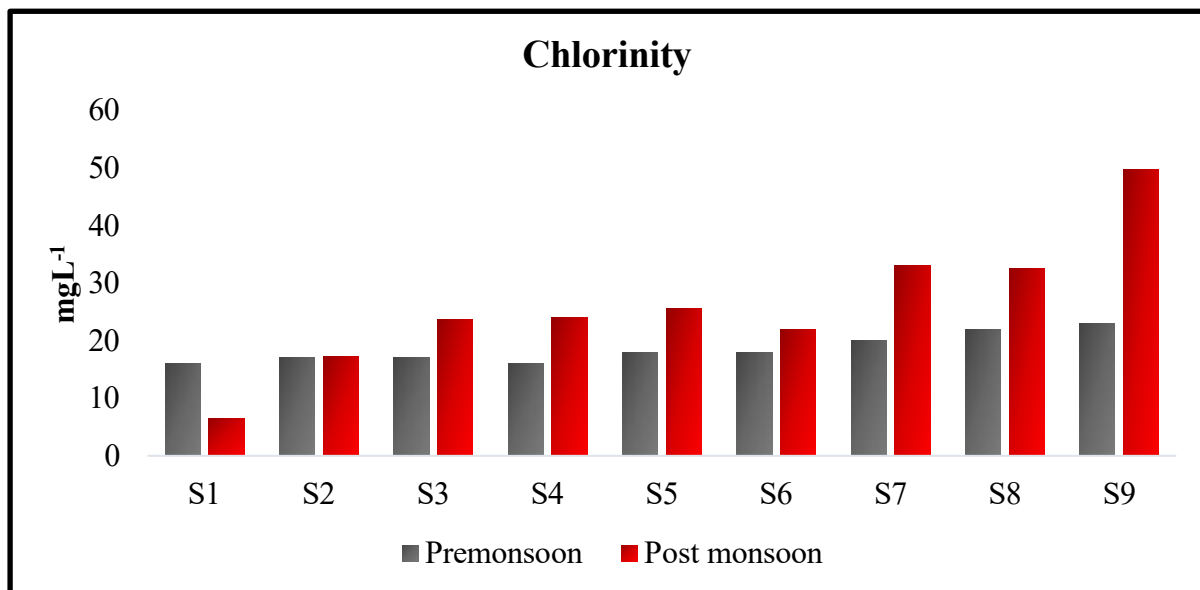


Fig. 14 Chlorinity range in all the sites during the study period

Biological oxygen demand (BOD)

Biological oxygen demand (BOD) showed variation across the sampling sites (S₁–S₉). In general, pre-monsoon BOD values are higher than post-monsoon, indicating greater organic load and reduced dilution during the low-flow period. Sites S₄, S₆, and S₇ record notably high pre-monsoon BOD. During the post-monsoon season, BOD values decline at most sites (S₁, S₂, S₅), likely due to increased river discharge and dilution. However, S₃ and S₇ showed

comparatively higher post-monsoon BOD values, which may be attributed to runoff-driven inputs of organic matter after rainfall. Overall, the BOD levels mostly remain within a moderate range suggesting low organic pollution (Fig.15).

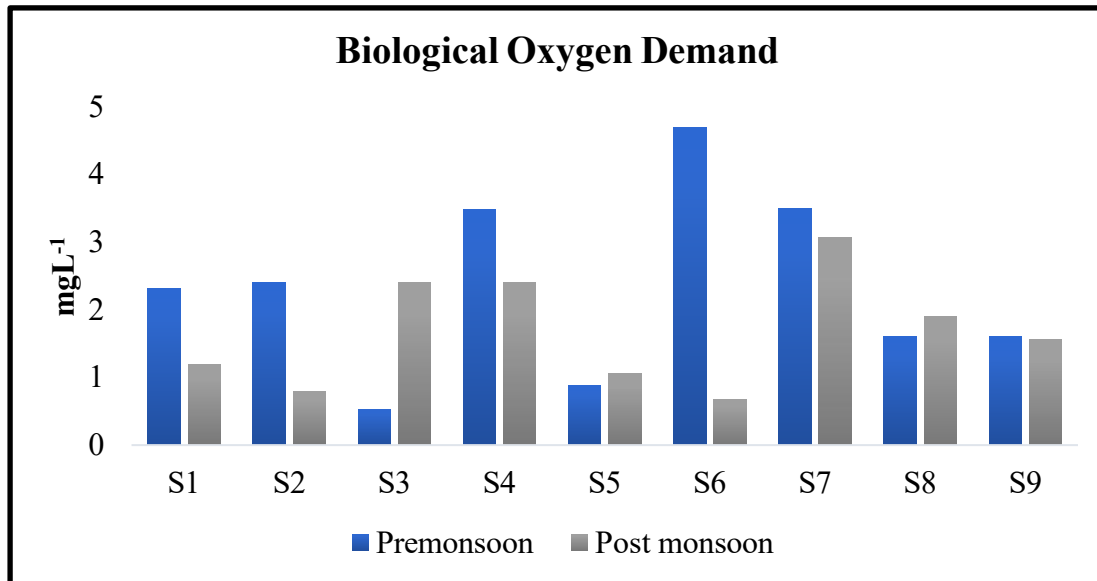


Fig. 15 Diagram showing BOD value recorded during the study period.

Chlorophyll

Across all sites (S₁–S₉), chlorophyll pigments show lower concentrations during the pre-monsoon and higher concentrations during the post-monsoon (Fig. 16). For chlorophyll-a, pre-monsoon values remain low, ranging approximately from 0.069 mg L⁻¹ at S₁ to 0.26 mg L⁻¹ at S₃.

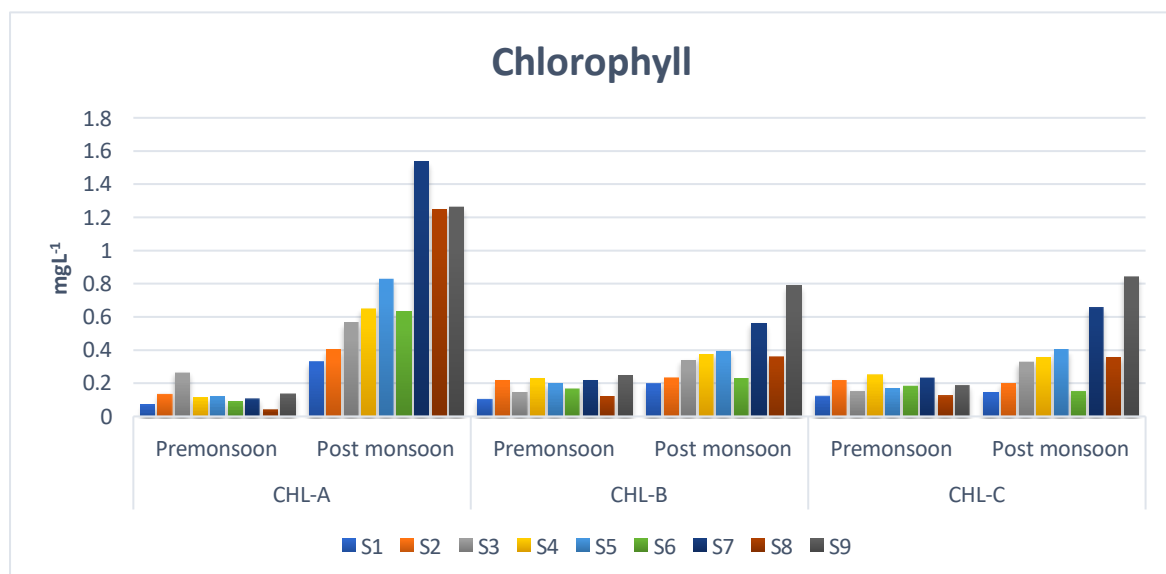


Fig. 16 Comparative value of chlorophyll concentration recorded during the study period.

In the post-monsoon, chlorophyll-a increases markedly, with values rising to about 0.33 mg L^{-1} at S₁, 0.56 mg L^{-1} at S₃, 0.63 mg L^{-1} at S₆, and reaching the highest levels at S₇ (1.54 mg L^{-1}), S₈ (1.245 mg L^{-1}), and S₉ (1.264 mg L^{-1}). Chlorophyll-b shows pre-monsoon values between 0.10 – 0.244 mg L^{-1} , with the lowest at S₁ and relatively higher values at S₄–S₆. During the post-monsoon, chlorophyll-b increases across all sites, from about 0.20 mg L^{-1} at S₁ to 0.22 mg L^{-1} at S₆, with a distinct peak at S₉ (0.789 mg L^{-1}). For chlorophyll-c, pre-monsoon concentrations are consistently low, varying from 0.128 mg L^{-1} at S₁ to 0.25 mg L^{-1} at S₄. Post-monsoon values show an increasing toward downstream, starting from 0.14 mg L^{-1} at S₁, 0.405 mg L^{-1} at S₅, and attaining the highest concentrations at S₉ (0.85 mg L^{-1}). Overall, the trend indicates a site-wise increase in chlorophyll-a, b, and c from pre-monsoon to post-monsoon, with the most pronounced increases consistently observed at S₇, S₈, and S₉.

Available and Total phosphorus

During the pre-monsoon season, available phosphorus remained very low at all sites, ranging from 0.012 – 0.033 mg L^{-1} , with slightly higher values at S₂ and S₃, while S₅ recorded the lowest concentration. In contrast, total phosphorus during the same period showed comparatively higher values, generally between 0.20 – 0.33 mg L^{-1} , except at S₆, which exhibited a markedly elevated concentration (3.03 mg L^{-1}), clearly standing out from all other sites. In the post-monsoon season, available phosphorus increased substantially at most sites, indicating enhanced bioavailable fractions.

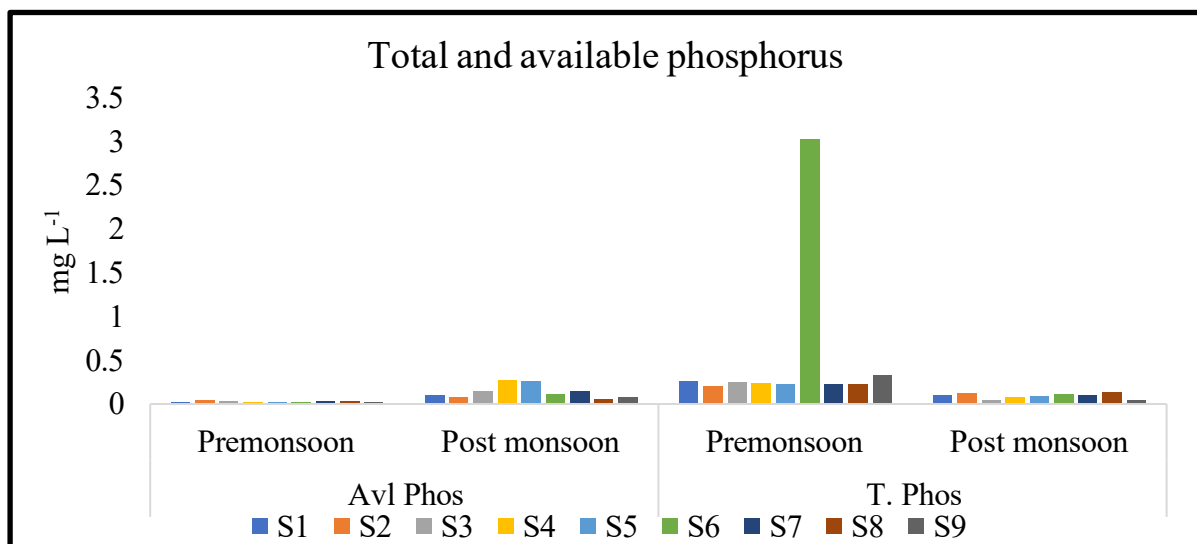


Fig.17 Available total phosphate recorded during pre-monsoon and post-monsoon season

The highest post-monsoon available phosphorus was recorded at S₄ (0.273 mg L^{-1}) and S₅ (0.256 mg L^{-1}), followed by S₃ and S₇, while S₈ showed the lowest value (0.052 mg L^{-1}).

Conversely, total phosphorus declined sharply at all sites during the post-monsoon, falling within a narrow range of 0.034–0.125 mg L⁻¹, with the lowest value at S₃ and relatively higher values at S₈ and S₂ (Fig. 17). Overall, the result indicate an opposite seasonal trend between total and available phosphorus, with higher total phosphorus during the pre-monsoon and a notable increase in available phosphorus during the post-monsoon, alongside a general reduction in total phosphorus across most sites.

Total Nitrogen

Post-monsoon total nitrogen in the Narmada River varied across sites S₁–S₉, ranging from about 0.06 to 0.115 mg/L. The highest concentrations occurred at S₁, S₃, and S₆, while the lowest was recorded at S₇, followed by S₈. Overall, the trend shows noticeable spatial variability, with moderate to higher values at upstream and midstream sites and comparatively lower levels at downstream locations. The detailed value of all the water quality parameters is depicted in the below Table. 5

Table 5. Water quality parameter of pre and post monsoon season

| S.no | Parameters | Garudeshwar | Poicha | Sisodra | Lilod | Jhanor | Shuklatirth | Bharuch | Sakkarpura | Bhadbut |
|------|-------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| 1. | Temperature (°C) | 25.53±0.15 | 27.03±0.05 | 26.33±0.05 | 27.03±0.05 | 27.23±0.05 | 26.03±0.05 | 26.2±0.10 | 27.9±0.10 | 28.03±0.15 |
| | | 27±0.00 | 27.03±0.06 | 25±0.00 | 26.06±0.11 | 23±0.00 | 24.03±0.06 | 24±0.00 | 25±0.00 | 25±0.00 |
| 2. | Water flow (m/s) | 1.30±0.01 | 1.10±0.01 | 0.76±0.01 | 0.42±0.01 | 0.32±0.01 | 0.36±0.01 | 0.25±0.00 | 0.62±0.00 | 0.55±0.01 |
| | | 0.39±0.00 | 0.81±0.00 | 0.38±0.00 | 0.18±0.00 | 0.18±0.00 | 0.27±0.00 | 0.44±0.00 | 1.07±0.00 | 0.47±0.00 |
| 3. | Depth (m) | 3.5±0.00 | 3.26±0.00 | 3.9±0.00 | 9.6±0.00 | 5.46±0.00 | 4.7±0.00 | 11.46±0.00 | 5.2±0.00 | 7.76±0.00 |
| | | 0.96±0.00 | 3.86±0.00 | 6.72±0.00 | 6.85±0.00 | 6.86±0.00 | 3.30±0.00 | 4.41±0.00 | 3.28±0.00 | 4.67±0.00 |
| 4. | Transparency (cm) | 6.8±0.00 | 9.7±0.00 | 8.2±0.00 | 8.5±0.00 | 10.3±0.00 | 11.1±0.00 | 7.6±0.00 | 8.1±0.00 | 7.9±0.00 |
| 5. | pH | 8.25±0.01 | 8.37±0.00 | 8.31±0.00 | 8.14±0.02 | 8.31±0.00 | 8.25±0.02 | 8.12±0.01 | 8.24±0.01 | 8.11±0.01 |
| | | 8.36±0.05 | 8.30±0.06 | 8.27±0.06 | 8.62±0.04 | 8.5±0.04 | 8.6±0.05 | 8.7±0.00 | 8.60±0.10 | 8.60±0.11 |
| 6. | EC (µS/cm) | 289.03±0.05 | 204.1±0.10 | 222.1±0.10 | 186.66±0.30 | 222.16±0.47 | 188.2±0.20 | 334.53±0.50 | 360.06±0.40 | 386.06±0.81 |
| | | 212±2.64 | 225±4.58 | 280.67±4.50 | 238.66±2.08 | 239.33±4.50 | 241±5.56 | 286.67±0.58 | 270.33±3.78 | 293.33±5.50 |
| 7. | TDS (mg/L) | 162.13±0.15 | 143.37±1.27 | 158.3±0.26 | 133.03±0.05 | 158.03±0.55 | 188.23±0.25 | 236.73±0.74 | 182.63±0.60 | 181.27±0.30 |
| | | 212±2.64 | 225±4.58 | 280.66±4.50 | 238.33±2.08 | 239.33±4.50 | 241±5.56 | 286.66±0.58 | 270.33±3.78 | 293.33±5.50 |
| 8. | Salinity (ppt) | 0.08±0.00 | 0.10±0.00 | 0.11±0.00 | 0.09±0.00 | 0.10±0.00 | 0.08±0.00 | 0.23±0.00 | 0.23±0.00 | 0.27±0.00 |
| | | 0.01±0.00 | 0.13±0.00 | 0.17±0.00 | 0.14±0.00 | 0.12±0.00 | 0.14±0.00 | 0.17±0.00 | 0.11±0.00 | 0.17±0.00 |

| | | | | | | | | | | |
|-----|--|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| 9. | Dissolve oxygen (mg/L) | 7.12±0.02 | 7.20±0.01 | 4.96±0.02 | 6.26±0.03 | 5.66±0.02 | 6.70±0.01 | 5.15±0.02 | 6.40±0.03 | 5.21±0.01 |
| | | 5.16±0.04 | 5.36±0.02 | 7.19±0.04 | 6±0.05 | 5.53±0.04 | 5.57±0.02 | 6.06±0.04 | 5.53±0.05 | 5.16±0.02 |
| 10. | Free CO ₂ (mg/L) | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 |
| | | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 7.46±0.83 | 6.10±0.17 | 0.00±0.00 | 0.00±0.00 |
| 11. | Total alkalinity (mg/L) | 117.66±0.57 | 87.66±2.51 | 101.00±1.00 | 86.33±2.51 | 86.66±2.30 | 86.66±2.51 | 115.33±1.15 | 77.00±1.73 | 107.33±2.08 |
| | | 133±2.64 | 135±5.19 | 149.67±3.21 | 144±3 | 140.66±2.30 | 144.66±4.93 | 151.33±1.52 | 152.67±1.15 | 145±5.56 |
| 12. | Hardness (mg/L) | 95.83±0.76 | 72.07±0.30 | 92.10±0.36 | 80.17±0.76 | 85.4±4.85 | 68.27±0.25 | 103.97±0.45 | 96.10±0.36 | 108±0.20 |
| | | 122.66±3.78 | 115.33±3.05 | 148.66±3.21 | 131.66±3.51 | 129.66±1.52 | 143±4.35 | 143.66±0.57 | 139.67±2.08 | 138.67±1.52 |
| 13. | Nitrate-N (mg/L) | 0.08±0.00 | 0.24±0.01 | 0.05±0.00 | 0.14±0.00 | 0.07±0.00 | 0.07±0.00 | 0.15±0.00 | 0.07±0.00 | 0.25±0.00 |
| | | 0.70±0.00 | 0.56±0.00 | 1.57±0.00 | 0.90±0.00 | 1.31±0.00 | 0.65±0.00 | 0.72±0.00 | 0.72±0.00 | 0.60±0.00 |
| 14. | Silicate (mg/L) | 10.41±0.02 | 7.74±0.02 | 11.85±0.00 | 7.12±0.00 | 8.45±0.00 | 7.74±0.00 | 9.30±0.00 | 9.25±0.01 | 10.17±0.00 |
| | | 10.53±0.03 | 11.24±0.02 | 12.44±0.01 | 11.33±0.06 | 11.61±0.04 | 11.25±0.05 | 11.62±0.03 | 11.54±0.05 | 12.82±0.05 |
| 15. | Chlorinity (mg/L) | 16.01±0.01 | 17.00±0.00 | 17.00±0.01 | 16.00±0.00 | 18.00±0.00 | 18.00±0.00 | 20.00±0.01 | 22.00±0.02 | 23.00±0.01 |
| | | 6.46±0.06 | 17.33±0.42 | 23.66±0.58 | 23.96±0.87 | 25.6±1.15 | 21.9±1.01 | 33.03±2.43 | 32.5±0.50 | 49.73±0.30 |
| 16. | Avl. Phosphate (mg/L) | 0.02±0.00 | 0.03±0.00 | 0.03±0.00 | 0.02±0.00 | 0.01±0.00 | 0.02±0.00 | 0.03±0.00 | 0.03±0.00 | 0.02±0.00 |
| | | 0.09±0.00 | 0.07±0.00 | 0.15±0.00 | 0.27±0.00 | 0.25±0.00 | 0.10±0.00 | 0.14±0.00 | 0.05±0.00 | 0.07±0.00 |
| 17. | BOD (mg/L) | 2.31±0.02 | 2.40±0.01 | 0.52±0.00 | 3.48±0.02 | 0.88±0.01 | 4.70±0.02 | 3.51±0.01 | 1.60±0.02 | 1.60±0.01 |
| | | 1.20±0.00 | 0.8±0.00 | 2.40±0.08 | 2.40±0.05 | 1.06±0.15 | 0.67±0.15 | 3.06±0.15 | 1.90±0.10 | 1.56±0.06 |
| 18. | Chlorophyll- <i>a</i> (mg/m ³) | 0.07±0.00 | 0.14±0.00 | 0.27±0.00 | 0.12±0.00 | 0.12±0.00 | 0.09±0.00 | 0.12±0.00 | 0.05±0.00 | 0.14±0.00 |
| | | 0.33±0.00 | 0.40±0.00 | 0.56±0.00 | 0.65±0.00 | 0.83±0.00 | 0.63±0.00 | 1.53±0.00 | 1.24±0.00 | 1.26±0.00 |
| 10. | Chlorophyll- <i>b</i> (mg/m ³) | 0.11±0.00 | 0.22±0.00 | 0.14±0.00 | 0.23±0.00 | 0.20±0.00 | 0.17±0.00 | 0.22±0.00 | 0.12±0.00 | 0.25±0.00 |
| | | 0.20±0.00 | 0.23±0.00 | 0.33±0.00 | 0.37±0.00 | 0.39±0.00 | 0.22±0.00 | 0.56±0.00 | 0.36±0.00 | 0.78±0.00 |
| 20. | Chlorophyll- <i>c</i> (mg/m ³) | 0.12±0.00 | 0.22±0.00 | 0.16±0.00 | 0.25±0.00 | 0.17±0.00 | 0.19±0.00 | 0.24±0.00 | 0.13±0.00 | 0.19±0.00 |
| | | 0.14±0.00 | 0.20±0.00 | 0.33±0.00 | 0.35±0.00 | 0.40±0.00 | 0.15±0.00 | 0.65±0.00 | 0.35±0.00 | 0.84±0.00 |
| 21. | Total Nitrogen (mg/L) (Postmonsoon) | 0.12±0.00 | 0.08±0.00 | 0.11±0.00 | 0.08±0.00 | 0.10±0.00 | 0.11±0.00 | 0.06±0.00 | 0.07±0.01 | 0.09±0.01 |

Sediment quality Parameters

pH

The sediment pH of the Narmada River across the nine sampling sites (S₁–S₉) remained in the alkaline range during both seasons. In the pre-monsoon, sediment pH showed a gradual increase from S₁ (7.6) to S₇ (8.59), followed by a slight decrease at S₈ and a marginal rise at S₉. During the post-monsoon, sediment pH values were generally higher, ranging from about 7.6 at S₄ to nearly 8.72 at S₉. Higher post-monsoon pH was observed at all the sampling sites, with noticeable higher value at S₁, S₆, S₇, and S₉, while comparatively lower values at S₃, S₂ and S₄. Overall, the result indicates clear spatial variation in sediment pH along the Narmada River, with consistently alkaline conditions in both pre- and post-monsoon periods (Fig 18).

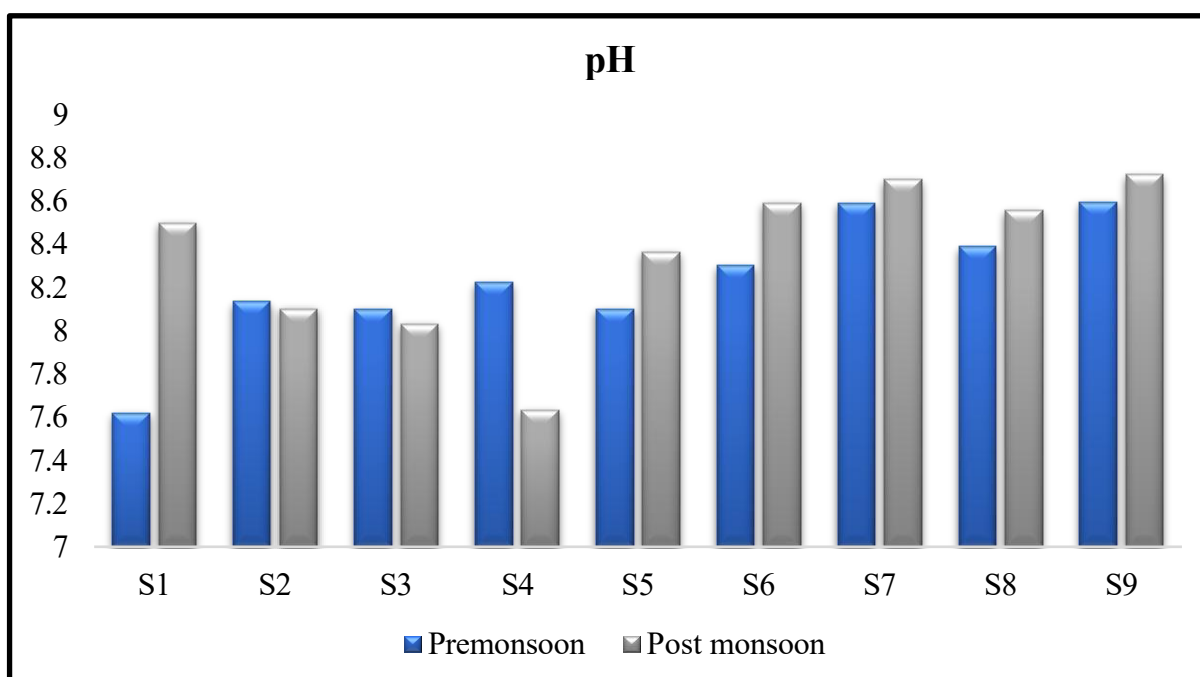


Fig. 18 Diagrammatic representation of comparative pH value recorded during the study period

Electrical Conductivity

Electrical conductivity (EC) of soil is an indicator of the total soluble salt content present in the soil matrix. It is widely used to assess soil salinity status. Electrical conductivity (EC) of Narmada River sediment exhibited marked spatial and seasonal variation across the sampling sites. During the pre-monsoon period, sediment EC ranged from about 69 $\mu\text{S}/\text{cm}$ at S₂ to 391 $\mu\text{S}/\text{cm}$ at S₃, with intermediate values at S₄ and S₅, and relatively lower value at S₆ and S₇. In the post-monsoon season, sediment EC increased at all sites, varying from 25 $\mu\text{S}/\text{cm}$ at S₂ to a

maximum of 286 $\mu\text{S}/\text{cm}$ at S₃, while S₇ and S₈ showed comparatively lower conductivity levels (Fig. 19).

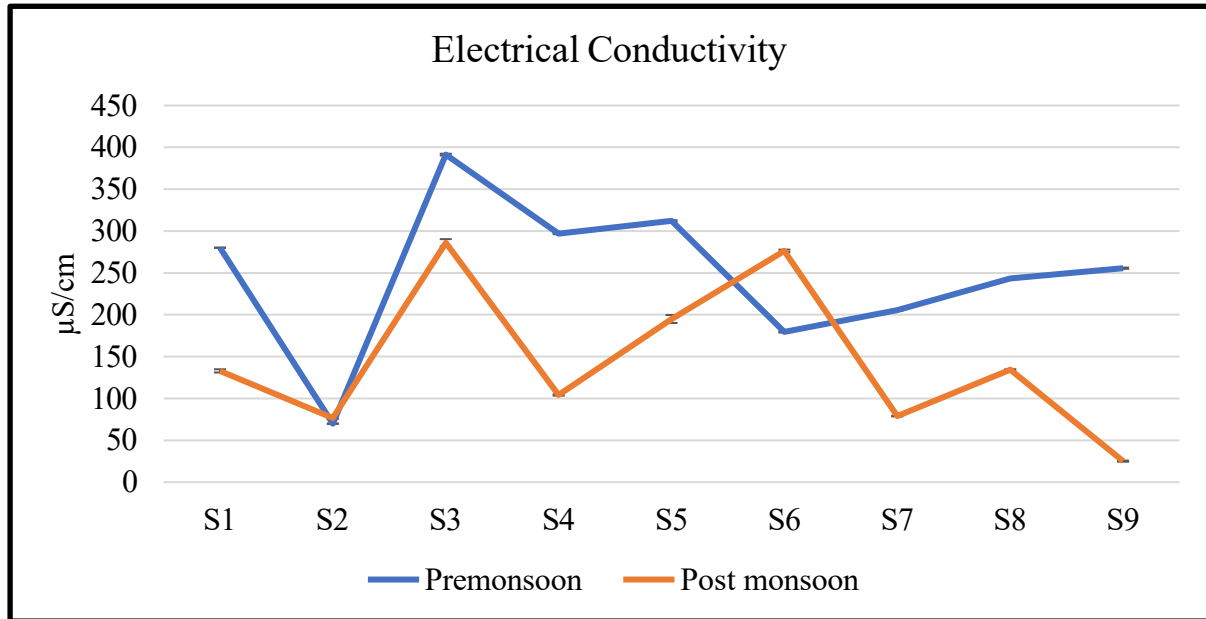


Fig. 19 Conductivity range recorded in sampling stations during the study period.

Organic Carbon

During the pre-monsoon season, organic carbon content was highest at S₁ (1.28%), indicating comparatively richer carbon content at this site. Lower values were observed at S₂ (0.37%), while moderate to relatively higher concentrations were recorded at S₃ (0.85%), S₄ (0.94%), and S₅ (0.88%). Further downstream, organic carbon showed moderate levels at S₆ (0.65%) and

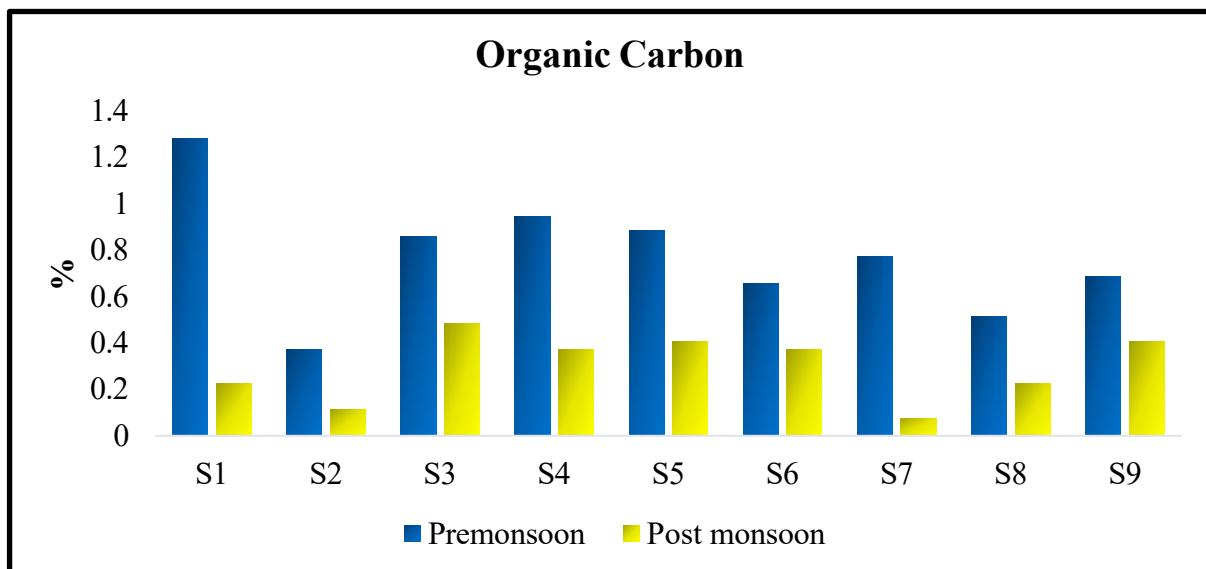


Fig. 20 Value of organic carbon content recorded during the study period.

S₇ (0.77%), followed by a decline at S₈ (0.51%) and a slight increase again at S₉ (0.68%). In contrast, the post-monsoon period showed consistently lower organic carbon percentages across all sites. Values ranged from 0.07% at S₇ (lowest) to 0.48% at S₃ (highest). Moderate concentrations were observed at S₄, S₅, S₆, and S₉, while comparatively lower values occurred at S₁, S₂, and S₈. Overall, organic carbon content was notably reduced during the post-monsoon season across the river stretch (Fig. 20).

Free calcium carbonate

Free calcium carbonate (CaCO₃) content in the sediment showed significant seasonal variation during the study period. During the pre-monsoon season, less free CaCO₃ concentration was recorded across the sites, ranging from about 3.0 mg/L at S₂ to 9.03 mg/L at S₈. Site S₁ exhibited lower values, while moderate concentrations were observed at S₃, S₄, S₅, and S₆. A relative increase was observed at S₇ and S₈, followed by S₉ with slight reduction in value. In the post-

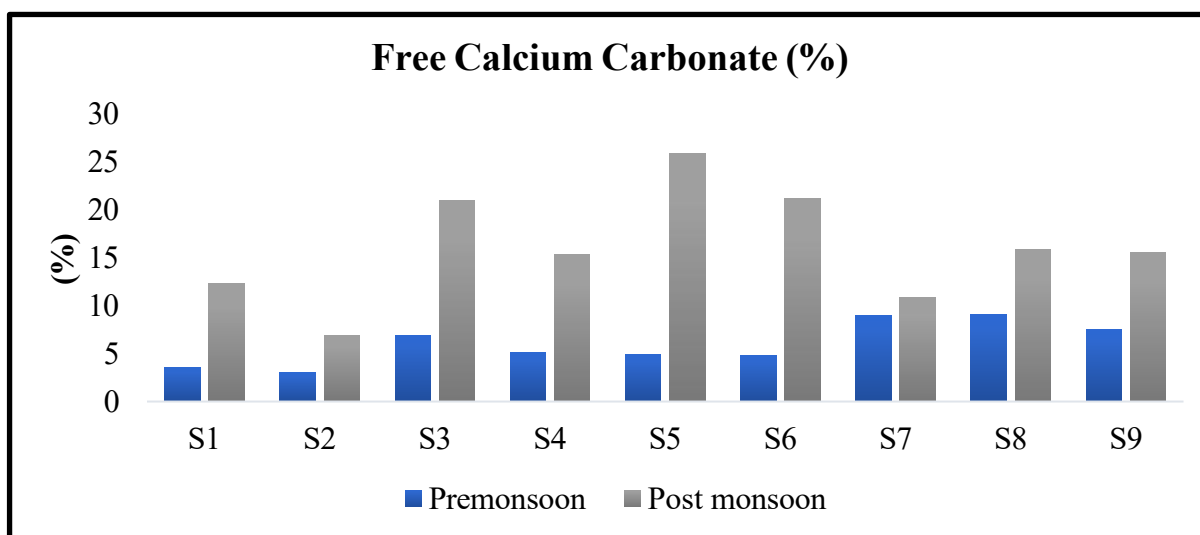


Fig. 21 Value of free calcium carbonate in all the sampling sites recorded during the study period.

monsoon period, free calcium carbonate levels increased markedly at all sampling locations. Values ranged from 6.8 mg/L at S₂ to a maximum of 25.8 mg/L at S₅. Elevated concentrations were also recorded at S₃ (21 mg/L) and S₆ (21.16 mg/L), while moderate levels were observed at S₄, S₈, and S₉. Comparatively lower but increased values were noted at S₁ and S₇, indicating overall enrichment of free calcium carbonate in sediments during the post-monsoon season (Fig. 21).

Total nitrogen

During the pre-monsoon season, total nitrogen ranged from about 0.025% at S₂ (lowest) to 0.14% at S₁ (highest). Moderate concentrations were observed at S₃ (0.09%) and S₅ (0.10%), while relatively lower values occurred at S₄, S₆, S₇, and S₉, indicating variability along the river stretch. In the post-monsoon period, total nitrogen levels increased across all sampling sites. Values varied from 0.075% at S₂ to a maximum of 0.23% at S₃, with consistently elevated concentrations at S₅, S₆, S₈, and S₉. Sites S₁, S₄, and S₇ showed moderate levels around 0.10% (Fig. 22).

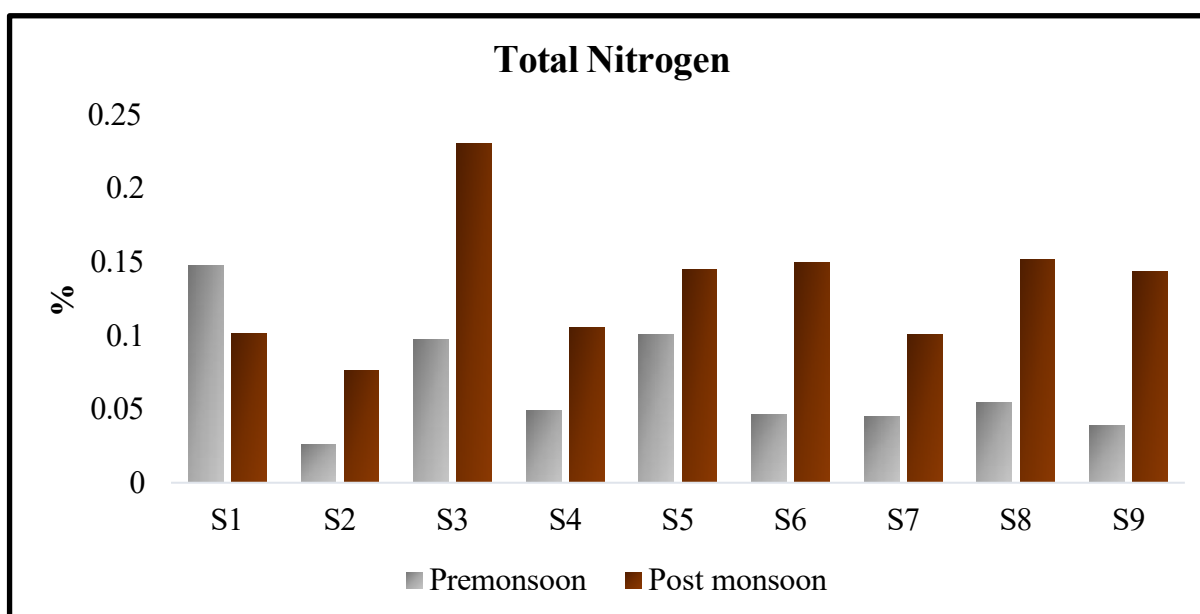


Fig. 22 Value of total nitrogen of sediment recorded during the study period.

Available Nitrogen

Available nitrogen in the sediment of the Narmada River showed pronounced spatial variation and a strong seasonal contrast between pre- and post-monsoon periods. During the pre-monsoon season, available nitrogen remained relatively low across all sites, ranging from about 4.4 mg/100 g to 9.0 mg/100 g. Moderate values were recorded at S₁ and S₃, while comparatively lower concentrations were observed at S₄, S₇, S₈, and S₉, indicating limited nitrogen availability before the monsoon. In contrast, the post-monsoon period exhibited substantially higher available nitrogen levels at all sampling locations. Values ranged from 23 mg/100 g at S₄ to a maximum of 40 mg/100 g at S₈. Elevated concentrations were also noted at S₁, S₃, S₅, and S₆, while relatively lower but still increased values occurred at S₂, S₇, and S₉, reflecting overall enrichment of sediment available nitrogen following the monsoon (Fig. 23).

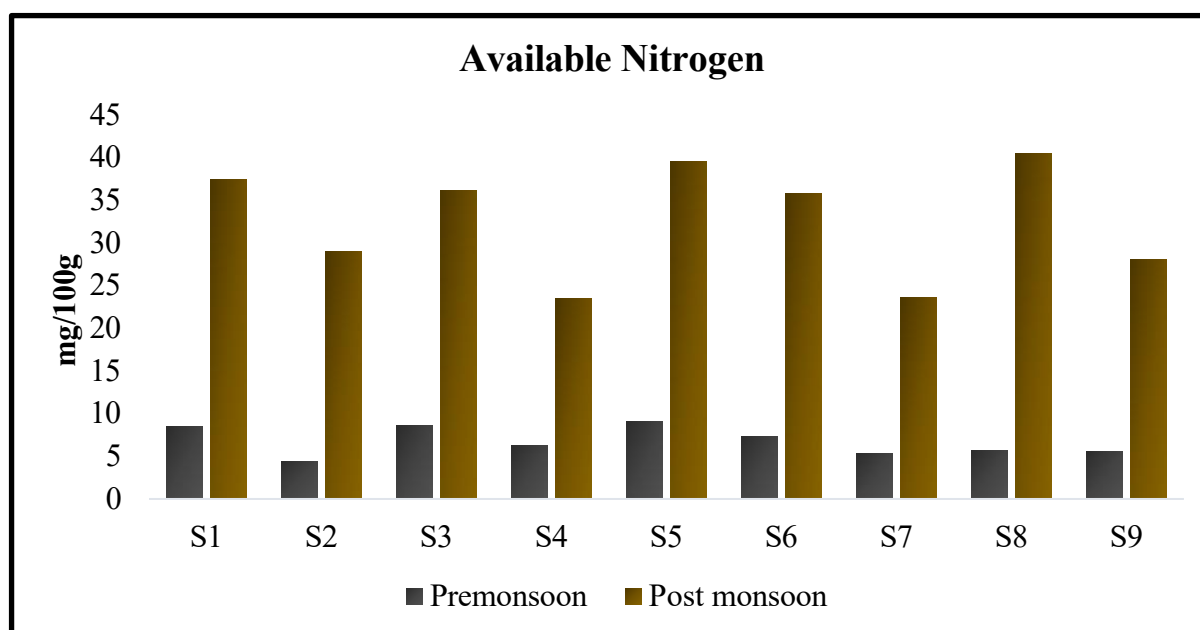


Fig.23 Available nitrogen of sediment recorded during the study period.

Available & Total Phosphorus

Phosphorus is a key nutrient in riverine sediments, playing a crucial role in regulating primary productivity, nutrient cycling, and overall ecosystem functioning. Sediment-bound phosphorus acts as both a sink and a potential source to the overlying water column, thereby influencing trophic status of aquatic systems. During the pre-monsoon period, the highest TP value was observed at S₁ (375 mg/kg), followed by S₂ and S₄. Sites S₃, S₅, and S₆ recorded comparable concentrations ranging from 295 to 305 mg/kg, whereas relatively lower values were noted at S₇ (\approx 275 mg/kg) and S₈ (\approx 220 mg/kg). In the post-monsoon season, TP concentrations declined at several locations. A noticeable reduction was recorded at S₁ (315 mg/kg) and a pronounced decrease at S₅ (192.48 mg/kg). The lowest post-monsoon TP value was observed at S₅ (Fig. 24). Overall, the sediment TP levels indicate that pre-monsoon concentrations were higher than post-monsoon values at most sites.

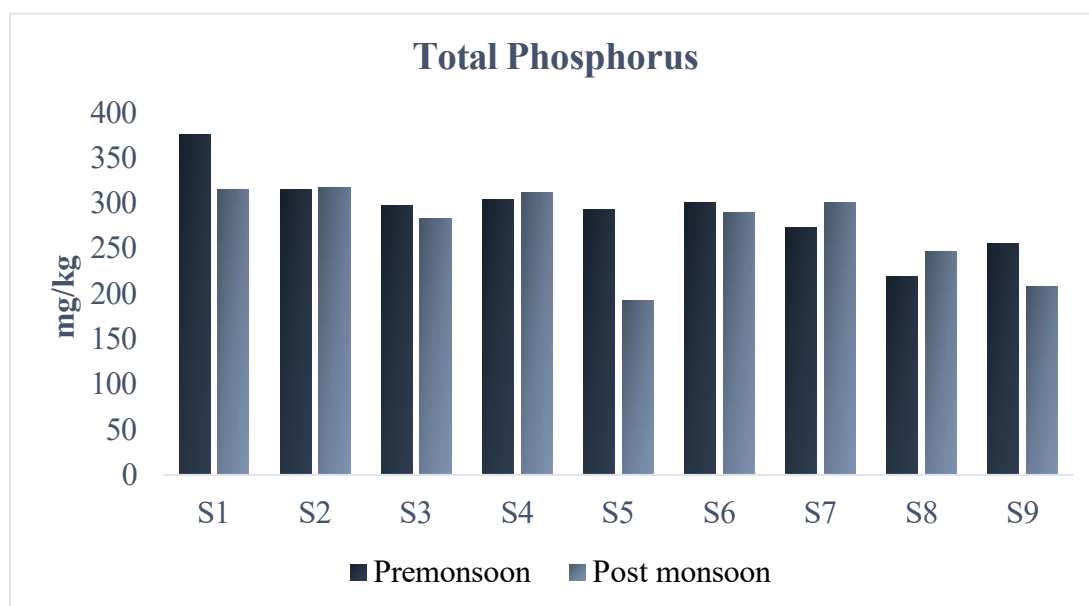


Fig. 24 Total phosphorous value recorded both in pre- and post-monsoon period

Available Phosphorus

Pre-monsoon concentrations were consistently higher at all sites (3.5–5.0 mg/L), with maximum values at S₁ and S₄, while relatively lower levels were observed at S₅. In contrast, post-monsoon available phosphorus declined sharply across all sites (0.3–1.2 mg/L), with the lowest value at S₃ and comparatively higher levels at S₁, S₇, and S₈ (Fig. 25).

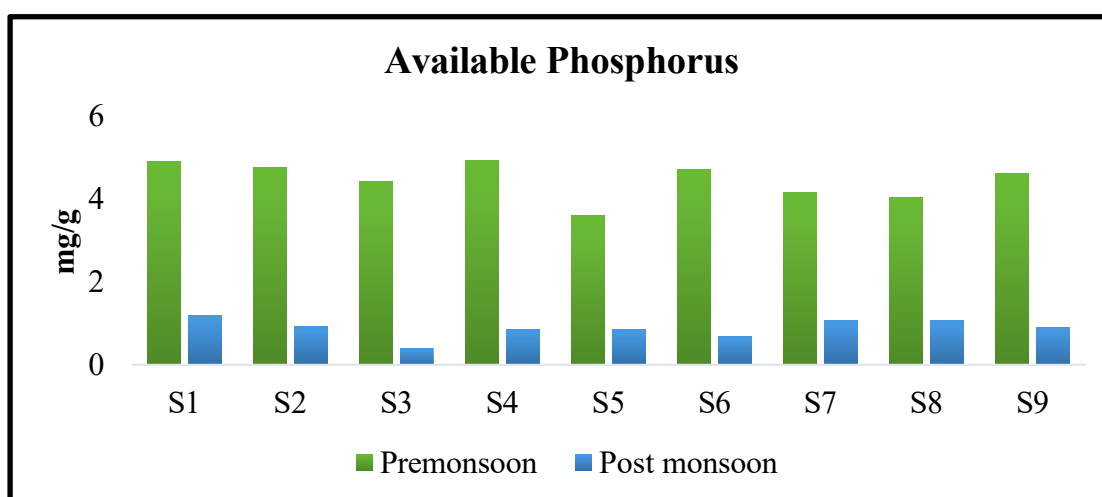


Fig. 25 Comparative value of available phosphorus recorded during the study period.

Overall, the data indicate a clear dominance of higher bioavailable phosphorus during the pre-monsoon season, followed by a substantial reduction in the post-monsoon period.

Soil Texture

During the pre-monsoon season, sand content ranged from 50–95%, with the highest proportion at S₂ (95%), followed by S₄ (70%) and S₅ (65%). Silt varied between 5–35%, being lowest at S₂ (5%) and highest at S₃ (35%), while clay content remained relatively low (0–20%), with maximum values at S₈ and S₉ (20%). In the post-monsoon season, sand content showed notable redistribution, ranging from 40–85%. Very high sand percentages were observed at S₁ and S₇ (85%), whereas lower values occurred at S₃ (40%) and S₄ and S₆ (50%). Silt content increased at several sites, ranging from 10–55%, with the highest value at S₅ (55%), followed by S₄ (45%) and S₃ and S₆ (40%). Clay content generally increased during the post-monsoon, particularly at S₃ and S₅ (20%), while S₁ showed complete absence of clay (0%) (Fig.26). Overall, the sediment texture across the study sites remained sand-dominated, with a post-monsoon increase in silt and clay fractions at several locations, indicating seasonal redistribution of finer particles along the river stretch.

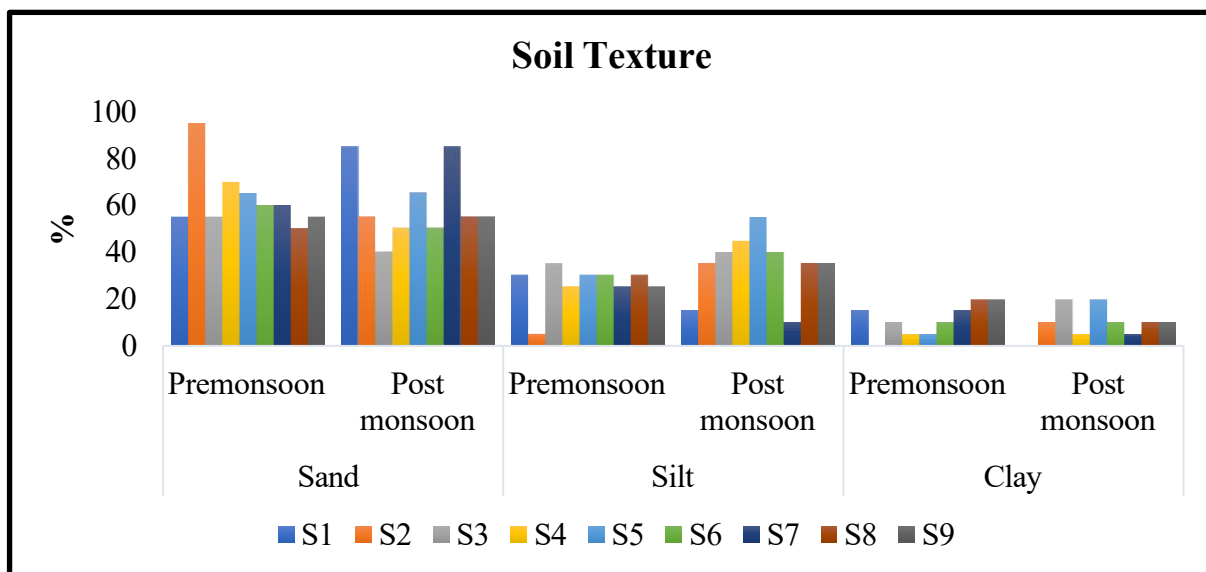


Fig. 26 Graphical representation of soil texture pattern (%) of selected sampling stations.

Plankton Dynamics

Phytoplankton dynamics

A total of six phytoplankton taxa were observed from the downstream stretch of the Sardar Sarovar Dam (SSD) on the Narmada River during the pre-monsoon study from nine different sampling stations. Among all the recorded phytoplankton groups, *Pediastrum simplex* was found to be the most abundant. The other species recorded included *Closterium* sp., *Coscinodiscus* sp., *Spirogyra* sp., *Ceratium* sp., and *Fragilaria* sp. A total of five phytoplankton

taxa were observed during post-monsoon period. Among the recorded taxa, *Pediastrum* sp. exhibited the highest cell density (1300 cells/ml), indicating its dominance and strong adaptability under post-monsoon environmental conditions. *Eudorina* sp. was also recorded with a cell density of 200 cells ml⁻¹. Other phytoplankton taxa observed during the post-monsoon season included *Staurastrum* sp., *Spirogyra* sp., and *Coelastrum* sp., reflecting a diverse phytoplankton community structure during this period. Phytoplankton observed during the pre- and post-monsoon seasons are shown in Annexure 1.

Zooplankton dynamics

Zooplankton diversity in the downstream stretch of the Sardar Sarovar Dam (SSD) on the Narmada River was comparatively low during the study period. A total of three zooplankton taxa were recorded, and their overall density remained very low across the sampling stations. During the pre-monsoon season, the zooplankton community was mainly represented by copepods, with *Mesocyclops* being the dominant form observed. In contrast, the post-monsoon season showed a slight change in species composition, with the occurrence of *Keratella* sp. (Rotifera) and *Cyclops* sp. The low abundance and limited diversity of zooplankton during both seasons indicate a sparse zooplankton community structure in the study area. Phytoplankton observed during the pre- and post-monsoon seasons are shown in Annexure 2.

Benthic communities

A total of 13 macro- and meiobenthic taxa were recorded from the downstream stretch of the Sardar Sarovar Dam (SSD) on the Narmada River during the pre-monsoon season. The benthic community included four molluscan species—*Thiara scabra*, *Tarebia lineata*, *Parreysia caerulea*, and *Indoplanorbis exustus*—of which three species were exclusively reported from the Sakkarpura sampling station. Crustacean forms such as prawn larvae and crab juveniles were observed at the Sisodara and Lilod sampling stations, respectively. In addition, arthropods were recorded from several sites along the study stretch. Notably, polychaetes belonging to the family Syllidae were observed at the Bharuch and Bhadbhut stations. During the post-monsoon season, six benthic macroinvertebrate species, all belonging to Mollusca, were recorded from the same study area. The gastropod assemblage comprised *Tarebia granifera*, *Bellamya crassa*, *Thiara tuberculata*, and *Bellamya dissimilis*, while the bivalve fauna included *Corbicula striatella* and *Parreysia favidens*. The occurrence of both gastropod and bivalve species during the post-monsoon period reflects a moderately diverse molluscan assemblage in the downstream stretch of the SSD. Benthic diversity observed during the pre- and post-monsoon seasons are shown in Annexure 3.

Fish diversity and fisheries

Pre-monsoon Sampling

The Narmada river system has rich fish diversity. Since the present investigation has concentrated on limited stretches of the river, the fish diversity may not be matched with the total diversity available in the river Narmada. In the pre-monsoon sampling, a total of 1959 individual fish samples were recorded from selected sampling sites in pre-monsoon season. The fishes belong to 11 orders, 15 families, 28 genera, and 36 species (Table 6).

Total 36 fish species are reported from lower stretch of Narmada River during the pre-monsoon period. The highest number of species reported from station S₃ (23) while lowest was from S₉ (5) (Fig. 27). The relative abundance of fish species across different sampling stations (S₁–S₉) (Fig.28) during pre-monsoon shows that at S₁, the fish community was relatively diverse, with *Clupisoma garua* (19.83%) emerging as the dominant species, followed by *Osteobrama cotio* (15.01%) and *Salmophasia bacaila* (10.99%), while other species such as *Pethia conchonius* (8.57%) and *Systemus sarana* (9.91%) also contributed notably to the species diversity. In S₂, the composition changes, where *Pethia conchonius* (31.97%) was dominant followed by *Puntius sophore* (20.68%) forming the bulk of the catch, along with significant proportions of *Chanda nama* (14.10%) and *Salmophasia bacaila* (10.34%). In Sampling station 3 (S₃), *Amblypharyngodon mola* (24.15%) was the most abundant species, while *Pethia conchonius* (7.58%) and *Clupisoma garua* (4.19%) also maintained their presence, suggesting a moderately diverse fish assemblage. Some species were not reported such as *Salmophasia bacaila* which was found one of the dominant species in S₁ and S₂. In this site along with fin fish species *Macrobrachium rosenbergii* was also reported contributing to 9.98 % of relative abundance. The community structure at S₄ was dominated by *Salmophasia bacaila* (37.77%), followed by *Pethia conchonius* (20.74%) and *Macrobrachium rosenbergii* (20.37%). Similarly, in S₅ showed mixed relative dominance of *Clupisoma garua* (14.93%) and *Macrobrachium rosenbergii* (11.03%) constituting the highest percentage in this site, while *Pethia conchonius* and *Mystus cavasius* contribute equally (7.14%) remaining species contributed less than 4 % each. In S₆, *Salmophasia bacaila* (27.77%) again became dominant but the relative abundance was less as compared to S₄, followed by *Chanda nama* (16.66%) and *Mystus cavasius* (14.81%), showing the prominence of small-sized fishes and catfishes in this stretch. A marked shift in dominance was observed from S₇ onwards, where *Mystus cavasius* (19.56%) became the most abundant species, reflecting the dominance of catfishes

towards the downstream stretch. At S₈, *Tenualosa ilisha* was the most dominant species (39.28%), followed by *Escualosa thoracata* (19.64%) and *Otolithoides pama* (8.92%), indicating an increasing influence of clupeid fishes in the lower reaches due to estuarine zone. The trend was even more pronounced at S₉, only 5 species of fishes were reported among all *Tenualosa ilisha* majorly dominates due to migration to freshwater contributing relative abundance of 60.17%, followed by *Escualosa thoracata* (23.45%) and smaller proportions of *Otolithoides pama* (9.29%).

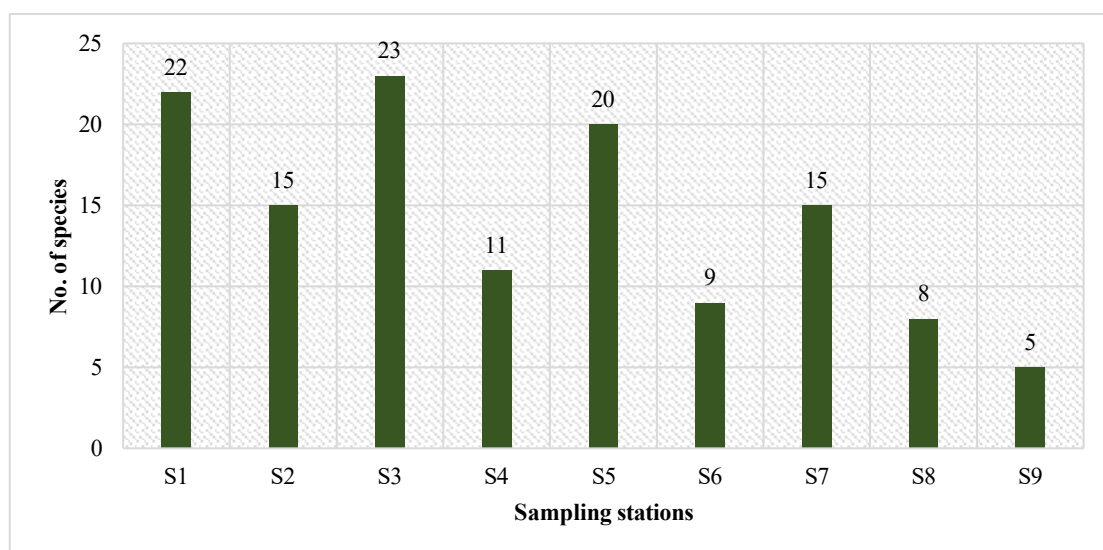


Figure 27: Number of species obtained during pre-monsoon from different sampling stations.

Table 6: Details of the fish species reported from the study area (Pre-monsoon)

| Family | Fish species | IUCN status | Garudeshwar | Poicha | Sisodra | Lilod | Jhanor | Suklatirth | Bharuch | Sakkarpura | Bhadbhut |
|-----------------|-----------------------------------|-------------|-------------|--------|---------|-------|--------|------------|---------|------------|----------|
| Ailiidae | <i>Clupisoma garua</i> | LC | + | + | + | - | - | - | - | + | - |
| Ambassidae | <i>Chanda nama</i> | LC | - | + | + | - | + | + | - | - | - |
| | <i>Parambassis ranga</i> | LC | - | - | + | + | + | + | - | - | - |
| Bagridae | <i>Mystus cavasius</i> | LC | + | - | + | + | + | + | + | - | - |
| | <i>Sperata seenghala</i> | LC | + | + | + | - | + | + | - | + | - |
| | <i>Spreta aor</i> | LC | + | - | + | - | + | - | + | - | - |
| | <i>Rita rita</i> | LC | + | - | + | + | - | - | + | + | - |
| | <i>Mystus bleekeri</i> | LC | - | + | + | + | + | - | + | - | - |
| Channidae | <i>Channa marulius</i> | LC | + | + | - | - | + | - | - | - | - |
| Cobitidae | <i>Lepidocephalichthys guntea</i> | LC | + | - | + | - | + | - | - | - | - |
| Cyprinidae | <i>Amblypharyngodon mola</i> | LC | + | + | + | - | + | - | - | - | - |
| | <i>Cirrhinus mrigala</i> | LC | + | + | + | + | - | + | - | - | - |
| | <i>Cirrhinus reba</i> | LC | + | - | + | - | - | - | - | - | - |
| | <i>Labeo boga</i> | LC | + | + | - | - | + | - | - | - | - |
| | <i>Labeo boggut</i> | LC | - | + | + | - | + | - | - | - | - |
| | <i>Labeo calbasu</i> | LC | - | + | + | - | + | - | + | - | - |
| | <i>Labeo dyocheilus</i> | LC | + | + | - | - | - | - | - | - | - |
| | <i>Labeo rohita</i> | LC | + | - | + | - | + | - | - | - | - |
| | <i>Osteobrama cotio</i> | LC | + | - | + | + | - | + | - | - | - |
| | <i>Pethia conchoniis</i> | LC | + | + | + | + | + | - | + | - | - |
| | <i>Puntius sophore</i> | LC | + | + | + | - | + | - | + | - | - |
| | <i>Salmophasia bacaila</i> | LC | + | + | - | + | - | + | - | - | - |
| | <i>Systemus sarana</i> | LC | + | - | - | - | - | - | - | - | - |
| | <i>Tor tor</i> | DD | - | - | - | + | + | - | - | - | - |
| Mastacembelidae | <i>Mastacembelus armatus</i> | LC | + | - | + | - | + | - | + | - | - |
| Notopteridae | <i>Notopterus notopterus</i> | LC | + | - | + | - | + | + | + | - | - |

| | | | | | | | | | | | |
|---------------|----------------------------------|----|---|---|---|---|---|---|---|---|---|
| Schilbeidae | <i>Eutropiichthys vacha</i> | LC | + | - | + | + | + | - | + | - | - |
| Siluridae | <i>Ompok bimaculatus</i> | NT | - | + | + | - | - | - | + | - | - |
| | <i>Wallago attu</i> | VU | + | - | + | + | + | - | + | - | - |
| Dorosomatidae | <i>Escualosa thoracata</i> | LC | - | - | - | - | - | - | + | + | + |
| Clupeidae | <i>Tenuالosa ilisha</i> | LC | - | - | - | - | - | - | - | + | + |
| Sciaenidae | <i>Otolithoides pama</i> | DD | - | - | - | - | - | - | + | + | + |
| Scatophagidae | <i>Scatophagus argus</i> | LC | - | - | - | - | - | - | - | + | + |
| Cichlidae | <i>Oreochromis niloticus</i> | LC | + | - | - | - | - | - | - | - | - |
| Latidae | <i>Lates calcarifer</i> | LC | - | - | - | - | - | - | + | + | + |
| Palaemonidae | <i>Macrobrachium rosenbergii</i> | LC | - | + | + | + | + | - | - | - | - |

IUCN Red List: DD-Data deficient, LC-Least concern, NT-Near threatened, VU-Vulnerable, EN-Endangered,

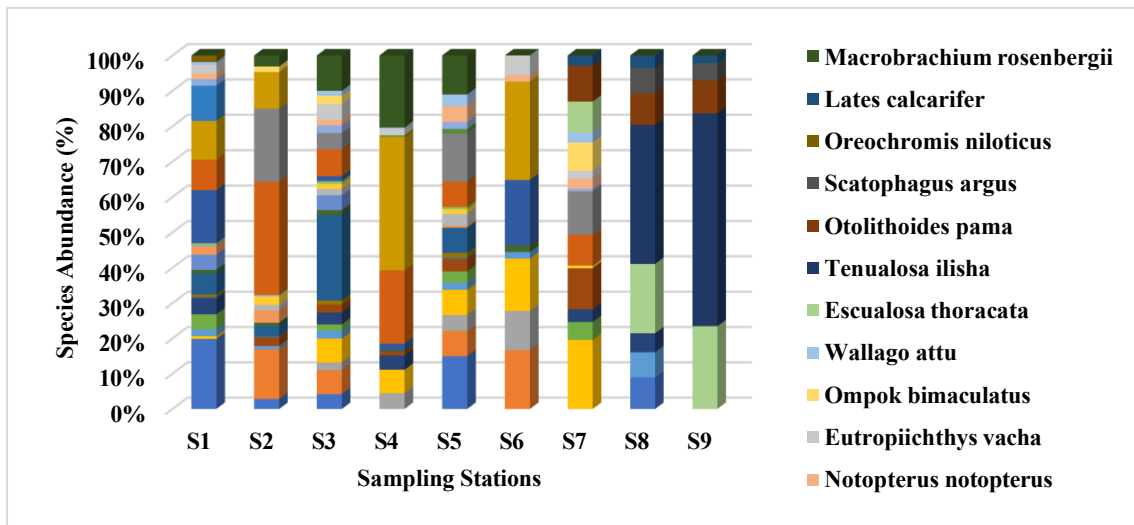


Fig 28: Species relative abundance percentage reported during pre-monsoon period from different sampling stations.

Cyprinidae is the most dominant family in the downstream of SSD, with the highest contribution recorded at S₂ (74.60%) and S₄ (61.11%). Its share, however, gradually decreases downstream, especially at S₇–S₉ due to estuarine zone (Fig. 29). Bagridae family is consistently

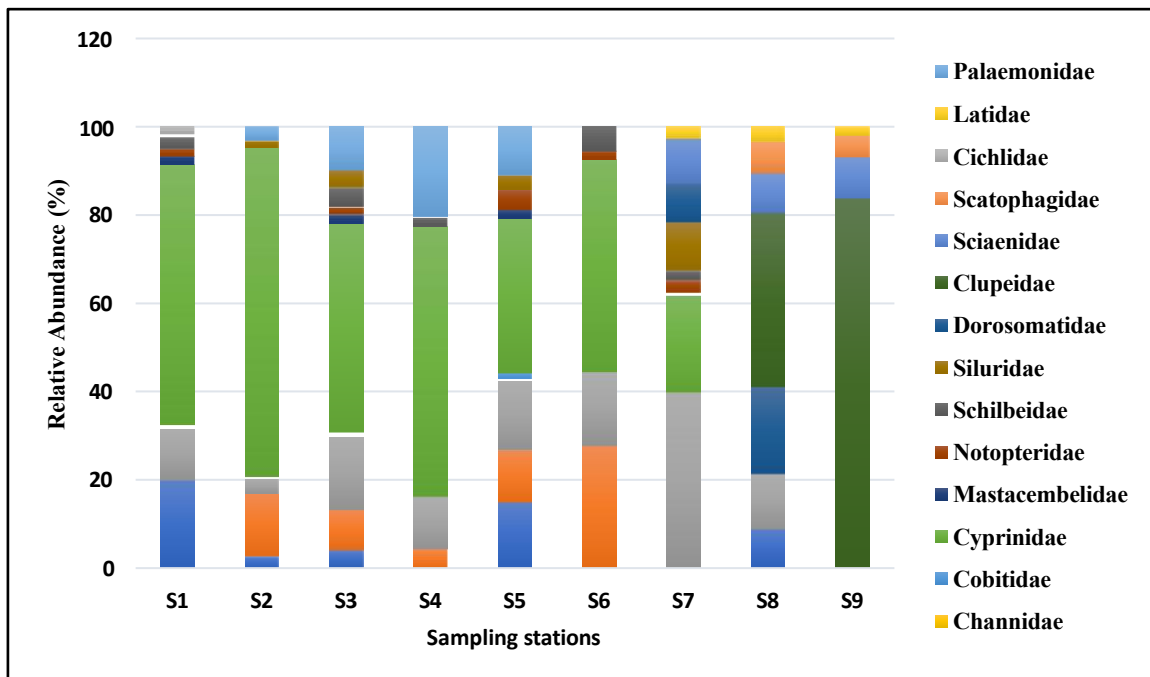


Fig 29: Relative abundance of fish species belonging to different families in the Narmada River downstream of SSD during pre- monsoon period.

present across most stations and becomes highly abundant at S₇ (39.85%), while Ambassidae shows its peak at S₆ (27.77%). Palaemonidae which include *Macrobrachium rosenbergii* occurs mainly in the midstream, with high values at S₄ (20.37%) and S₅ (11.04%). In the downstream stations, a major shift in dominance is observed where Clupeidae and Sciaenidae replace Cyprinidae as the leading families. Clupeidae dominates at S₈ (39.28%) followed by Dorosomatidae (19.64 %) and 83.62% at S₉, while Sciaenidae maintains considerable abundance at S₇–S₉, with more than 9% at each station. Other families such as Channidae, Cobitidae, Mastacembelidae, Notopteridae, Schilbeidae, Siluridae, Cichlidae, and Latidae occur in low percentages (< 10%) and are limited to specific sites. Overall, data showed that freshwater families like Cyprinidae dominates middle and upper stretch, whereas estuarine-associated families such as Clupeidae and Sciaenidae dominate downstream, showing a clear longitudinal shift in fish family composition.

Further, fish species documented during sampling are categorized into fourteen major fish groups. Catfishes (CTF) formed the major group with 9 fish species followed by (BML) Barbs, Minnows and Loaches, which mainly includes small indigenous fishes, and Minor and Peninsular Carps (MPC) (Fig.30).

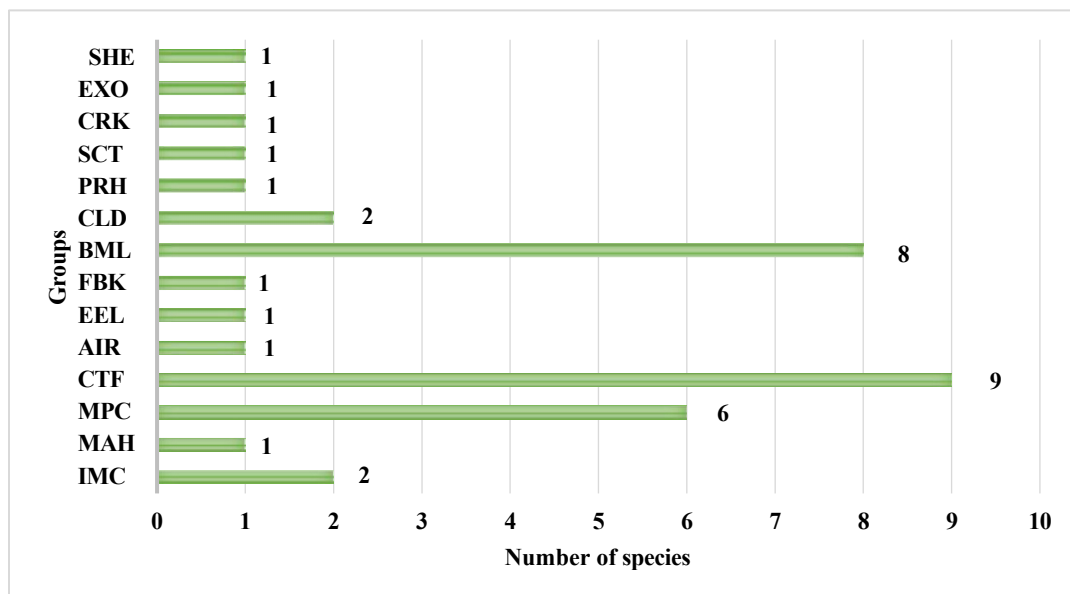


Fig 30: Group wise number of species reported during study period

Indian major carps IMC, MAH-Mahseer, MPC-Minor and peninsular carps, CTF- Catfishes, AIR-Air breathing fishes, EEL-Eels, FBK- Featherbacks, BML-Barbs, Minnows and Loaches, CLD- Clupids, PRH- Peach SCT-Scat, CRK-Croaker, EXO-Exotics, SHE-Shell fish

Distribution of migratory fishes

In the present study during pre-monsoon season, the migratory fish species mostly available in the stretch between Garudeshwar to Bhadbhut were *Tor tor* and *Tenuulosa Ilisha*. The stretch around Sisodra to Bhadbhut has been identified as hilsa fishing zone and as such there was no regular fishing activity in the upper stretches of river Narmada. In general, catch of *T. Ilisha* abundantly at Bhadbhut and Bharuch area whereas according to fishermen perception *T. Ilisha* occasionally caught at Sisodra area also during heavy rain. In the stretch between Garudeshwar to Shuklatirth, the migratory species *Tor tor* was found dominated during rainy season along with other fish species.

Early life stages of fishes

The early life stages of fishes in the natural aquatic environment including eggs, fry, larvae and juveniles play the crucial role for population success and ecosystem health because they are highly vulnerable to predators and environmental changes and their development determines the new recruitment of fish fauna diversity in the river habitats. During the sampling period significantly not much more juveniles and fry of the fish species were found due to the heavy downpour and overcast condition through entire tour period.

Fish diversity during post-monsoon season

In the post-monsoon sampling (Nov. 2025) a total of 1207 individual fish samples were recorded from selected sampling stations and surrounding places. The fishes belong to 12 orders, 19 families, 34 genera, and 42 species (Table 8.). One species of shell fishes *Macrobrachium rosenbergii* belonging to family Palaemonidae recorded from Bhadbhut. Cyprinid was the dominant group (38.09%) followed by Bagridae (7.14%), Schilbeidae (4.76 %) and Dorosomatidae (4.76 %) respectively (Fig 31). *Escualosa thoracata* was the dominant species with Relative Abundance (RA) of 6.29 % and individual nos. (n) of 76 recorded from Bhadbhut followed by *Otolithoides pama* (RA 4.63 %, n= 56) from Bhadbhut, *Salmophasia bacaila* (RA 3.39%, n=41) recorded from Lilod, *Labeo boggu* (RA. 2.81%, n=34) from Garudeshwar and *Puntius sophore* (RA 3.06%, n=77) respectively. Other dominant species were *Osteobrama cotio* (RA 2.58%) and *Chanda nama* (RA 2.62%). Maximum species occurrence (n= 25) was recorded from Garudeshwar followed by Sisodra (n=23), Poicha (n=18), Bhadbhut (n=13) and Jhanor (n=12) respectively (Fig. 32).

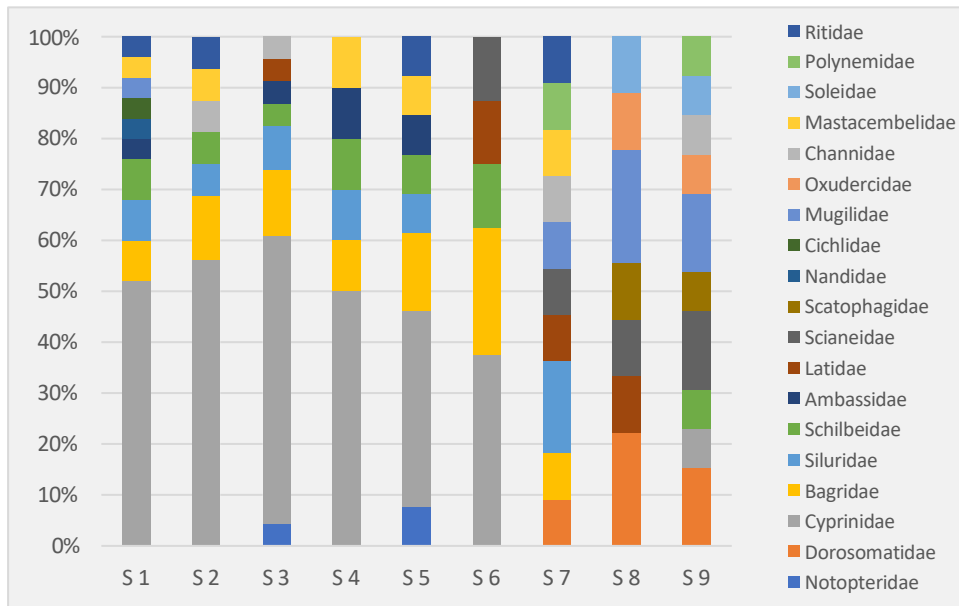


Fig 31. Overall site wise family distributions

Bagridae and Siluridae were the most well contributed group distributed in all the sampling sites except Sakkarpura and Bhadbhut followed by cyprinidae which was distributed in all the sampling sites except Bharuch, Sakkarpura and Bhadbhut. Thirteen species under the family cyprinidae recorded from Garudeshwar, 12 nos. species from Sisodra and 5 nos. species recorded from Lilod and Jhanor sites each respectively. Less nos. of species ($n=3$) under cyprinid group documented from Shuklatirth site. Ten family were identified which contributing only one species. The maximum occurrence of the individual sample ($n=76$) and ($n=56$) was recorded from Bhadbhut followed by Lilod ($n=41$) and Garudeshwar ($n=34$) respectively. Significantly, a stable population of fishes (9.52%) was found in the studied area which are considered as endangered as per IUCN criteria in other water bodies. Significantly 35.71 % of total species are considered as major food fishes, 40.47 % are recognized as food fishes and 21.42 % fishes are potential ornamental fishes which are very impressive as fish composition is concern. Among catfishes *Sperata aor*, *Sperata seenghala*, *Rita rita*, *Clupisoma garua*, *Eutropichthys vacha* and *Mystus cavasius* were the most important species recorded from Garudeshwar to Bharuch which are located in upper stretches of the studied area. In the present study the most important species were found *Clupisoma garua*, *Rita rita*, *Cirrhinus reba*, *Eutropiichthys vacha*, *Labeo rohita*, *Cirrhinus mrigala*, *Salmophasia bacaila*, *Tor tor*, *Labeo calbasu*, *Labeo boga*, *Labeo boggut*, *Tenuulosa Ilisha* and *Lates calcarifer*.

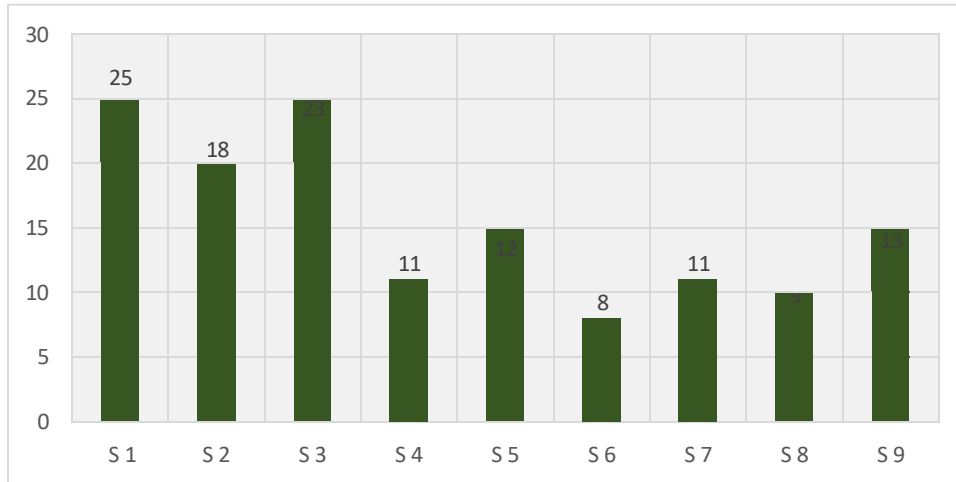


Fig 32. Graphical representation of site wise species richness

Further, fish species documented during sampling are categorized into 19 major fish groups. Catfishes (CTF) formed the major group with 8 fish species followed by BML (Barbs, Minnows and Loaches), minor and peninsular carp (n=6), Indian Major Carp (n=3), Air breathing fish, Clupids, Croaker, Mullet with 2 species each. Remaining group contains 1 species each (Table 7. & Fig 33.). It is clearly indicating that the selected stretches of river Narmada inhabit rich ichthyofauna with diverse groups.

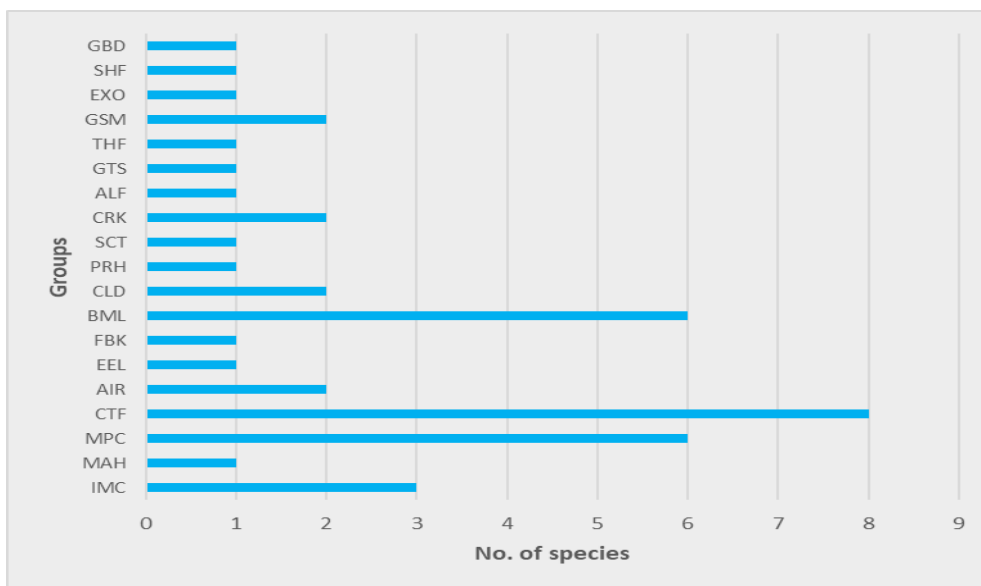


Fig 33. Graphical representation of major fish groups at various stations along river Narmada

IMC= Indian major carps; MAH=Mahseer; MPC = Minor and peninsular carps; CTF = Cat fishes; AIR = Air breathing fishes; EEL = Eel; FBK = Feather backs; BML = Barbs and minnows; CLD = Clupids; PRH = Perch; SCT = Scat; CRK = Croaker; ALF = Asian leaf fish; GTS = Gangetic tongue sole; THF = Threadfin Fish; GSM = Gold spot mullet; EXO = Exotic; SHF = Shell fish; GBD = Gobid.

Table 7. Fish group observed during the post-monsoon sampling at different stations

| Sl. No. | Groups | Code | Species | Number |
|---------|----------------------------|------|---|--------|
| 1. | Indian major carps | IMC | <i>Cirrhinus mrigala, Labeo rohita, Labeo calbasu</i> | 3 |
| 2. | Mahseer | MAH | <i>Tor tor</i> | 1 |
| 3. | Minor and peninsular carps | MPC | <i>Cirrhinus reba, Labeo boggut, Systomus sarana, Labeo boga, Labeo bata, Labeo goniuis</i> | 6 |
| 4. | Catfishes | CTF | <i>Wallago attu, Sperata seenghala, Clupisoma garua, Mystus cavasius, Ompok bimaculatus, Sperata aor, Eutropiichthys vacha, Rita rita</i> | 8 |
| 5. | Air breathing fishes | AIR | <i>Channa Punctatus, Channa striatus</i> | 2 |
| 6. | Eels, gobby | EEL | <i>Mastacembelus armatus</i> | 1 |
| 7. | Featherbacks | FBK | <i>Notopterus notopterus</i> | 1 |
| 8. | Barbs and Minnows | BML | <i>Puntius sophore, Salmophasia bacaila, Chanda nama, Amblypharyngodon mola, Osteobrama cotio, Pethia conchoniuis</i> | 6 |
| 9. | Clupids | CLD | <i>Tenualosa ilisha, Escualosa thoracata</i> | 2 |
| 10. | Pearch | PRH | <i>Lates calcarifer</i> | 1 |
| 11. | Scat | SCT | <i>Scatophagus argus</i> | 1 |

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| | | | | |
|-----|--------------------------|-----|---|---|
| 12. | Croaker | CRK | <i>Otolithoides pama, Protonibea diacanthus</i> | 2 |
| 13. | Asian leaf fish | ALF | <i>Nandus nandus</i> | 1 |
| 14. | Gangetic tongue sole | GTS | <i>Cynoglossus cynoglossus</i> | 1 |
| 15. | Threadfin Fish | THF | <i>Eleutheronema tetradactylum</i> | 1 |
| 16. | Gold spot Mullet, Mullet | GSM | <i>Liza parsia, Rhinomugil corsula</i> | 2 |
| 17. | Exotics | EXO | <i>Oreochromis niloticus</i> | 1 |
| 18. | Shell fish | SHF | <i>Macrobrachium rosenbergii</i> | 1 |
| 19. | Gobid | GBD | <i>Odontamblyopus rubicundus</i> | 1 |

Catch Per Unit Effort (CPUE):

Catch per unit effort (CPUE) is one of the important quantitative indices used worldwide to describe fish abundance and fish population. These indices may use for assessing the fish population, relative abundance, occurrence and composition of fish diversity of a particular stretch of river. CPUE can be applied to make a decision for how to manage conservation strategies, catch restriction and closed season. It is assumed that declining of CPUE reflect the decrease in fish stock. CPUE is calculated by dividing the total catch (in weight) in an hour by a single person or unit.

CPUE during pre-monsoon period

In the present investigation CPUE is calculated in each sampling sites (Figure 34). higher value of CPUE (1.6 kg/hr/person) recorded from Bhadbhut site and lowest value (0.55 kg/hr/person) recorded from Lilod. Significantly less fish diversity recorded from Bhadbhut but probably due to huge hilsa catch triggered the CPUE value at the site.

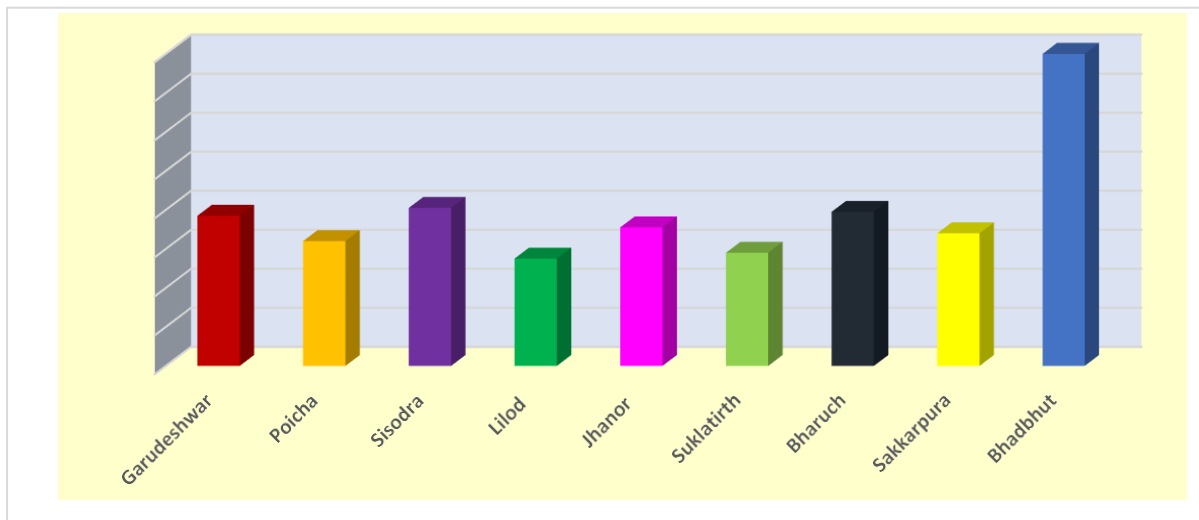


Fig 34: Diagram representing site-wise CPUE value (Kg/ hr/person)

CPUE during post-monsoon period

During post-monsoon sampling CPUE value was calculated based on total fish catch per person in an hour. In the present post-monsoon sampling CPUE is recorded in each sampling sites (Fig. 35). higher value of CPUE (12.5 kg/hr/person) recorded from Bhadbhut site and lowest value (2.0 kg/hr/person) was recorded each from Garudeshwar site. Large sized fishes recorded from Bhadbhut support the higher CPUE value. Large sized fishes added more weight to the

total catch by an individual which is trigger the CPUE value. Comparatively less CPUE value recorded from Garudeshwar and Poicha (2.7 kg/hr/person) sites mainly due to less species richness and smaller size of fishes. Remaining other sites showed medium CPUE value which are acceptable as per as aquatic habitat is concern.

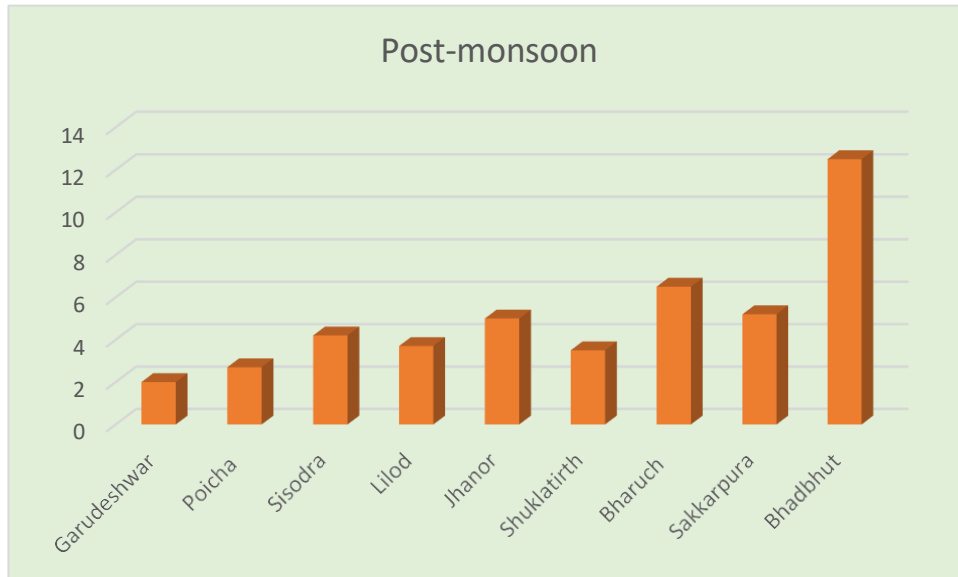


Fig 35. Site-wise CPUE value of fisherman

| | | | | | | | | | | | |
|-----|--|----|---|---|---|---|---|---|---|---|---|
| 25. | <i>Clupisoma garua</i> | LC | + | + | - | - | - | - | - | - | + |
| 26. | <i>Eutropiichthys vacha</i> | LC | + | - | + | + | + | + | - | - | - |
| | Family: Ambassidae | | | | | | | | | | |
| 27. | <i>Chanda nama</i> | LC | + | | + | + | + | - | - | - | - |
| | Family: Latidae | | | | | | | | | | |
| 28. | <i>Lates calcarifer</i> | LC | - | + | + | + | - | - | + | + | + |
| | Family: Sciaenidae | | | | | | | | | | |
| 29. | <i>Otolithoides pama</i> | LC | - | - | - | - | - | + | + | + | + |
| 30. | <i>Protonibea diacanthus</i> | NT | - | - | - | - | - | - | + | - | - |
| | Family: Scatophagidae | | | | | | | | | | |
| 31. | <i>Scatophagus argus</i> | LC | - | - | - | - | - | - | - | + | + |
| | Family: Nandidae | | | | | | | | | | |
| 32. | <i>Nandus nandus</i> | LC | + | - | - | - | - | - | - | - | + |
| | Family: Cichlidae | | | | | | | | | | |
| 33. | <i>Oreochromis niloticus</i> (Exo.) | LC | + | - | - | - | - | - | - | - | - |
| | Family: Mugilidae | | | | | | | | | | |
| 34. | <i>Liza parsia</i> | LC | - | - | - | - | - | - | - | + | + |
| 35. | <i>Rhinomugil corsula</i> | LC | + | - | + | - | - | - | + | + | + |
| | Family: Palaemonidae | | | | | | | | | | |
| 36. | <i>Macrobrachium rosenbergii</i> (Shell fish) | LC | - | - | + | + | + | | + | | + |
| | Family: Oxudercidae | | | | | | | | | | |
| 37. | <i>Odontamblyopus rubicundus</i> | LC | - | - | - | - | - | - | - | + | + |
| | Family: Channidae | | | | | | | | | | |
| 38. | <i>Channa punctatus</i> | EN | - | + | + | - | - | - | + | - | - |
| 39. | <i>Channa striatus</i> | LC | - | - | - | - | - | - | - | - | + |
| | Family: Mastacembelidae | | | | | | | | | | + |
| 40. | <i>Mastacembelus armatus</i> | LC | + | + | - | + | + | - | + | - | - |
| | Family: Soleidae | | | | | | | | | | |
| 41. | <i>Cynoglossus cynoglossus</i> | LC | - | - | - | - | - | - | - | + | + |
| | Family: Polynemidae | | | | | | | | | | |
| 42. | <i>Eleutheronema tetradactylum</i> | LC | - | - | - | - | - | - | + | - | + |
| | Family: Ritidae | | | | | | | | | | |
| 43. | <i>Rita rita</i> | LC | + | + | - | - | + | - | + | - | - |

Remarks:

A total of 3352 individuals fishes belonging to 12 orders, 20 families, 36 genera and 47 fish species have been documented from the sampling sites of the river Narmada during pre-monsoon (June' 25) and post-monsoon (November'25) sampling (Table 9.). During pre-monsoon sampling 36 no. fish species have been documented and 42 species have been recorded during post-monsoon season. *Rhinomugil corsula*, *Labeo bata*, *Labeo gonius*, *Protonibea diacanthus*, *Osteochilus vittatus*, *Channa punctatus*, *Channa striatus* and *Cynoglossus cynoglossus* was recorded during post-monsoon season whereas *Labeo dyocheilus*, *Channa marulius* and *Parambassis ranga* were documented in pre-monsoon season, remaining species recorded in both the seasons.

As result obtained from the above study cyprinid was the major group (36.07%) followed by Bagridae (8.51%), Channidae (6.38%) and Sciaenidae (4.25%) respectively. Maximum species richness in both the season was recorded at Garudeshwar (n=30, 63.82%) followed by Sisodra (n= 29, 61.70%), Poicha (n=24, 51.06%) and Jhanor (n=21, 44.68%) respectively. Significantly it has been found that, species richness gradually decreased with the decrease of river elevation (Fig 36.).

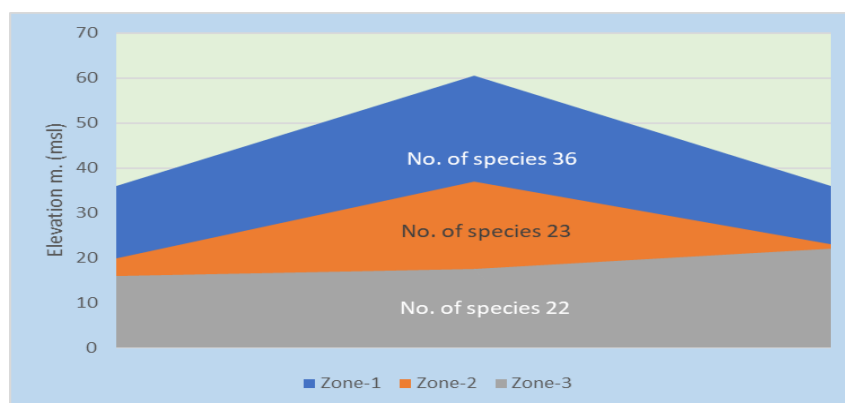


Fig 36. Graphical representation of species occurrence at different elevation.

(Zone 1 = Garudeshwar, Poicha, Sisodra; Zone 2 =Lilod, Jhanor, Shuklatirth, Zone 3 =Bharuch, Sakkarpura, Bhadbhut

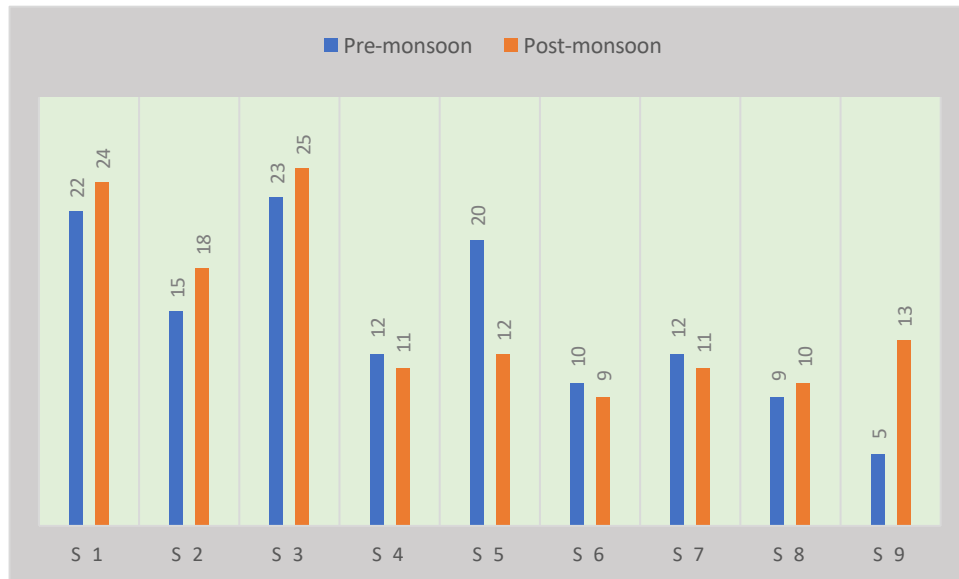


Fig 37. Season-wise species occurrence at different sampling stations.

In the stretch between Garudeshwar to Shuklatirth, the species composition was found dominated by *Labeo calbasu*, *Cirrhinus reba*, *Cirrhinus mrigala*, *Labeo bata*, *Labeo calbasu*, *Labeo boga*, *Labeo boggut*, *Salmophasia bacaila*, *Clupisoma garua*, *Eutropiichthys vacha*, *Tor tor*. Among catfishes *Sperata aor*, *S. seenghala*, *R. rita*, *C. garua*, *E. Vacha* and *Mystus* spp. were the most important species available almost throughout the stretch except Sakkarpura and Bhadbhut which are located in tidal oscillation zone. Species occurrence observed in both the seasons indicating that not much variations were recorded in sampling sites. Maximum species (n=25) recorded during post monsoon season in Sisodra followed by Garudeshwar (n=24) (Fig. 37). In remaining sites species richness were almost same in both the seasons. Significantly a wide variety of small indigenous fish (SIF) (19.14%) diversity was observed in the upstream at Garudeshwar to Shuklatirth sites. These are *Amblypharyngodon mola*, *Cirrhinus reba*, *Chanda nama*, *Parambassis ranga*, *Nandus nandus*, *Osteobrama cotio*, *Puntius sophoe*, *Pethia conchonius*, *Systemus sarana*.

Further, fish species documented during sampling are categorized into 19 major fish groups. Catfishes (CTF) formed the major group with 8 fish species followed by BML (Barbs, Minnows and Loaches), minor and peninsular carp (n=6), Indian Major Carp (n=3), Air breathing fish, Clupids, Croaker, Mullet with 2 species each. Remaining group contains 1 species each. It is clearly indicating that the selected stretches of river Narmada inhabit rich ichthyofauna with diverse groups.

Catch Per Unit Effort (CPUE) was calculated in each sampling centre during pre-monsoon and post-monsoon season. In pre-monsoon sampling, higher value of CPUE (1.6 kg/hr/person) recorded from the Bhadbhut site, and the lowest value (0.55 kg/hr/person) was recorded from Lilod. Significantly less fish diversity was recorded from Bhadbhut, but probably due to the huge hilsa catch triggered the CPUE value at the site. Significantly in post monsoon season CPUE value was higher than pre-monsoon season in all the sampling stations (Fig. 38). This was probably due to large sized fishes caught by the fishermen. In post monsoon sampling highest value of CPUE (12.5 kg/hr/person) was recorded from the Bhadbhut site, and the lowest value (2.0 kg/hr/person) was recorded from Garudeshwar. Large sized fishes recorded from Bhadbhut support the higher CPUE value. Large sized fishes added more weight to the total catch by an individual, which triggers the CPUE value. Comparatively less CPUE value recorded from Garudeshwar and Poicha (2.7 kg/hr/person) sites mainly due to smaller size of fish. The remaining sites showed medium to high CPUE value which are acceptable as per the aquatic habitat concern.

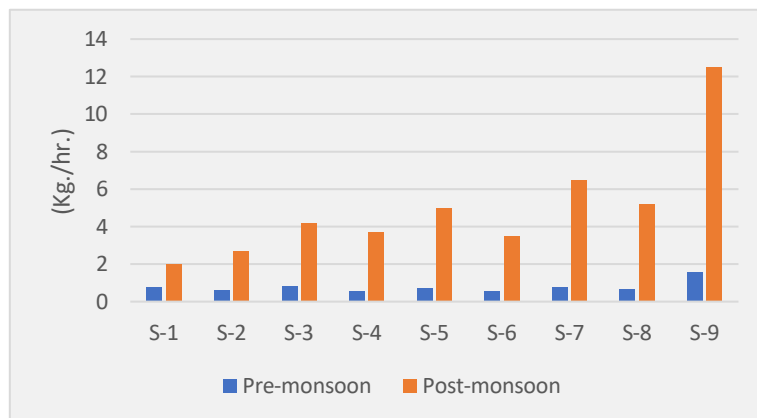


Fig. 38 Comparative value of CPUE in pre and post monsoon sampling.

Further, total fishes recorded during pre-monsoon and post-monsoon seasons are categorized into three important categories, i.e., Food fishes, major food fishes and ornamental fish. The existence of food fishes and potential ornamental fishes indicating acceptable habitat and aquatic ecological integrity that supports the intolerant species like ornamental fishes for surviving. In the present study, out of 47 fish species, 21 (44.68%) species were categorized as food fishes, 10 (21.27%) species were put under ornamental fishes, and 16 (34.04%) species regarded as major food fish (Fig 39.). Significantly all the ornamental fishes recorded from the upstream of the river from Garudeshwar to Shuklatirth sites.

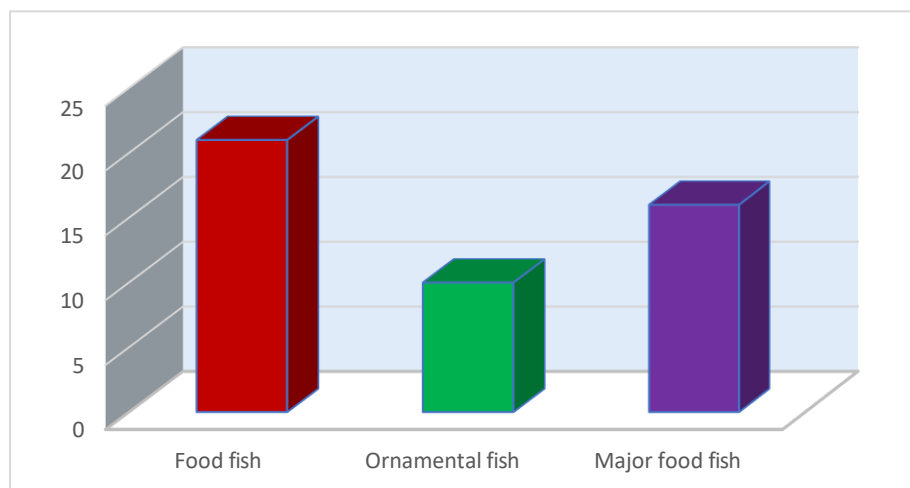


Fig 39. Diagrammatic representation of the categorization of fishes recorded during both the seasons.

Distribution of migratory fishes

Fish migration is relocation of fishes from one area to another. Many types of fish migrate on a regular basis from one habitat to another on time scale mainly due to feeding, spawning and seeking better habitat. Fish migrations involve movements of schools of fish on a scale and duration larger than those arising during normal daily activities. Some particular types of migration are *anadromous*, in which adult fish live in the sea and migrate into fresh water to spawn; and *catadromous*, in which adult fish live in fresh water and migrate into salt water to spawn. Another type of migration in which fish migrations occur wholly within fresh water is *Potamodromous*.

In the present study, in pre-monsoon and post-monsoon seasons, the migratory fish species mostly available in the stretch between Garudeshwar to Bhadbhut were *Tor tor* and *Tenualosa Ilisha* and *Lates calcarifer*. The stretch around Sisodra to Bhadbhut has been identified as hilsa fishing zone, and as such, there was no regular fishing activity in the upper stretches of the river Narmada. In general, catch of *T. Ilisha* is abundant at Bhadbhut and Bharuch area due to tidal oscillation zone, whereas according to fishermen, *T. Ilisha* is occasionally caught at Sisodra area also during the rainy season. In the stretch between Garudeshwar to Shuklatirth, the migratory species *Tor tor* was found to be dominant during the rainy season along with other fish species.

Fish species not encountered during the sampling

The following fish species were not encountered during the sampling period which are occasionally caught in the river Narmada as per fishermen perception. These are: *Chagunius chagunio*, *Bagarius bagarius*, *Macragnathus pancalus*, *Gudusia chapra*, *Jhonijs coitor*, *Corica soborna*, *Gonialosa manmina*, *Crossocheilus latius*, *Labeo catla*. The fishes caught abundantly by the fishermen during summer and monsoon season.

Less abundant of fish species

Species belonging to the following genera under different families have been found to be quantitatively less abundant as has been revealed in the present investigation during November 2025 (Table. 9)

Table 9. List of fish species recorded quantitatively less abundant

| Family | Species |
|---------------|---|
| Cyprinidae | <i>Tor tor</i> , <i>Labeo bata</i> , <i>Ciirrhinus mrigala</i> , <i>Labeo calbasu.</i> , <i>Labeo rohita</i> , <i>Labeo gonijs</i> , <i>Systomus sarana</i> , <i>Osteochilus vittatus</i> |
| Bagridae | <i>Sperata seenghala</i> |
| Channidae | <i>Channa striatus</i> |
| Schilbeidae | <i>Clupisoma garua</i> |
| Polynemidae | <i>Eleutheronema tetradactylum</i> |
| Nandidae | <i>Nandus nandus</i> |
| Soleidae | <i>Cynoglossus cynoglossus</i> |
| Scatophagidae | <i>Scatophagus argus</i> |
| Ritidae | <i>Rita rita</i> |
| Siluridae | <i>Ompok bimaculatus</i> |
| Latidae | <i>Lates calcarifer</i> |

It reveals that the Family Cyprinidae had the maximum (n=8) less abundant species followed by Bagridae, Channidae, Schilbeidae, polynemidae, Nandidae, Soleidae, Scatophagidae, Ritidae, Siluridae and Latidae with less abundant group respective.

Table 10. Representative fish species documented from river Narmada during pre and post monsoon sampling period.

| | | Sampling stations | | | | | | | | | | | | | | | | | |
|------------------------|------------------------------|-------------------|----|--------|----|---------|----|-------|----|--------|----|-------------|----|---------|----|------------|----|------------|----|
| | | Garudeshwar | | Poicha | | Sisodra | | Lilod | | Jhanor | | Shuklatirth | | Bharuch | | Sakkarpura | | Bhadbu\hut | |
| Months | | 6 | 11 | 6 | 11 | 6 | 11 | 6 | 11 | 6 | 11 | 6 | 11 | 6 | 11 | 6 | 11 | 6 | 11 |
| Family | Species | | | | | | | | | | | | | | | | | | |
| Cyprinidae | <i>Amblypharyngodon mola</i> | + | + | + | + | + | + | | + | + | - | - | - | - | - | - | - | - | - |
| | <i>Cirrhinus mrigala</i> | + | + | + | - | + | + | + | - | - | - | + | + | - | - | - | - | - | - |
| | <i>Cirrhinus reba</i> | + | + | - | + | + | + | - | - | - | - | - | - | - | - | - | - | - | + |
| | <i>Labeo bata</i> | - | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - | - | - |
| | <i>Labeo boga</i> | + | + | + | + | | + | - | + | + | + | - | - | - | - | - | - | - | - |
| | <i>Labeo boggut</i> | - | + | + | + | + | - | - | - | + | + | - | - | - | - | - | - | - | - |
| | <i>Labeo calbasu</i> | - | + | + | - | + | + | - | | + | + | - | - | - | - | - | - | - | - |
| | <i>Labeo dyocheilus</i> | + | - | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | <i>Labeo gonius</i> | - | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - | - | - |
| | <i>Labeo rohita</i> | + | + | - | + | + | + | - | - | + | - | - | - | - | + | - | - | - | - |
| | <i>Osteobrama cotio</i> | + | + | - | - | + | + | + | + | - | - | + | + | - | - | - | - | - | - |
| | <i>Osteochilus vittatus</i> | - | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | <i>Pethia conchoniuis</i> | + | + | + | + | + | + | + | + | + | + | - | - | + | - | - | - | - | - |
| | <i>Puntius sophore</i> | - | + | + | + | + | + | - | - | + | + | - | - | + | - | - | - | - | - |
| | <i>Salmophasia bacaila</i> | + | + | + | + | - | - | + | + | - | - | + | + | - | - | - | - | - | - |
| <i>Systemus sarana</i> | + | - | - | + | - | + | - | - | - | - | - | - | - | - | - | - | - | - | |
| <i>Tor tor</i> | - | + | - | + | - | + | + | - | + | - | - | - | - | - | - | - | - | - | |
| Ambassidae | <i>Chanda nama</i> | - | + | + | - | + | + | - | + | + | + | + | + | - | - | - | - | - | |
| | <i>Parambassis ranga</i> | - | - | - | - | + | - | + | | + | - | + | - | - | - | - | - | - | |
| Channidae | <i>Channa marulius</i> | + | - | + | - | - | - | - | - | + | - | - | - | - | - | - | - | - | |
| | <i>Channa punctatus</i> | - | - | - | + | - | + | - | - | - | - | - | - | - | - | - | - | - | |
| | <i>Channa striatus</i> | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | |
| Schilbeidae | <i>Clupisoma garua</i> | + | + | + | + | + | - | - | - | + | - | - | - | - | - | + | - | - | |
| | <i>Eutropiichthys vacha</i> | + | + | - | - | + | + | + | + | - | + | + | + | + | - | - | - | - | |

| Soleidae | <i>Cynoglossus cynoglossus</i> | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | - | + |
|------------------------|-------------------------------------|-------------|----|--------|----|---------|----|-------|----|--------|----|-------------|----|---------|----|------------|----|---------|----|
| | | | | | | | | | | | | | | | | | | | |
| | | Garudeshwar | | Poicha | | Sisodra | | Lilod | | Jhanor | | Shuklatirth | | Bharuch | | Sakkarpura | | Bhadbut | |
| | | 6 | 11 | 6 | 11 | 6 | 11 | 6 | 11 | 6 | 11 | 6 | 11 | 6 | 11 | 6 | 11 | 6 | 11 |
| Polynemidae | <i>Eleutheronema tetradactylum</i> | - | - | - | - | - | - | - | - | - | - | - | - | - | + | - | - | - | + |
| Dorosomatidae | <i>Escualosa thoracata</i> | - | - | - | - | - | - | - | - | - | - | - | - | + | + | + | + | + | + |
| | <i>Tenualosa ilisha</i> | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | + | + | + |
| Latidae | <i>Lates calcarifer</i> | - | - | - | + | - | + | - | + | - | + | - | + | + | + | + | + | + | + |
| Mugilidae | <i>Liza parsia</i> | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | | + |
| | <i>Rhinomugil corsula</i> | - | + | - | - | - | + | - | - | - | - | - | - | - | + | - | + | | + |
| Mastacembelidae | <i>Mastacembelus armatus</i> | + | + | - | + | + | - | - | + | + | - | + | - | - | + | - | + | - | - |
| Bagridae | <i>Mystus bleekeri</i> | - | - | + | - | + | - | + | - | + | - | - | - | + | - | - | - | - | - |
| | <i>Mystus cavasius</i> | + | - | - | + | + | + | + | + | + | + | + | + | + | - | - | - | - | - |
| | <i>Sperata aor</i> | + | + | - | + | + | + | - | - | + | + | - | - | + | + | - | - | - | - |
| | <i>Sperata seenghala</i> | + | + | + | - | + | + | - | - | + | - | + | + | - | - | + | - | - | - |
| Nandidae | <i>Nandus nandus</i> | - | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Notopteridae | <i>Notopterus notopteus</i> | + | - | - | - | + | + | - | - | + | + | + | - | + | - | - | - | - | - |
| Oxudercidae | <i>Odontamblyopus rubicundus</i> | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | - | + |
| Siluridae | <i>Ompok bimaculatus</i> | - | - | + | + | + | + | + | - | - | - | - | - | - | + | + | - | - | - |
| | <i>Wallago attu</i> | + | + | - | - | + | + | + | + | + | + | - | - | + | - | - | - | - | - |
| Sciaenidae | <i>Otolithoides pama</i> | - | - | - | - | - | - | - | - | - | - | - | + | + | + | + | + | + | + |
| | <i>Protonibea diacanthus</i> | - | - | - | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - |
| Ritidae | <i>Rita rita</i> | + | + | - | + | + | + | + | - | - | - | - | - | + | + | + | - | - | - |
| Scatophagidae | <i>Scatophagus argus</i> | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | + | + | + |
| Cobitidae | <i>Lepidocephalichthys guntea</i> | + | - | - | - | + | - | - | - | + | - | - | - | - | - | - | - | - | - |
| Cichlidae | <i>Oreochromis niloticus</i> (Exo.) | + | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Palaemonidae | <i>Macrobrachium rosenbergii</i> | - | - | - | - | - | + | - | + | - | + | - | - | - | + | - | - | - | + |

Index of Biotic Integrity (IBI)

The Index of Biotic Integrity (IBI) is a scientific tool used to assess the ecological health of aquatic systems. The multi-metric index of biotic integrity (IBI) method (Karr, 1981) used worldwide in stream or river to integrate information from individual, population assemblage and ecosystem levels into a single numerical indicator and quality rating for water bodies. This metrics was applied in the present study in selected stretches of river Narmada for assessing its quality in terms of fish assemblages and to varying levels of physical and chemical aquatic degradation.

The IBI was calculated for each site following the methods of Fausch *et al.* (1984), Hughes *et al.* (1998). The scoring criteria were developed as per the methods of Hughes *et al.* (1998). The qualitative evaluation of the IBI scores were done following Hughes *et al.* (1998), Ganesan and Hughes (1998) and Das (2006). The impaired IBI score was when the value was less than 60 % of the maximum observed. Since the highest metric values observed do not represent numerically disturbed condition, a marginally impaired score was one ranging between 60 % and 80 % of the highest score.

Modification of IBI for river Narmada (Below SSD, Garudeshwar to Bhadbhut)

Species richness

This metric is a common measure of biological diversity that generally declines with environmental degradation (Karr, 1981). Referring the original metric of Karr (1981) total number of species was replaced by native species and number of native families by Ganesan and Hughes (1998) and Das (2006). The number of native species used is a measure of biological diversity that typically decreases with increased degradation. The number of native families was used since it is a measure of biodiversity at the family level that also decreases as anthropogenic disturbance increases.

Species composition

In the present study the four metrics, number of darter species, number of sunfish species, number of sucker species and % green sunfish individuals were replaced by number of benthic species, number of water column species and % individuals as tolerant species. Karr *et al.* (1986) suggested these substitutes and they are common substitutes when IBI is modified for use outside the United States (Hughes and Oberdorff, 1999). Ganesan and Hughes (1998) and Das (2006) also used the modification for central Indian rivers and included both large and small benthic species in this metric, rather than separate them into separate darter and sucker substitute metric. Both these two metrics are strongly responsive to change in water quality and habitat structure like

siltation, turbidity, reduced oxygen content and toxic chemical. Water column species are active swimmer that typically feed on drifting and surface invertebrates or other fishes whereas benthic species are sensitive to siltation and benthic oxygen depletion because they feed and reproduce in benthic habitats (Ganasan and Hughes, 1998). The metric percent tolerant species was retained as the percentage of tolerant individual increase with increased physical and chemical degradation. The tolerant species are the last to disappear following a disturbance and the first to reappear as the system begins to recover. Several of them have accessory respiratory organs. The metric, number of intolerant species was retained as it declines with environmental degradation (Karr 1981, 1986). This metric was also used in the Indian rivers (Ganasan and Hughes, 1998) and Das (2006). The degradation is associated with urban development but particularly sedimentation, turbidity, decreased dissolved oxygen and warming (Hughes and Oberdorff, 1999).

Trophic composition

Of the three metrics namely, percent of individual as omnivore and percent of individuals as top carnivores were retained and % of individual as insectivore (invertivore) was replaced with % of individuals as herbivores. In this study also as observed by Ganasan and Hughes (1998) and Das (2006) insectivore species and individuals were less common than herbivores in less polluted habitats of the estuary and more common in polluted habitats and were thus more sensitive than insectivore. Herbivores being sensitive to physical and chemical alteration in habitat are indicative of primary production status in the site.

Fish health and abundance

The original metrics 'total number of individuals in the samples' and % of individuals with disease or anomalies were retained. The new metric added by Ganasan and Hughes (1998) for Central Indian River and Das (2006) for river Hooghly was also retained % of individual as non-native, since exotic species are gradually becoming an important concern in Indian rivers. Non-native species are generally more successful where native species are depauperated or in anthropogenically altered systems (Ross, 1991). Total number of individuals is a gross measure of fish production and is lowest in highly disturbed system as well as in nutrient poor waters.

Table: 11. IBI at different selected sites of river Narmada

| Site | Garudeshwar | | Poicha | | Sisodra | | Lilod | | Jhanor | | Shuklatirth | | Bharuch | | Sakkarpura | | Bhadbhut | |
|---------------------------|-------------|------|--------|------|---------|------|-------|------|--------|------|-------------|------|---------|------|------------|------|----------|------|
| Month | 6 | 11 | 6 | 11 | 6 | 11 | 6 | 11 | 6 | 11 | 6 | 11 | 6 | 11 | 6 | 11 | 6 | 11 |
| Year | 2025 | | 2025 | | 2025 | | 2025 | | 2025 | | 2025 | | 2025 | | 2025 | | 2025 | |
| No. of Native sp. | 21 | 23 | 15 | 18 | 24 | 23 | 11 | 10 | 20 | 11 | 9 | 7 | 15 | 9 | 6 | 11 | 6 | 13 |
| No. of Native family | 9 | 9 | 5 | 7 | 9 | 8 | 6 | 6 | 8 | 7 | 5 | 4 | 10 | 9 | 8 | 8 | 5 | 11 |
| % of individual exotic | 4.54 | 4.16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| No. of Benthic spp. | 13 | 13 | 9 | 9 | 14 | 14 | 6 | 4 | 11 | 7 | 4 | 3 | 9 | 4 | 5 | 4 | 1 | 4 |
| No. of Column spp. | 7 | 8 | 5 | 6 | 8 | 8 | 3 | 4 | 7 | 3 | 3 | 2 | 5 | 4 | 4 | 4 | 4 | 6 |
| No. of intolerant spp. | 13 | 17 | 11 | 10 | 15 | 17 | 6 | 7 | 10 | 7 | 7 | 5 | 10 | 6 | 6 | 10 | 5 | 11 |
| % of individual tolerant | 40.9 | 33.3 | 26.6 | 33.3 | 33.3 | 30.4 | 45.4 | 60.0 | 45.0 | 27.2 | 22.2 | 28.5 | 40.0 | 33.3 | 50.0 | 0 | 0 | 18.1 |
| % of individual omnivore | 40.9 | 42.3 | 29.1 | 39.1 | 45.8 | 47.8 | 63.6 | 40.0 | 40.0 | 27.2 | 44.4 | 57.1 | 53.3 | 44.4 | 50.0 | 45.4 | 50.0 | 46.1 |
| % of individual carnivore | 40.9 | 40.9 | 26.6 | 27.7 | 41.6 | 34.7 | 36.3 | 40.0 | 45.0 | 54.5 | 55.5 | 42.8 | 46.6 | 55.5 | 66.6 | 66.6 | 16.6 | 46.1 |
| % of individual herbivore | 13.6 | 16.6 | 26.6 | 16.6 | 8.3 | 17.3 | 0 | 20.0 | 15.0 | 18.1 | 0 | 0 | 0 | 0 | 16.6 | 9.0 | 16.6 | 7.6 |
| Total no. of individuals | 373 | 264 | 309 | 184 | 491 | 168 | 215 | 147 | 137 | 113 | 54 | 52 | 138 | 67 | 34 | 36 | 90 | 142 |
| Total no. of spp. | 22 | 24 | 15 | 18 | 24 | 23 | 11 | 10 | 20 | 11 | 9 | 7 | 15 | 9 | 6 | 11 | 6 | 13 |
| IBI score | 33 | 35 | 35 | 29 | 39 | 37 | 23 | 27 | 29 | 29 | 25 | 29 | 25 | 19 | 27 | 35 | 23 | 29 |
| IBI score (average) | 34 | | 32 | | 38 | | 25 | | 29 | | 27 | | 22 | | 31 | | 26 | |
| Integrity class | A | | MI | | A | | MI | | MI | | MI | | MI | | MI | | MI | |

A= Acceptable; MI = Moderately Impaired

Table 12. Criteria for scoring of IBI metrics for river Narmada (Garudeshwar to Bhadbhut).

| Category | Metric | Scoring criteria | | |
|---------------------------|-------------------------------|------------------|---------|-----------|
| | | 5 (Best) | 3 | 1 (worst) |
| Taxonomic richness | No. of Native spp. | > 23 | 11-23 | < 11 |
| | No. of Native family | > 10 | 8-10 | < 8 |
| Habitat composition | No. of Benthic spp. | > 13 | 6-13 | < 6 |
| | No. of Column spp. | > 7 | 4-7 | < 4 |
| | No. of intolerant spp. | > 16 | 6-16 | < 6 |
| | % of individual tolerant | < 19 | 19-30 | > 30 |
| Trophic composition | % of individual omnivore | < 30 | 30-45 | > 45 |
| | % of individual carnivore | > 53 | 40-53 | < 40 |
| | % of individual herbivore | > 20 | 13-20 | < 13 |
| Fish health and abundance | Total no. of individuals | > 350 | 150-350 | < 150 |
| | % of individual as non-native | 0 | 1-5 | > 5 |
| | % individual with anomalies | – | – | – |

Scores 5,3,1 assigned according to whether its values approximate, deviates somewhat from or deviates strongly from value of least disturbed site.

IBI assessment and grading of river stretch

The IBI was calculated for each site following the methods of Fausch *et al.* (1984) and Hughes *et al.* (1993). We used the most desirable metric values as obtained at the least disturbed site *i.e.* Sisodra as estimates of the reference condition. The scoring criteria was developed for river Narmada (Table 12) as per the methods of Hughes *et al.* (1993).

In the present investigation, among the metric included in the index, all the metric changed. The number of native species and families in the reference site is significantly higher than that observed in the slight stressed zone. A comparison of the species composition revealed that the number of benthic species, the number of water column species and the number of intolerant species have reduced in sites where biotic integrity was found to be moderately impaired (Lilod, Jhanor, Shuklatirth, Bharuch and Bhadbhut). Whereas percentage of tolerant species have increased in these sites. The most common species at the disturbed sites were *Eutropiicthys vacha*, *Pethia conchoni*, *Mastacembelus armatus*, *Mystus cavasius*, *Rita rita*, *Otolithoides pama* and *Sperata aor*. The trophic composition also showed alteration in the stressed sites (moderately impaired). Percent omnivores and carnivores increased and percent herbivores decreased. Fishes with disease or anomalies were not recorded during sampling. The index of fish assemblages decreased with distance downstream from undisturbed reference zone (Sisodra along Narmada River). Based on the modification of IBI Garudeshwar (S-1) and Sisodra (S-3) along river Narmada supported fish assemblages in acceptable condition (Table 11).

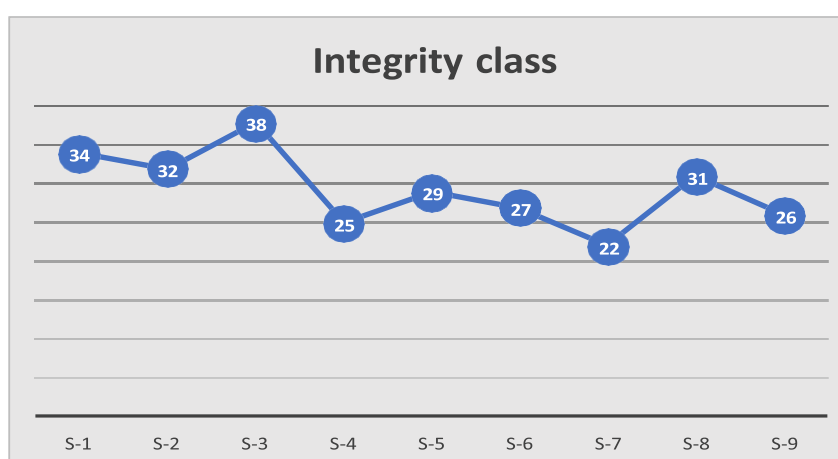


Fig. 40 Linear diagram representing integrity class of IBI at sampling sites
Value 34-38 = Acceptable; 22-32 = Moderately impaired

Remarks

From the present study, Sisodra was considered as the reference zone, being the least disturbed site with the highest fish diversity (Fig. 45). The remaining sampling sites along upstream and downstream to it recorded slight changes of IBI metrics. Garudeshwar and Sisodra were in the acceptable range. These sites thus reflected fewer disturbances with higher number of native species, intolerant, and herbivores. As such, environmental stress was minimal with the least effect on the fish assemblage. These sites can thus be inferred to support a healthy grade of fisheries. Significantly, one alien species, *Oreochromis niloticus* recorded from the Garudeshwar site in both seasons. The number of native species and native families is a measure of biological diversity and decreases with increasing anthropogenic disturbances (Karr, 1981). Whereas Poicha, Lilod, Shuklatirth, Bharuch, Sakkarpura and Bhadbhut were found to be moderately impaired. Though these sites were graded as moderately impaired as per IBI gradation, but all these sites are nearer to acceptable range which are significant as per as fish assemblage is concern. A little environmental stress at these sites. Sewage disposal, expulsion of waste on account of religious activities formed a source of major pollution at these sites. As such due to environmental stress, number of exotic (*viz. O. niloticus*) and tolerant species (*viz. R. rita, Channa, Aorichthys, and Mystus* species) had been recorded.

The decrease in number of benthic species and water column species is also indicative of deterioration of habitat quality. Both these metrics are strongly responsive to changes in water quality and habitat structure like siltation, turbidity, reduced oxygen content and toxic chemical. Water column species are active swimmers that feed on drifting and surface invertebrates or other fishes whereas benthic species are sensitive to siltation and benthic oxygen depletion because they feed and reproduce in benthic habitats (Ganasan and Hughes, 1998). Siltation and turbidity seem to be stressors in Bharuch, Lilod and Shuklatirth in the present study. Along with, the significant increase in the number of tolerant species and percent omnivores in the disturbed sites also indicate the deteriorated habitat in these sites. This is in agreement to the observation of Ganasan and Hughes (1998) who opined that tolerant fishes are opportunistic, invasive species that tend to be widely distributed and locally abundant, while intolerant fishes are more patchily distributed and not so abundant in anthropogenically stressed site. It is relevant to mention that though pollution to certain degree in stressed sites, water quality does not reflect significant contamination. Yet there is reduction in the IBI in Lilod and Bharuch. The possible reason could be the greater river width and presence of pools adjacent to main channel respectively. In agreement to the opinion of Ganasan and Hughes (1998), it is felt that the metric scoring criteria require further evaluation, as do reference

condition data from minimally disturbed sites. In the present investigation the site used as reference site might not be the ideal reference site as pristine sites in an ecoregion may not be always available as has been done in the investigation of Ganasan and Hughes (1998) and Das et al (2006).

In the present investigation, sampling sites were selected within a short longitudinal distance and did not cover all the climatic seasons for sampling, variations of environmental impact were little among the sampling sites, and these were also reflected in the IBI scores also. However, use of disturbed reference sites may be necessary for rehabilitating some of the worst conditions in an ecoregion; otherwise, in such water relation to natural conditions might be considered so unrealistic that nothing would be done and upstream reaches in better condition would continue to be degraded. Since the Sakkarpura and Bhadbhut sites are located in the tidal oscillation zone, therefore IBI scores may be varied from time to time, because of frequent visit of fishes with different trophic level. Overall, all sampling sites located in the study area are considered as acceptable and moderately impaired as per IBI scores with suitable ecological habitat and environmental flow.

Hydrological Assessment Using ADCP

An acoustic Doppler current profiler, or ADCP, is a device used worldwide to measure the speed and direction of currents throughout the water column by using sound waves. It provides information about how water in the rivers moves, and provides important information about the biological, chemical, and physical properties of the lotic water bodies.

During the post-monsoon sampling, an Acoustic Doppler Current Profiler (ADCP) survey was conducted along the lower stretch of the Narmada River, covering nine sites from Garudeshwar to Bhadbhut, representing an important transitional zone from regulated upstream reaches to the estuarine influence near the river mouth. The survey generated site-specific data on river width, discharge, flow velocity, and depth, which were further compared with available pre-monsoon depth and flow conditions to understand seasonal hydrological variability and its implications for river health and fisheries.

River Width and Channel Geometry

The river width showed a progressive downstream increase, reflecting channel expansion towards the estuarine zone. Width ranged from 213.7 m at Garudeshwar to 965.95 m at Bhadbhut, with notable widening at Bharuch (785.55 m) and Sakkarpura (589.9 m). This

widening contributes to flow dispersion, reduced mean velocities, and enhanced lateral habitat diversity, which are critical for fish spawning, nursery grounds, and migratory pathways.

Discharge Characteristics

River discharge exhibited substantial spatial variation across sites. The lowest discharge (46.25 m³/s) was recorded at Garudeshwar, indicating strong upstream regulation effects and reduced flow availability in the upper part of the lower stretch. Discharge increased downstream, reaching 693 m³/s at Poicha, 1270 m³/s at Bharuch, and peaking at 2095 m³/s at Sakkarpura, before slightly declining at Bhadbhut (1430 m³/s). This increasing discharge trend downstream is attributed to tributary inflows, tidal backwater influence, and widening channel geometry. Compared to pre-monsoon flow velocities (0.32–1.30 m/s), present discharge conditions suggest enhanced post-monsoon flow connectivity, which is crucial for nutrient transport, sediment flushing, and maintenance of fish migration routes.

Flow Velocity Patterns

Maximum current velocities varied between 0.85 m/s (Jhanor) and 3.03 m/s (Bhadbhut), while mean velocities generally remained low to moderate (0.02–1.07 m/s) (Fig 16.). High maximum velocities at Bhadbhut and Garudeshwar indicate localized constrictions or tidal influence zones. The overall low mean velocities at sites such as Lilod, Suklatirth, and Jhanor suggest the presence of low-energy habitats favourable for benthic and column-feeding fish species, whereas moderate to high velocities at Poicha, Sakkarpura, and Bharuch support migratory species and aid in preventing excessive sediment deposition.

Depth Distribution and Comparison with Pre-monsoon Conditions

Maximum observed depths ranged from 1.56 m (Garudeshwar) to 17.0 m (Sisodara), while mean depths varied between 0.76 m (Garudeshwar) and 6.97 m (Jhanor) (Fig 15.). Deeper channel sections at Sisodara, Jhanor, and Lilod indicate the presence of pools that act as thermal refugia and resting zones for large-bodied fish, especially during lean periods. When compared with pre-monsoon depths, the present observations show a general reduction in depth at several locations (*e.g.*, Lilod: 9.6 m pre-monsoon vs. 4.93 m observed mean depth; Bharuch: 11.46 m vs. 4.29 m), indicating sediment redistribution and seasonal drawdown. Such depth reduction can directly affect fish refuge availability during lean seasons and intensify competition for space and oxygen (Table 13).

Table13: Hydrological parameters recorded from the selected sites of the river Narmada using ADCP.

| | Width | Discharge | Max. Vel | Mean Vel. | Max. Depth | Mean Depth |
|-------------|--------|---------------------|----------|-----------|------------|------------|
| | (m) | (m ³ /s) | (m/s) | (m/s) | (m) | (m) |
| Garudeshwar | 213.70 | 46.25 | 2.69 | 0.17 | 1.56 | 0.76 |
| Poicha | 271.30 | 693.00 | 1.73 | 0.75 | 5.00 | 3.42 |
| Sisodara | 198.00 | 293.50 | 1.00 | 0.14 | 17.00 | 4.86 |
| Lilod | 242.50 | 150.00 | 1.77 | 0.02 | 12.30 | 4.93 |
| Jhanor | 461.70 | 540.00 | 0.85 | 0.17 | 15.45 | 6.97 |
| Suklatirth | 300.90 | 184.00 | 1.44 | 0.02 | 7.29 | 2.50 |
| Bharuch | 785.55 | 1270.00 | 1.49 | 0.36 | 6.50 | 4.29 |
| Sakkarpura | 589.90 | 2095.00 | 1.88 | 1.07 | 5.91 | 3.31 |
| Bhadbhut | 965.95 | 1430.00 | 3.03 | 0.23 | 9.81 | 4.13 |

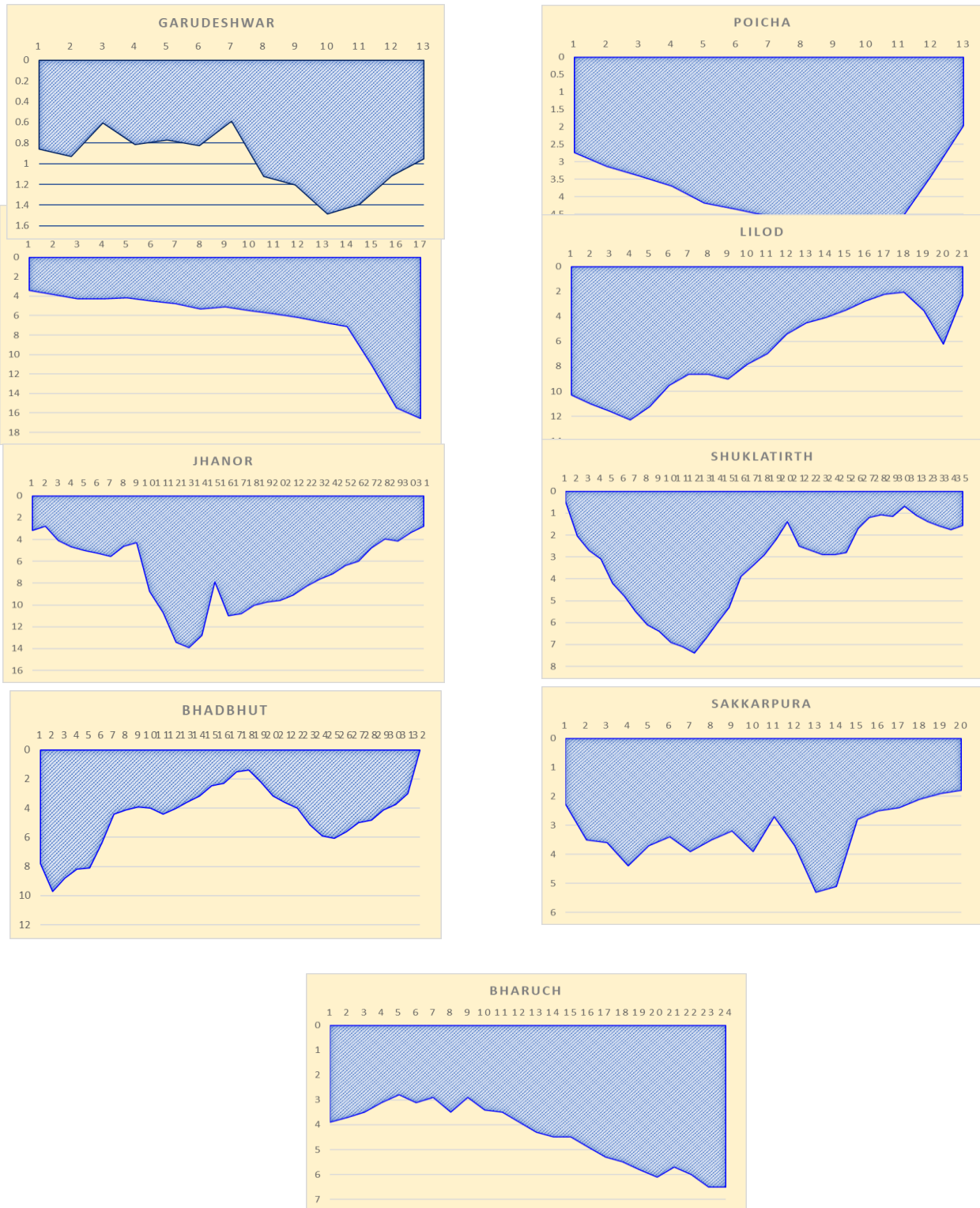
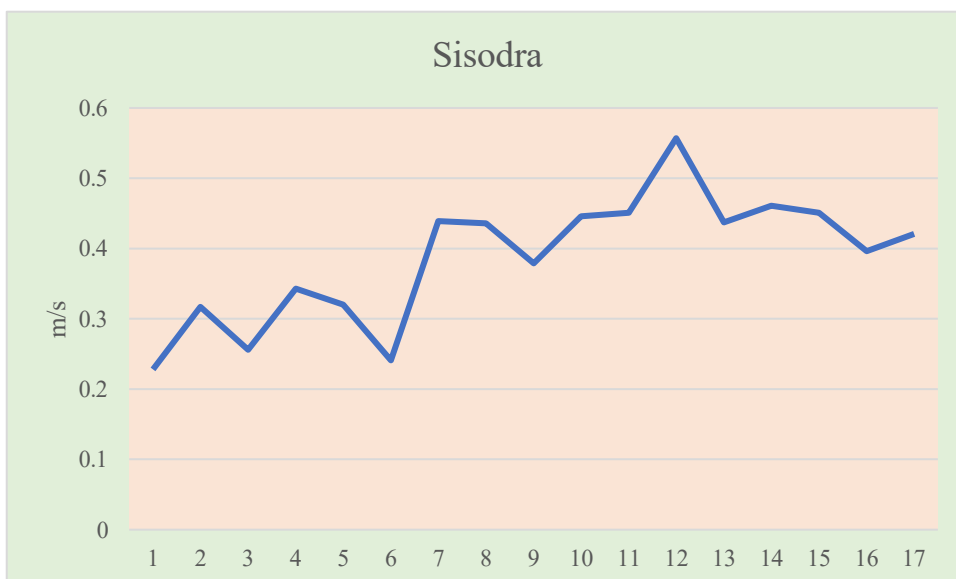
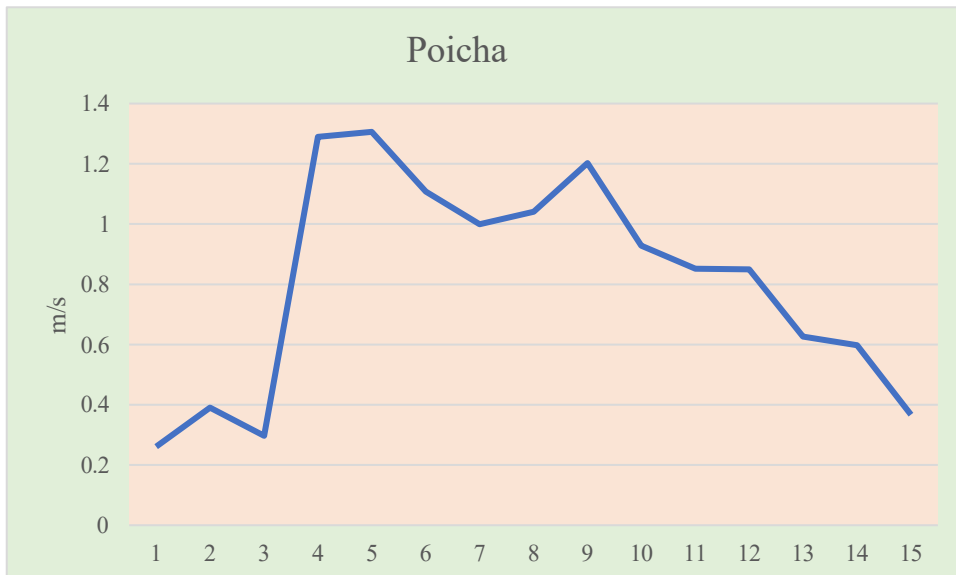
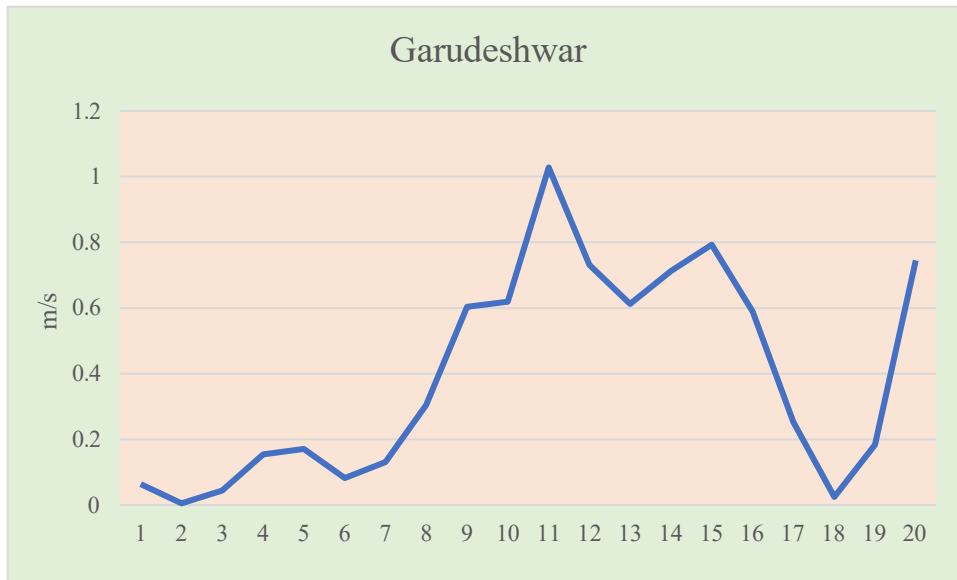
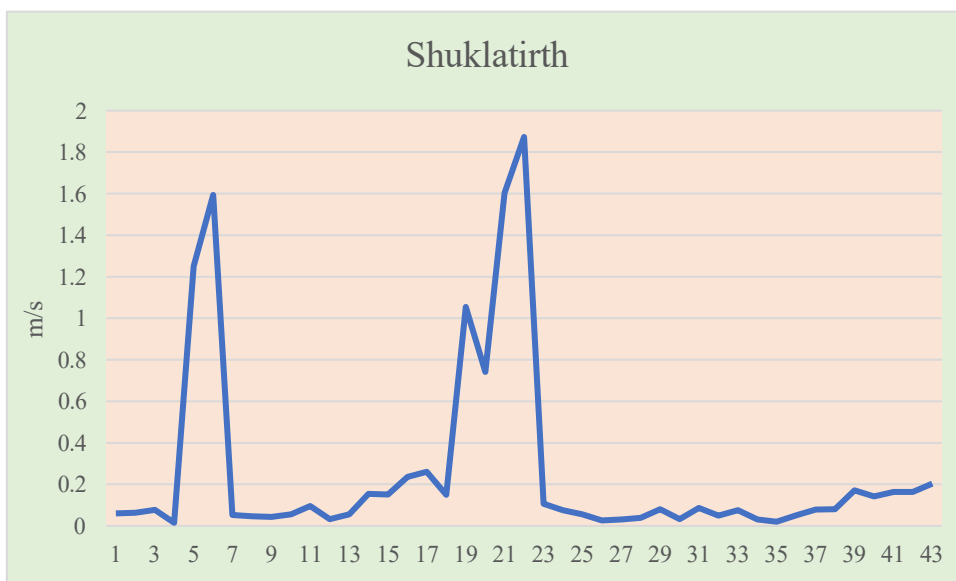
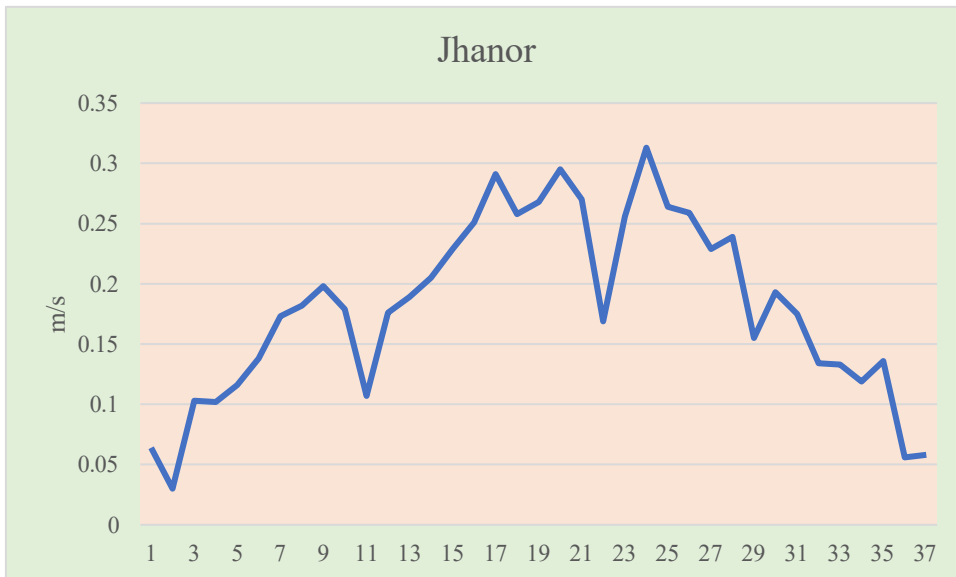
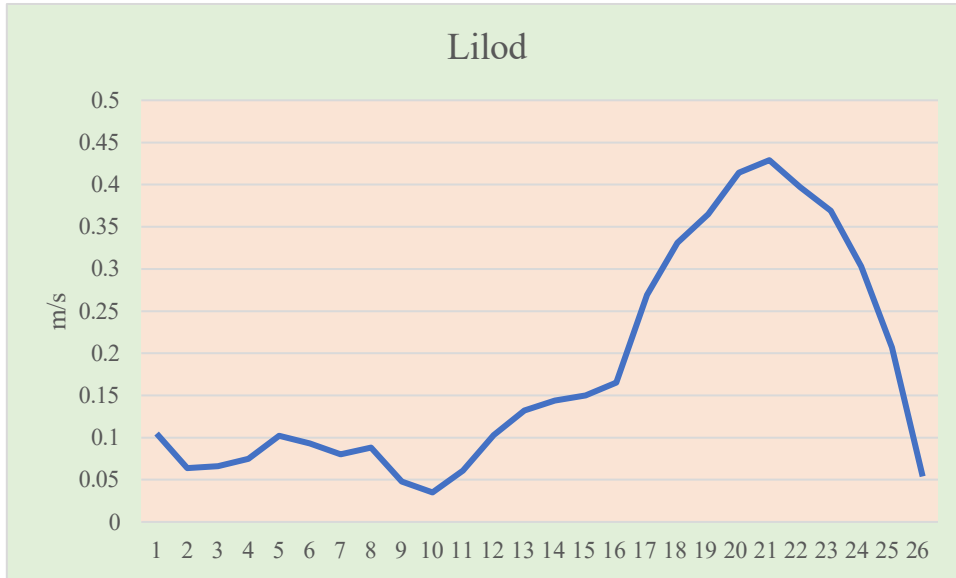


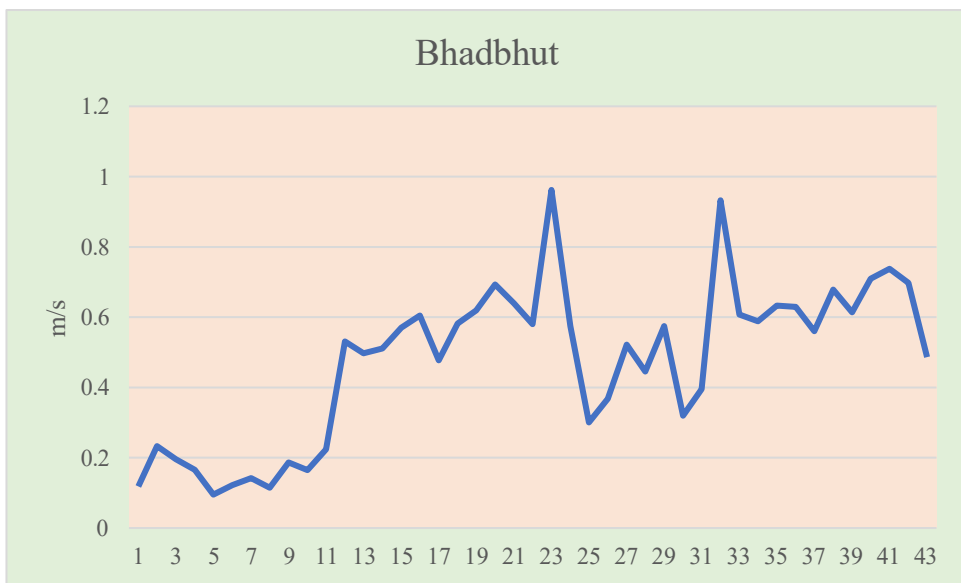
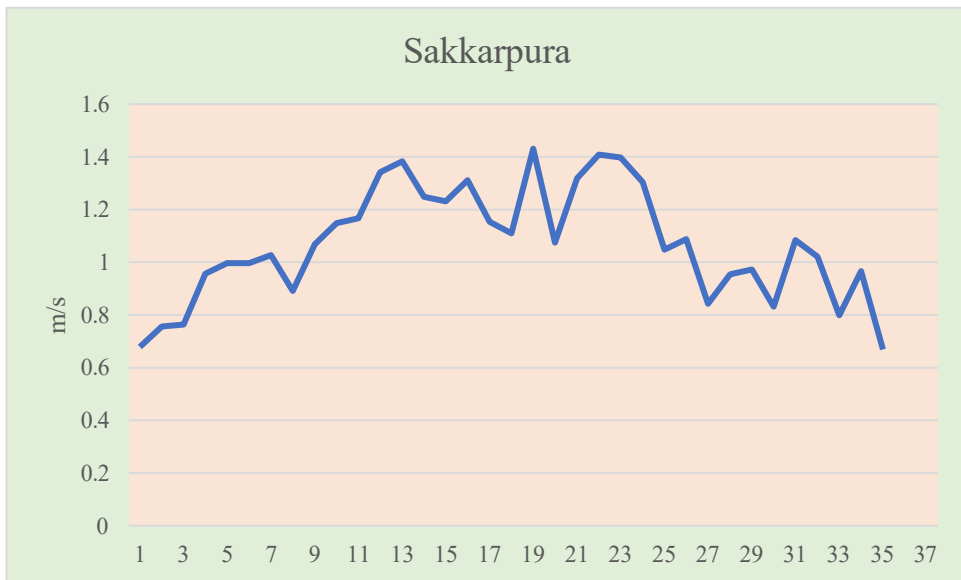
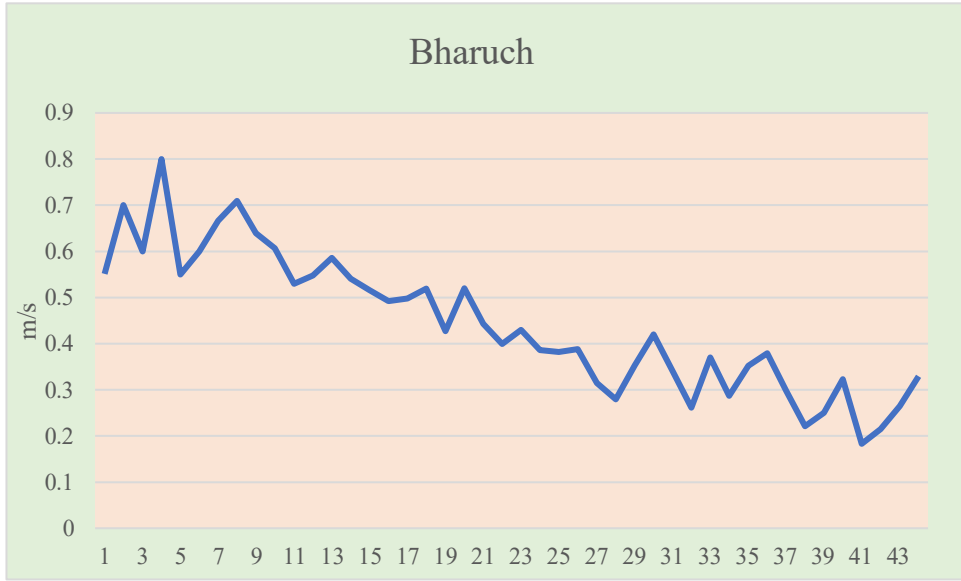
Fig 41. Graphical representation of site-wise cross-sectional depth (m.) measured by ADCP

Fig 42. Diagrams representing site wise cross sectional water velocity measured by ADCP.



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Implications for River Health

The observed longitudinal gradient in width, discharge, and depth reflects a hydrologically dynamic but regulated river system. Reduced discharge at upstream sites such as Garudeshwar may impact longitudinal connectivity, whereas higher downstream discharge helps sustain estuarine productivity. However, sharp spatial variability in flow and depth suggests altered sediment dynamics, potentially affecting channel stability and habitat complexity.

Fisheries Perspective

From a fisheries standpoint, sections with moderate discharge (Poicha–Bharuch) and greater depth heterogeneity support better fish assemblage diversity, spawning grounds, and migratory movement. High-discharge zones such as Sakkarpura and Bhadbhut are particularly important for migratory fishes, providing hydraulic cues for upstream movement. Conversely, shallow and low-discharge zones upstream may pose barriers during critical life stages, especially for long-distance migratory species.

Water velocity and fish diversity

Water velocity in the river plays a crucial role in sustenance and fish diversity. It is a strong driver influencing habitat, spawning, and species assemblages. Natural variable flows from Dams favour generalist species. Diverse, heterogeneous habitats (e.g., rocky substrate with deep pools) generally support more species than a uniform, low-flow environment. Different fish species prefer specific flow requirements; for instance, some prefer fast-flowing, rocky environments while others prefer low-flowing environments. Higher spatial variation in flow, such as in rocky shallow stream habitats, typically supports higher species richness than deep uniform habitats. Ideal river water velocity varies widely from time to time, depending on ecological or engineering needs. A healthy river often flows between 0.3 m/s and 3.1 m/s. Moderate velocities are ideal for aquatic habitats, while rapid flow (> 2 m/s) is common in mountain streams, and lesser flow (< 0.5 m/s) is typical for low gradient rivers.

Table 14. Fish species assemblage in the sampling sites with respect to water velocity.

| Sampling sites | Water velocity (m./sec.) | | Important fishes | |
|----------------|--------------------------|------|------------------|---|
| | Maximum | Mean | No. of species | Major fish species |
| Garudeshwar | 2.69 | 0.17 | 30 | <i>Cirrhinus mrigala</i> , <i>Labeo boggut</i> , <i>Labeo calbasu</i> , <i>Labeo dyocheilus</i> , <i>Labeo rohita</i> , <i>Tor tor</i> , <i>Nandus nandus</i> , <i>Channa marulius</i> , <i>Clupisoma garua</i> , <i>Eutropiichthys vacha</i> , <i>Sperata aor</i> , <i>Sperata seenghala</i> |
| Poicha | 1.73 | 0.75 | 23 | <i>Labeo calbasu</i> , <i>Labeo boggut</i> , <i>Cirrhinus mrigala</i> , <i>Labeo boga</i> , <i>Labeo rohita</i> , <i>Tor tor</i> , <i>Clupisoma garua</i> , <i>Lates calcarifer</i> , <i>Sperata aor</i> , <i>Sperata seenghala</i> , <i>Ompok bimaculatus</i> , <i>Rita rita</i> |
| Sisodra | 1.00 | 0.14 | 30 | <i>Cirrhinus mrigala</i> , <i>Cirrhinus reba</i> , <i>Labeo boga</i> , <i>Labeo boggut</i> , <i>Labeo calbasu</i> , <i>Labeo gonius</i> , <i>Labeo rohita</i> , <i>Tor tor</i> , <i>Clupisoma garua</i> , <i>Eutropiichthys vacha</i> , <i>Lates calcarifer</i> , <i>Sperata aor</i> , <i>Sperata seenghala</i> , <i>Ompok bimaculatus</i> , <i>Wallago attu</i> , <i>Rita rita</i> |
| Lilod | 1.77 | 0.02 | 16 | <i>Cirrhinus mrigala</i> , <i>Labeo boga</i> , <i>Tor tor</i> , <i>Eutropiichthys vacha</i> , <i>Lates calcarifer</i> , <i>Ompok bimaculatus</i> , <i>Wallago attu</i> , <i>Rita rita</i> , |
| Jhanor | 0.85 | 0.17 | 22 | <i>Labeo boga</i> , <i>Labeo boggut</i> , <i>Labeo calbasu</i> , <i>Labeo rohita</i> , <i>Tor tor</i> , <i>Channa marulius</i> , <i>Clupisoma garua</i> , <i>Eutropiichthys vacha</i> , <i>Lates calcarifer</i> , <i>Sperata aor</i> , <i>Sperata seenghala</i> , <i>Wallago attu</i> , |
| Shuklatirth | 1.44 | 0.02 | 12 | <i>Cirrhinus mrigala</i> , <i>Eutropiichthys vacha</i> , <i>Lates calcarifer</i> , <i>Sperata seenghala</i> , <i>Otolithoides pama</i> , |
| Bharuch | 1.49 | 0.36 | 16 | <i>Labeo rohita</i> , <i>Eutropiichthys vacha</i> , <i>Eleutheronema tetradactylum</i> , <i>Lates calcarifer</i> , <i>Sperata aor</i> , <i>Ompok bimaculatus</i> , <i>Wallago attu</i> , <i>Otolithoides pama</i> , <i>Protonibea diacanthus</i> , |
| Sakkarpura | 1.88 | 1.07 | 14 | <i>Clupisoma garua</i> , <i>Tenualosa Ilisha</i> , <i>Lates calcarifer</i> , <i>Liza parsia</i> , <i>Otolithoides pama</i> , <i>Rita rita</i> , |
| Bhadbhut | 3.03 | 0.23 | 13 | <i>Cirrhinus reba</i> , <i>Channa striatus</i> , <i>Clupisoma garua</i> , <i>Eleutheronema tetradactylum</i> , <i>Tenualosa Ilisha</i> , <i>Lates calcarifer</i> , <i>Liza parsia</i> , <i>Otolithoides pama</i> , |

During the study period, water velocity was measured in all the sampling sites. The maximum value (2.69 m/s) was recorded from the Garudeshwar site, and the minimum value (0.85 m/s) was recorded from Jhanor (Table. 14). In the present study, it has been observed that 63.8% species richness (n=30) was recorded from Garudeshwar and Sisodra sites, where water velocity varied from 1.0 to 2.69 (m./sec.) and mean velocity varied between 0.14 and 0.17 (m./sec.). In the Shuklatirth site, 25.5% of species richness (n=12) was recorded during the study period, where the maximum water velocity was recorded as 1.44 m/s, and the mean velocity was 0.02 m/s. which was a comparatively lower value of water velocity. Significantly maximum value of water velocity (3.03 m/s) was recorded from the Bhadbhut site, where the occurrence of fish species was significantly less (n=13). The above observations indicate that many aquatic species prefer higher velocity (2.0 to > 3.0 m/s), creating rapid and slow speed characterizing pools.

It is evident that water velocity in the rivers is not constant and varies based on slope, gradient, and channel roughness. During the exploration, water velocity recorded from all the sampling sites has been graded as moderate except Jhanor and Shuklatirth. As we know, moderate water velocities are ideal for aquatic habitats.

Assessment of environment flow as per hydraulic rating method using HEC-RAS Model

Introduction

For environment flow study using habitat simulation cum hydraulic rating method, the assessment of environment flow can be scientifically made using habitat data by running the hydraulic simulation on HEC-RAS. The present study pertains for the river reach of Narmada from Garudeshwar weir up to Bhadbhut. In this reach of the river the surveyed river cross sections have been provided by Government of Gujarat. A Google Earth screen shot of study reach is given in Fig-43.

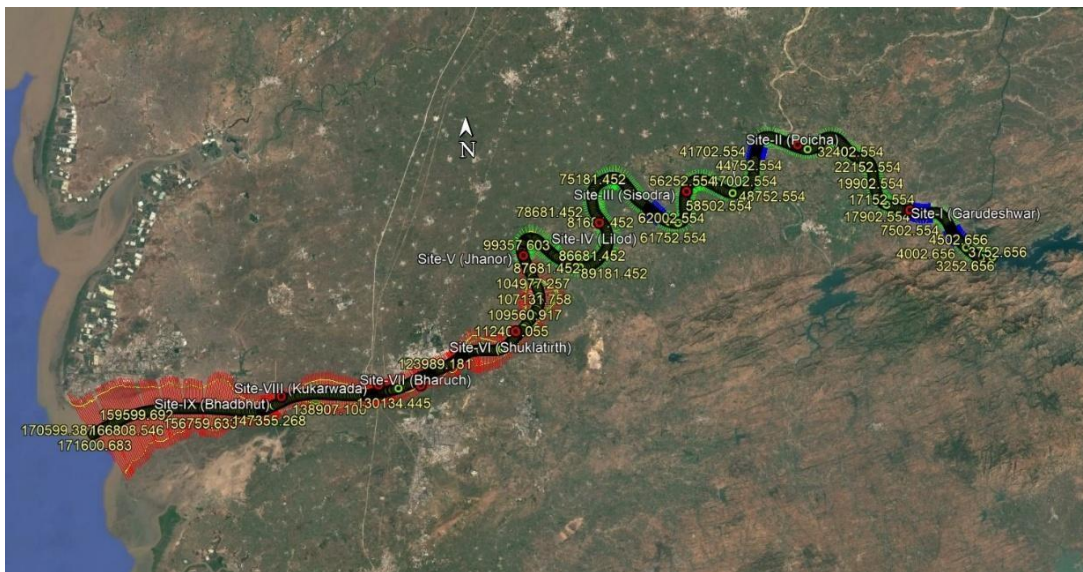


Fig43: Study reach of river Narmada

The Habitat sampling has been carried out at 9 sampling sites in the above reach of river. These sites are Garudeshwar, Poicha, Sisorda, Lilod, Jhanor, Shuklatirtha, Bharuch, Sakkarpura/Kukarwada, and Bhadbhut. It may be noted that the reach of Narmada from Bharuch downstream lies in backwater zone of Arabian Sea wherein a minimum depth of about 0.5m above msl is always present. The study reach of the river is having very mild slop of the order of 1:3000 to 1:5000 with predominance of alluvium. In such type of reaches riffles and pools are predominance phenomenon of river bed morphology. Hence, from modelling point of view, the depth of water above riffle locations becomes important for aquatic life migration. Further, based on the habitat sampling the above river reach can be divided into three zones a) Zone A: from Garudeshwar to Piocha where in Mahseer is the key stone species, b) Zone B: from Poicha downstream to Jhanor wherein Carps are predominance with occasional hilsa availability c) Zone C: from Jhanor downstream to Bhadbhut wherein Hilsa is predominance. The desirable depth at riffles for Mahseer is about 0.7-0.8m; wherein for Carp is 1.0-1.1 m and

for hilsa is about 1.2-1.5m. Accordingly, in the above three zones HES-RAS model has been set up at Poicha, Sisodra and Shuklatirth to estimate the depth of water, top flow width, velocity etc. at riffle and pool locations. Further from the Cross-section data and minimum water level data at Bharuch it has been found that the reach of river Narmada from Bharuch downstream remains under permanent back water effect of Arabian Sea. Hence, for environment flow simulation in back water affected zone will not yield any useful results as minimum water level at Bharuch from long term historical data of CWC Gauge is about 0.5 m resulting a minimum depth of about 4.5 to 5.0 m at Bharuch.

HEC-RAS model set up and simulation result at Poicha sampling site

To estimate the eflows at Poicha for Mahseer key stone species a reach of about 3 km length of river Narmada has been represented in HEC-RAS model by the surveyed cross section of the river. The cross-section ID as per model set up is given below in Tab. 15. the HEC-RAS model set up is given in Fig.44. The River bed in this reach consist of Gravel, Cobbles, Coarse sand, Clay & others. Accordingly, a conservative value of Manning's n of 0.030 has been adopted for this study reach. The upstream boundary has been applied at upstream most cross-section. The normal depth has been applied as downstream boundary at downstream most cross-section of the modelled river reach. In the Poicha area Mahseer is the key stone species for which a depth of 0.7-0.8 m is required.

Table-15: Cross section ID across the river at Poicha

| Cross section ID as per HEC-RAS model Setup | Location | Chainage as per surveyed cross section (m) |
|---|--------------------------------|--|
| 1000 | 1000 m U/S of Centre Line (CL) | 34153 |
| 750 | 750 m U/S of CL | 34403 |
| 500 | 500 m U/S of CL | 34653 |
| 250 | 250 m U/S of CL | 34903 |
| 0 | CL | 35153 |
| -250 | 250 m D/S of CL | 35403 |
| -500 | 500 m D/S of CL | 35653 |
| -750 | 750 m D/S of CL | 35903 |
| -1000 | 1000 m D/S of CL | 36153 |
| -1250 | 1250 m D/S of CL | 36403 |
| -1500 | 1500 m D/S of CL | 36653 |
| -1750 | 1750 m D/S of CL | 36903 |
| -2000 | 2000 m D/S of CL | 37153 |
| -2250 | 2250 m D/S of CL | 37403 |

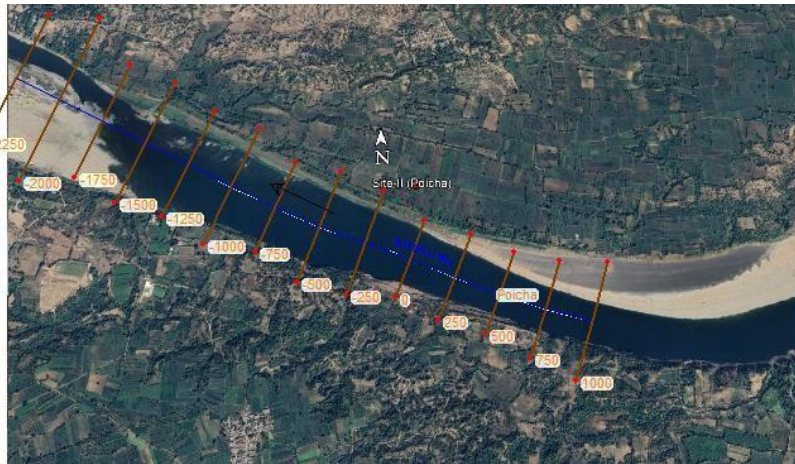


Fig-44: HEC-RAS model setup for Poicha Site

The longitudinal profile of the study river reach comprising of river bed level and simulated water surface level is given in Fig-45.

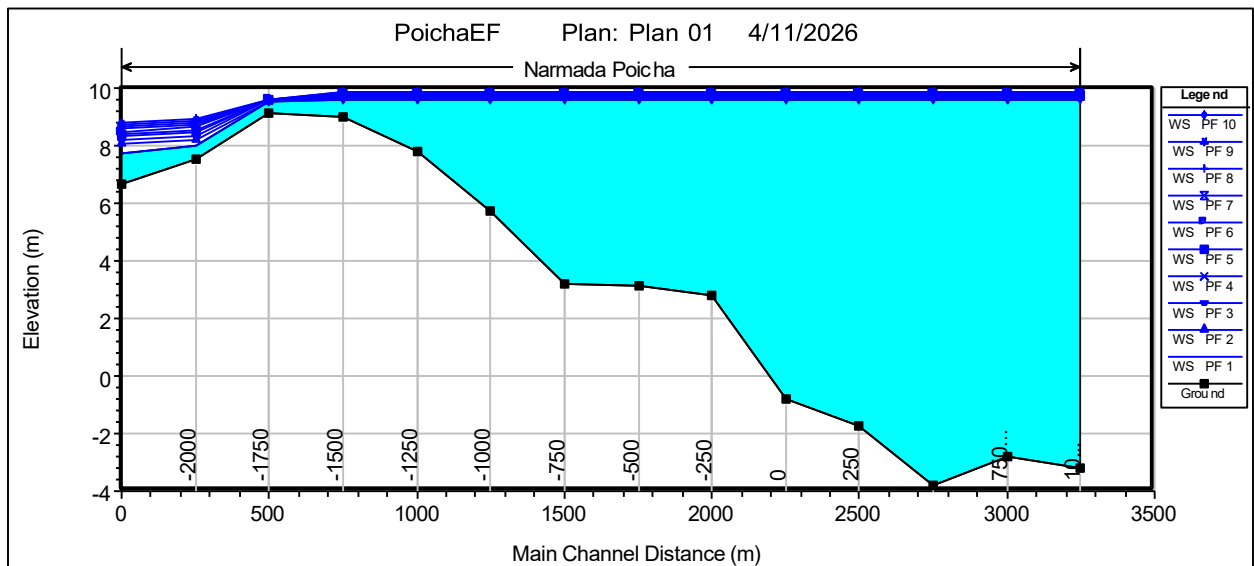


Fig-45: Longitudinal profile of study river reach at Poicha

From the longitudinal profile of Simulation results it can be visualise that Cross section ID (-1500) located 1500 m Downstream of the centre line is the representative riffle location in this reach. The cross-section ID (500) located 500 m upstream of the centre line represents the deepest pool location in this reach. Simulation results at above riffle and pool location are given in Table-16 & 17 respectively. From the results in this table it can be seen that a flow of about 35 cumec is optimum to get a depth of the order of 0.73 m. The plot of river cross-section at above riffle and pool location is given in Fig-46 & 47 respectively.

Table-16: Simulation results at riffle location of Poicha study reach

| Reach | River Sta | Profile | Q Total | Min Ch El | W.S. Elev | Depth | Vel Chnl | Flow Area | Top Width | Froude # Chl |
|--------|-----------|---------|---------------------|-----------|-----------|-------|----------|-------------------|-----------|--------------|
| | | | (m ³ /s) | (m) | (m) | (m) | (m/s) | (m ²) | (m) | |
| Poicha | -1500 | PF 1 | 10 | 9.01 | 9.58 | 0.57 | 0.11 | 92.35 | 355.49 | 0.07 |
| Poicha | -1500 | PF 2 | 20 | 9.01 | 9.66 | 0.65 | 0.16 | 124.14 | 415.35 | 0.09 |
| Poicha | -1500 | PF 3 | 25 | 9.01 | 9.69 | 0.68 | 0.18 | 136.3 | 422.81 | 0.1 |
| Poicha | -1500 | PF 4 | 30 | 9.01 | 9.72 | 0.71 | 0.2 | 148.03 | 430 | 0.11 |
| Poicha | -1500 | PF 5 | 35 | 9.01 | 9.74 | 0.73 | 0.22 | 159.05 | 436.84 | 0.12 |
| Poicha | -1500 | PF 6 | 40 | 9.01 | 9.77 | 0.76 | 0.24 | 169.65 | 443.31 | 0.12 |
| Poicha | -1500 | PF 7 | 45 | 9.01 | 9.79 | 0.78 | 0.25 | 180.07 | 451.67 | 0.13 |
| Poicha | -1500 | PF 8 | 50 | 9.01 | 9.81 | 0.8 | 0.26 | 190.05 | 461.74 | 0.13 |
| Poicha | -1500 | PF 9 | 55 | 9.01 | 9.83 | 0.82 | 0.28 | 199.24 | 466.97 | 0.13 |
| Poicha | -1500 | PF 10 | 60 | 9.01 | 9.85 | 0.84 | 0.29 | 208.28 | 469.45 | 0.14 |

Table-17: Simulation results at Pool location of Poicha study reach

| Reach | River Sta | Profile | Q Total | Min Ch El | W.S. Elev | Depth | Vel Chnl | Flow Area | Top Width | Froude # Chl |
|--------|-----------|---------|---------------------|-----------|-----------|-------|----------|-------------------|-----------|--------------|
| | | | (m ³ /s) | (m) | (m) | (m) | (m/s) | (m ²) | (m) | |
| Poicha | 500 | PF 1 | 10 | -3.81 | 9.58 | 13.39 | 0.01 | 1917.9 | 238.83 | 0 |
| Poicha | 500 | PF 2 | 20 | -3.81 | 9.67 | 13.48 | 0.01 | 1938.3 | 240.01 | 0 |
| Poicha | 500 | PF 3 | 25 | -3.81 | 9.7 | 13.51 | 0.01 | 1945.6 | 240.42 | 0 |
| Poicha | 500 | PF 4 | 30 | -3.81 | 9.73 | 13.54 | 0.02 | 1952.6 | 240.82 | 0 |
| Poicha | 500 | PF 5 | 35 | -3.81 | 9.75 | 13.56 | 0.02 | 1959.1 | 241.19 | 0 |
| Poicha | 500 | PF 6 | 40 | -3.81 | 9.78 | 13.59 | 0.02 | 1965.2 | 241.54 | 0 |
| Poicha | 500 | PF 7 | 45 | -3.81 | 9.8 | 13.61 | 0.02 | 1971.2 | 241.88 | 0 |
| Poicha | 500 | PF 8 | 50 | -3.81 | 9.83 | 13.64 | 0.03 | 1976.8 | 242.2 | 0 |
| Poicha | 500 | PF 9 | 55 | -3.81 | 9.85 | 13.66 | 0.03 | 1982 | 242.5 | 0 |
| Poicha | 500 | PF 10 | 60 | -3.81 | 9.87 | 13.68 | 0.03 | 1987 | 242.78 | 0 |

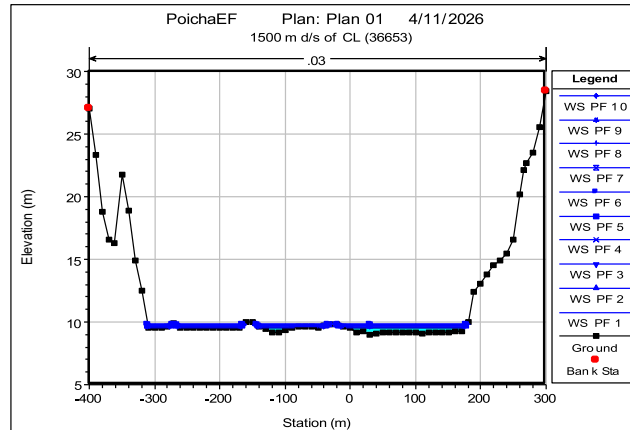


Fig-46: Plot of River Cross-section at Riffle location of Poicha study reach

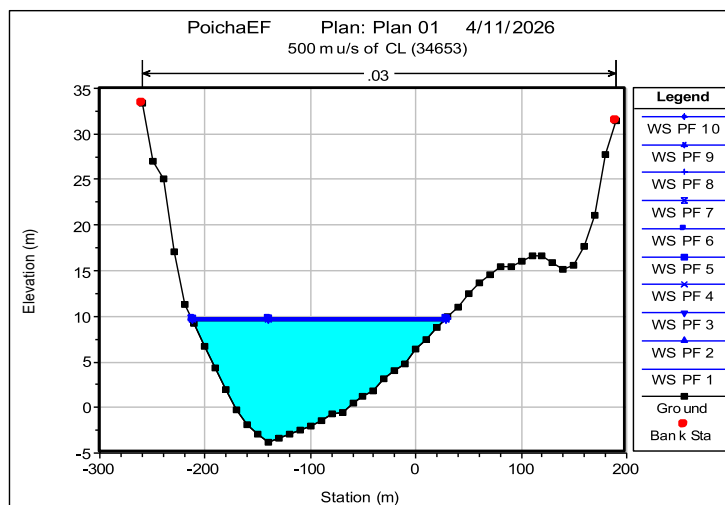


Fig-47: Plot of River Cross-section at Pool location of Poicha study reach

HEC-RAS model set up and simulation result at Sisodra sampling site

To estimate the eflows at Sisodra for Carp key stone species a reach of about 2 km length of river Narmada has been represented in HEC-RAS model by the surveyed cross section of the river. The cross-section ID as per model set up is given below in Table-18. the HEC-RAS model set up is given in Fig-48. The River bed in this reach consist of Gravel, Sand, Clay & others. Accordingly, a conservative value of Manning's n of 0.028 has been adopted for this study reach. The upstream boundary has been applied at upstream most cross-section. The normal depth has been applied as downstream boundary at downstream most cross-section of the modelled river reach. In the Sisodra area Carp is the key stone species with occasional hilsa availability for which a flow depth of 1.1 m is required at riffle location.

Table-18 Cross section ID across the river at Sisodra

| Cross section ID as per HEC-RAS model Setup | Location | Chainage as per surveyed cross section (m) |
|---|--------------------------------|--|
| 1000 | 1000 m U/S of Centre Line (CL) | 56003 |
| 750 | 750 m U/S of CL | 56253 |
| 500 | 500 m U/S of CL | 56503 |
| 0 | CL | 57003 |
| -250 | 250 m D/S of CL | 57253 |
| -500 | 500 m D/S of CL | 57503 |
| -750 | 750 m D/S of CL | 57753 |
| -1000 | 1000 m D/S of CL | 58003 |

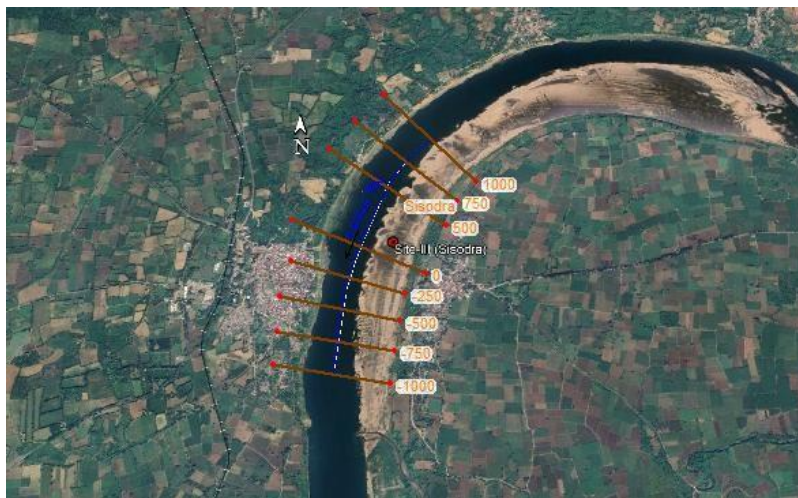


Fig-48: HEC-RAS model setup for Sisodra Site

The longitudinal profile of the study river reach comprising of river bed level and simulated water surface level is given in Fig-49.

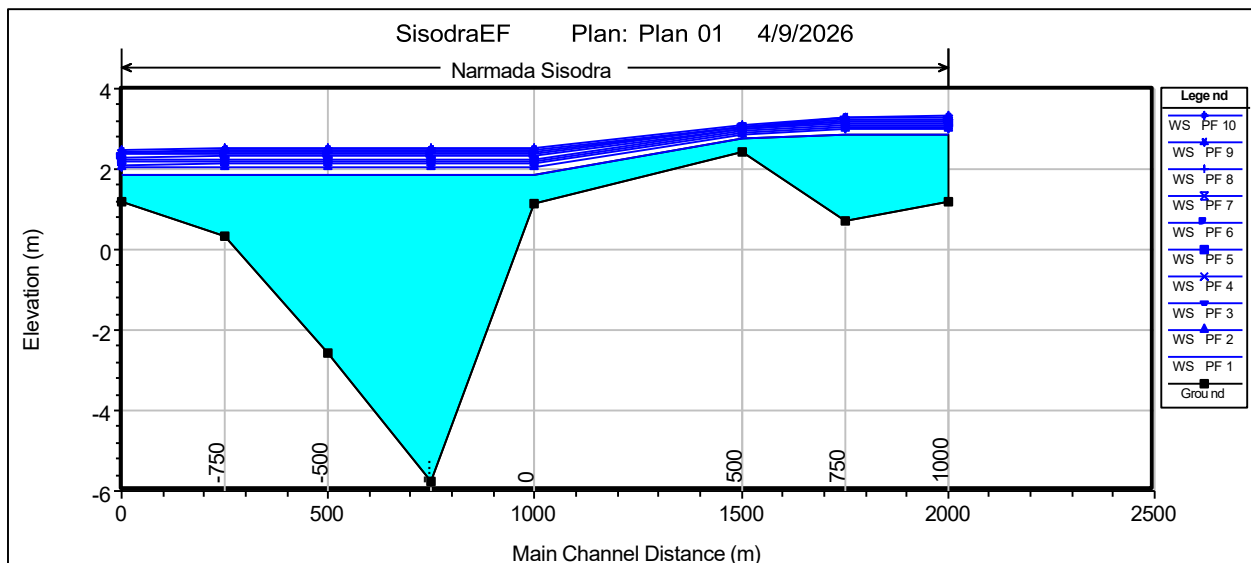


Fig-49: Longitudinal profile of study river reach at Sisodra

From the longitudinal profile of Simulation results it can be visualise that Cross section ID (0) located at centre line is the representative riffle location in this reach. The cross-section ID (-250) located 250 m Downstream of the centre line represents the deepest pool location in this reach. Simulation results at above riffle and pool location are given in Table-19 & 20 respectively. From the results in this table it can be seen that a flow of about 35 cumec is optimum to get a depth of the order of 1.11 m. The plot of river cross-section at above riffle and pool location is given in Fig-50 & 51 respectively.

Table-19: Simulation results at riffle location of Sisodra study reach

| Reach | River Sta | Profile | Q Total (m ³ /s) | Min Ch El (m) | W.S. Elev (m) | Depth (m) | Vel Chnl (m/s) | Flow Area (m ²) | Top Width (m) | Froude # Chl |
|---------|-----------|---------|--------------------------------|------------------|------------------|--------------|-------------------|--------------------------------|------------------|--------------|
| Sisodra | 0 | PF 1 | 10 | 1.14 | 1.84 | 0.7 | 0.22 | 46.29 | 91.83 | 0.1 |
| Sisodra | 0 | PF 2 | 20 | 1.14 | 2.05 | 0.91 | 0.3 | 66.05 | 101.97 | 0.12 |
| Sisodra | 0 | PF 3 | 25 | 1.14 | 2.12 | 0.98 | 0.34 | 74 | 105.81 | 0.13 |
| Sisodra | 0 | PF 4 | 30 | 1.14 | 2.19 | 1.05 | 0.37 | 81.43 | 109.24 | 0.14 |
| Sisodra | 0 | PF 5 | 35 | 1.14 | 2.25 | 1.11 | 0.4 | 88.4 | 112.24 | 0.14 |
| Sisodra | 0 | PF 6 | 40 | 1.14 | 2.32 | 1.18 | 0.42 | 95.82 | 115.32 | 0.15 |
| Sisodra | 0 | PF 7 | 45 | 1.14 | 2.38 | 1.24 | 0.44 | 103.2 | 118.3 | 0.15 |
| Sisodra | 0 | PF 8 | 50 | 1.14 | 2.43 | 1.29 | 0.46 | 108.42 | 120.36 | 0.16 |
| Sisodra | 0 | PF 9 | 55 | 1.14 | 2.47 | 1.33 | 0.48 | 113.5 | 122.34 | 0.16 |
| Sisodra | 0 | PF 10 | 60 | 1.14 | 2.51 | 1.37 | 0.51 | 118.39 | 124.21 | 0.17 |

Table-20: Simulation results at Pool location of Sisodra study reach

| Reach | River Sta | Profile | Q Total (m ³ /s) | Min Ch El (m) | W.S. Elev (m) | Depth (m) | Vel Chnl (m/s) | Flow Area (m ²) | Top Width (m) | Froude # Chl |
|---------|-----------|---------|--------------------------------|------------------|------------------|--------------|-------------------|--------------------------------|------------------|--------------|
| Sisodra | -250 | PF 1 | 10 | -5.77 | 1.84 | 7.61 | 0.01 | 767.15 | 155.31 | 0 |
| Sisodra | -250 | PF 2 | 20 | -5.77 | 2.05 | 7.82 | 0.03 | 799.43 | 158.69 | 0 |
| Sisodra | -250 | PF 3 | 25 | -5.77 | 2.13 | 7.9 | 0.03 | 811.75 | 160.06 | 0 |
| Sisodra | -250 | PF 4 | 30 | -5.77 | 2.2 | 7.97 | 0.04 | 822.95 | 161.39 | 0.01 |
| Sisodra | -250 | PF 5 | 35 | -5.77 | 2.26 | 8.03 | 0.04 | 833.26 | 162.59 | 0.01 |
| Sisodra | -250 | PF 6 | 40 | -5.77 | 2.33 | 8.1 | 0.05 | 844 | 163.84 | 0.01 |
| Sisodra | -250 | PF 7 | 45 | -5.77 | 2.39 | 8.16 | 0.05 | 854.47 | 165.05 | 0.01 |
| Sisodra | -250 | PF 8 | 50 | -5.77 | 2.43 | 8.2 | 0.06 | 861.82 | 165.89 | 0.01 |
| Sisodra | -250 | PF 9 | 55 | -5.77 | 2.48 | 8.25 | 0.06 | 868.92 | 166.7 | 0.01 |
| Sisodra | -250 | PF 10 | 60 | -5.77 | 2.52 | 8.29 | 0.07 | 875.67 | 167.47 | 0.01 |

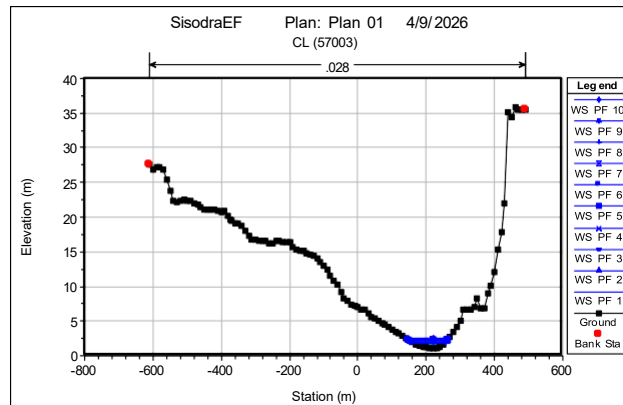


Fig-50: Plot of River Cross-section at Riffle location of Sisodra study reach

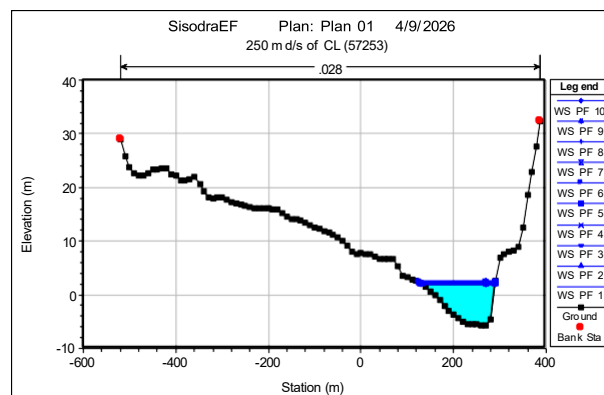


Fig-51: Plot of River Cross-section at Pool location of Sisodra study reach

HEC-RAS model set up and simulation result at Shuklatirth sampling site

To estimate the eflows at Shuklatirth for Hilsa key stone species a reach of about 2.5 km length of river Narmada has been represented in HEC-RAS model by the surveyed cross section of the river. The cross-section ID as per model set up is given below in Table-21. the HEC-RAS model set up is given in Fig-52. The River bed in this reach consist of Sandy Clay. Accordingly, a conservative value of Manning's n of 0.028 has been adopted for this study reach. The upstream boundary has been applied at upstream most cross-section. The normal depth has been applied as downstream boundary at downstream most cross-section of the modelled river reach. In the Shuklatirth area Hilsa is the key stone species for which a flow depth of 1.2 m is required at riffle location.

Table-21 Cross section ID across the river at Shuklatirth

| Cross section ID as per HEC-RAS model Setup | Location | Chainage as per surveyed cross section (m) |
|---|--------------------------------|--|
| 1498 | 1498 m U/S of Centre Line (CL) | 110420 |
| 1301 | 1301 m U/S of CL | 110617 |
| 1022 | 1066 m U/S of CL | 110896 |
| 471 | 471 m U/S of CL | 111447 |
| 228 | 228 m U/S of CL | 111690 |
| 0 | CL | 111918 |
| -220 | 220 m D/S of CL | 112137 |
| -485 | 485 m D/S of CL | 112403 |
| -750 | 750 m D/S of CL | 112668 |
| -1011 | 1011 m D/S of CL | 112929 |



Fig-52: HEC-RAS model setup for Shuklatirth Site

The longitudinal profile of the study river reach comprising of river bed level and simulated water surface level is given in Fig-53

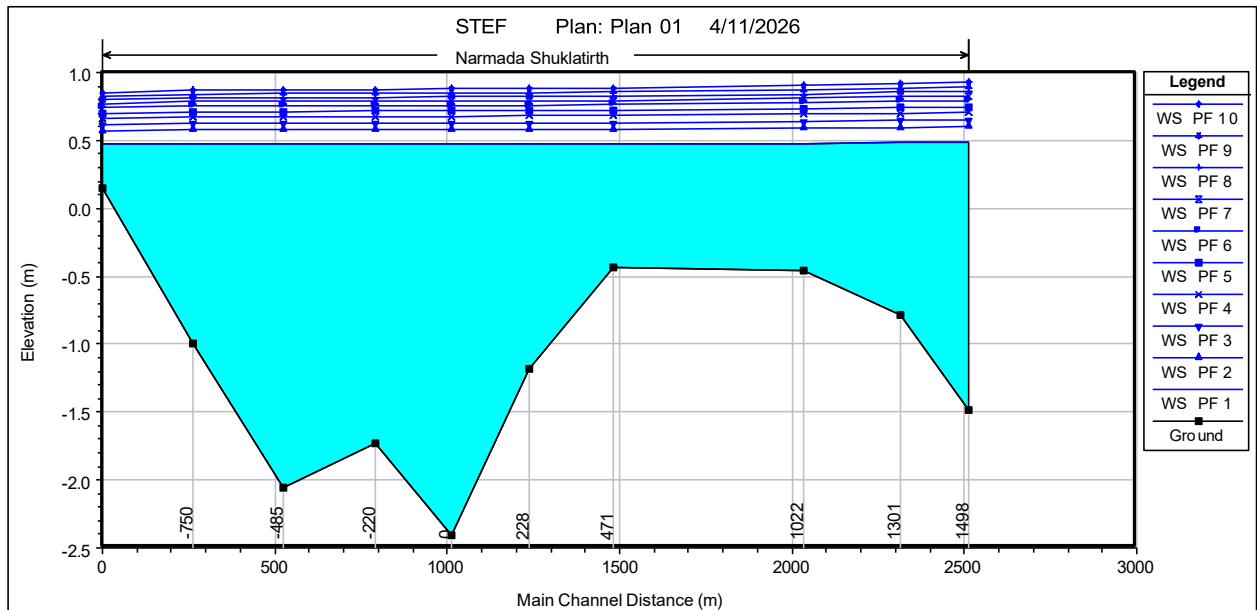


Fig-53: Longitudinal profile of study river reach at Shuklatirth

From the longitudinal profile of Simulation results it can be visualise that Cross section ID (471) located at 471 m Upstream of centre line is the representative riffle location in this reach. The cross-section ID (0) located at the centre line represents the deepest pool location in this reach. Simulation results at above riffle and pool location are given in Table-22 & 23 respectively. From the results in this table it can be seen that a flow of about 40 cumec is optimum to get a depth of the order of 1.2 m. The plot of river cross-section at above riffle and pool location is given in Fig-54 & 55 respectively.

Table-22: Simulation results at riffle location of Shuklatirth study reach

| Reach | River Sta | Profile | Q Total (m3/s) | Min Ch El (m) | W.S. Elev (m) | Depth (m) | Vel Chnl (m/s) | Flow Area (m2) | Top Width (m) | Froude # Chl |
|-------------|-----------|---------|-------------------|------------------|------------------|--------------|-------------------|-------------------|------------------|--------------|
| Shuklatirth | 471 | PF 1 | 10 | -0.44 | 0.48 | 0.92 | 0.05 | 219.99 | 392.58 | 0.02 |
| Shuklatirth | 471 | PF 2 | 20 | -0.44 | 0.58 | 1.02 | 0.08 | 261.76 | 395.06 | 0.03 |
| Shuklatirth | 471 | PF 3 | 25 | -0.44 | 0.63 | 1.07 | 0.09 | 279.62 | 396.11 | 0.03 |
| Shuklatirth | 471 | PF 4 | 30 | -0.44 | 0.68 | 1.12 | 0.1 | 301.06 | 397.37 | 0.04 |
| Shuklatirth | 471 | PF 5 | 35 | -0.44 | 0.72 | 1.16 | 0.11 | 316.33 | 398.26 | 0.04 |
| Shuklatirth | 471 | PF 6 | 40 | -0.44 | 0.76 | 1.2 | 0.12 | 333.07 | 399.24 | 0.04 |
| Shuklatirth | 471 | PF 7 | 45 | -0.44 | 0.8 | 1.24 | 0.13 | 346.32 | 400.01 | 0.04 |
| Shuklatirth | 471 | PF 8 | 50 | -0.44 | 0.83 | 1.27 | 0.14 | 358.59 | 400.72 | 0.05 |
| Shuklatirth | 471 | PF 9 | 55 | -0.44 | 0.86 | 1.3 | 0.15 | 370.43 | 401.41 | 0.05 |
| Shuklatirth | 471 | PF 10 | 60 | -0.44 | 0.88 | 1.32 | 0.16 | 381.78 | 402.07 | 0.05 |

Table-23: Simulation results at Pool location of Shuklatirth study reach

| Reach | River Sta | Profile | Q Total (m3/s) | Min Ch El (m) | W.S. Elev (m) | Depth (m) | Vel Chnl (m/s) | Flow Area (m2) | Top Width (m) | Froude # Chl |
|-------------|-----------|---------|-------------------|------------------|------------------|--------------|-------------------|-------------------|------------------|--------------|
| Shuklatirth | 0 | PF 1 | 10 | -2.4 | 0.48 | 2.88 | 0.03 | 363.48 | 332.09 | 0.01 |
| Shuklatirth | 0 | PF 2 | 20 | -2.4 | 0.58 | 2.98 | 0.05 | 400.8 | 389.39 | 0.02 |
| Shuklatirth | 0 | PF 3 | 25 | -2.4 | 0.63 | 3.03 | 0.06 | 418.18 | 390.78 | 0.02 |
| Shuklatirth | 0 | PF 4 | 30 | -2.4 | 0.68 | 3.08 | 0.07 | 439.18 | 392.45 | 0.02 |
| Shuklatirth | 0 | PF 5 | 35 | -2.4 | 0.72 | 3.12 | 0.08 | 454.06 | 393.63 | 0.02 |
| Shuklatirth | 0 | PF 6 | 40 | -2.4 | 0.76 | 3.16 | 0.09 | 470.43 | 394.92 | 0.02 |
| Shuklatirth | 0 | PF 7 | 45 | -2.4 | 0.79 | 3.19 | 0.09 | 483.34 | 395.94 | 0.03 |
| Shuklatirth | 0 | PF 8 | 50 | -2.4 | 0.82 | 3.22 | 0.1 | 495.28 | 396.87 | 0.03 |
| Shuklatirth | 0 | PF 9 | 55 | -2.4 | 0.85 | 3.25 | 0.11 | 506.82 | 397.78 | 0.03 |
| Shuklatirth | 0 | PF 10 | 60 | -2.4 | 0.88 | 3.28 | 0.12 | 517.87 | 398.64 | 0.03 |

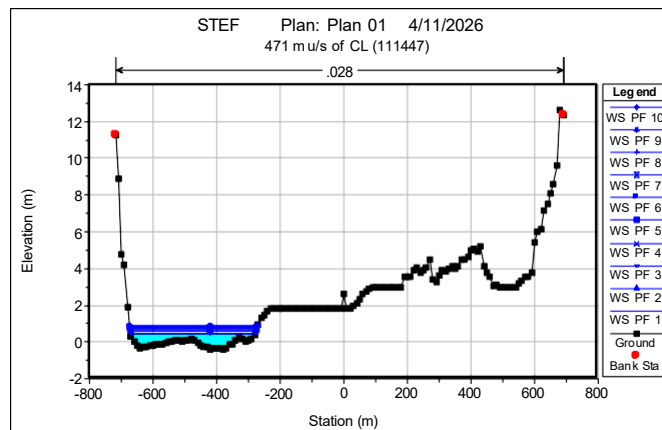


Fig-54: Plot of River Cross-section at Riffle location of Shuklatirth study reach

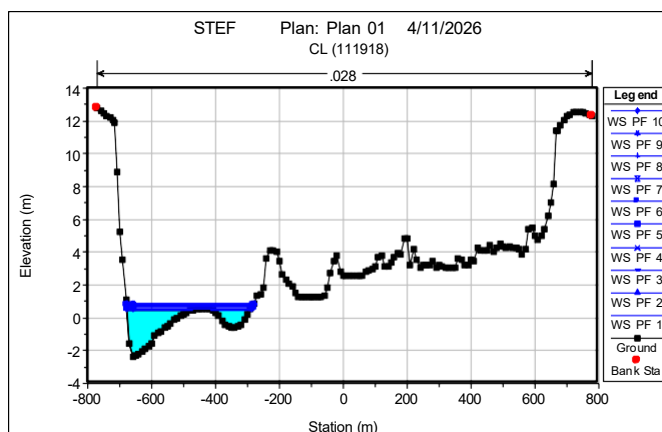


Fig-55: Plot of River Cross-section at Pool location of Shuklatirth study reach

The detailed tabular output of the simulations at Poicha, Sisodra and Shuklatirth are given at

Conclusions and E-flows recommendation:

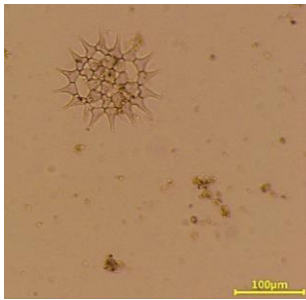
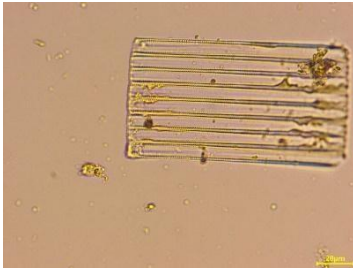
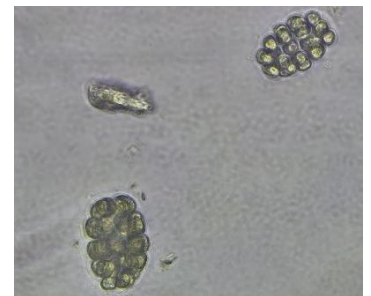
- A total of 47 fish species belonging to 20 families were recorded from the main channel of the river Narmada between SSD and Bhadbhut. The relative contribution of major fish groups are carps, catfishes, ornamental, miscellaneous, and exotic fishes were 12.76%, 14.89%, 21.27%, 51.06% and 2.12 % respectively. It clearly indicates a diminishing presence of indigenous carp, catfish, ornamental fishes, and an increase in miscellaneous fish species with presence of invasive exotic fish species *Tilapia*, *Oreochromis niloticus*.
- The migratory fish species mostly available in the stretch between Garudeshwar to Bhadbhut were *Tor tor*, *Tenualosa ilisha* and *Lates calcarifer*. The stretch between Sisodra and Bhadbhut has been identified as hilsa fishing zone. Current study recorded *T. Ilisha* is most abundant at Bhadbhut and Bharuch. While, *T. ilisha* is occasionally caught at Sisodra.
- Nine sampling sites were assessed from Garudeshwar to Bhadbhut in relation to fish biotic integrity. Sisodra represented the reference site for IBI studies. It indicated that the stretches of Garudeshwar and Sisodra were in acceptable condition in terms of fish assemblages; the remaining seven sites were moderately impaired, though the sites were nearer to acceptable condition.
- The water and sediment quality such as D.O, pH, Electrical conductivity, TDS, Salinity, Free CO₂, Total alkalinity, etc. of the river Narmada, at the majority of the sites, had optimal water quality for fish and aquatic organisms. Physical parameters like water velocity and depth were also ascertained and found ideal for an aquatic habitat.
- Habitat profile of the selected sites was recorded during both pre/post monsoon seasons and was considered based on the substrate types, deep pools, riparian vegetation, water depth, water velocity and width of the channel. Based on the substate, Garudeswar to Sisodra was recorded majorly boulders, gravels and cobbles. While from Sisodra to Shuklatirth majorly by sandy clay. While Bharuch to downstream majorly dominated by Clay and Sand. With varied substrates depth and velocity and species composition varied.
- ADCP reading indicates that distinct spatial variations in hydrological conditions across the lower stretches of Narmada below SSD. It is observed

that the water velocity was moderate and has diminished at two sites due to various anthropogenic activities in the form of hydraulic structures, water extraction, river channelling, sedimentation, and sand gravelling. This is also reflected in the diminished water velocity at Jhanor and Shuklatirth, altering the aquatic environment. The decrease in major carp abundance in the river is evident, along with a significant rise in the exotic carp (n=1) because of favourable habitat.

- Catch per unit efforts (CPUE) was calculated based on total fish catch per person in an hour. Higher value of CPUE (1.6 kg/hr/person) was recorded from Bhadbhut site and lowest value (0.55 kg/hr/person) recorded from Lilod during pre-monsoon. While, in post monsoon season higher value of CPUE (12.5 kg/hr/person) recorded from Bhadbhut site and lowest value (2.0 kg/hr/person) was recorded each from Garudeshwar site. This indicates monsoon discharge has significant impact on hilsa upstream migration and catch at Bhadbhut.
- Based on the habitat characteristics, and key fish species, the entire selected stretch is classified into three zones for the environmental flows estimation. Zone I: Key species as Mahseer *Tor tor*, Zone II: Carps (Large) Zone III: Hilsa *T. Ilisha*. The habitat suitability requirement was estimated majorly on the depth and velocity requirement.
- Environmental flows was estimated by habitat cum hydraulic rating curve using HEC-RAS model. The simulation was done at Poicha, Sisorda and Shuklatirth. These three sites are the representation of the key fish species habitat suitability. Poicha as Mahseer species, Sisorda as large bodied Carps and Shuklatirth as Hilsa habitat suitability. Based on the habitat suitability of fish species depth and velocity, the HEC-RAS model was set.
- Based on the habitat requirement for selected key stone fish species, environmental flows between SSD and Bhadbhut was estimated and a flow of the order of 35-40 cumec is optimum for this key fish species recruitment and sustainability between Garudeshwar and Bhadbhut. As Hilsa migrates in a shoal minimum 1.2 m depth is essential. Therefore, in the downstream from Shuklatirth 40 cumec is recommended. While for Mahseer and Carps, a discharge of 35 cumec is optimum. This discharge will help the migration, spawning and sustainable recruitment of fish population.

References:

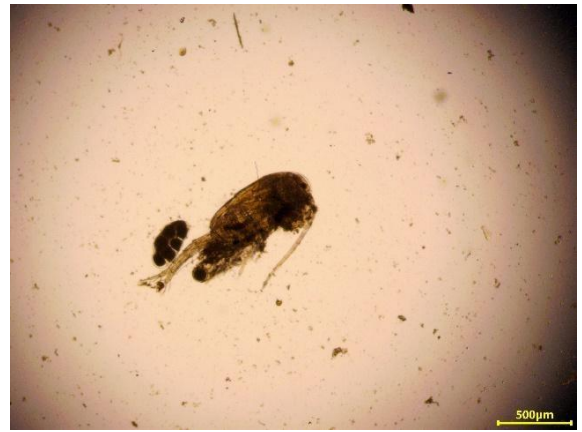
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2. Fausch, K.D., Karr and Yant, P.R. 1984. Regional application of an index of biotic integrity based on stream fish communities. *Transactions of the American Fisheries Society*, 113:39-55.
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5. Hughes, R.M., Kaufmann, P.R., Herlihy, A.T., Kincaid, T.M., Reynolds and Larsen, D.P.1998. A process for developing and evaluating indices of fish assemblages' integrity. *Canadian Journal of Fisheries and Aquatic Sciences*, 55.
6. Ganasan, V. and Hughes, R.M. 1998. Application of an index of biological integrity (IBI) to fish assemblages of the rivers Khan and Kshipra (Madhya Pradesh), India, *Freshwater Biology*, 40(2):361-384.
7. Das, M.K. & Samanta, S. 2006. Application of an index of biotic integrity (IBI) to the fish assemblage of the tropical Hooghly estuary. *Indian Journal of Fisheries*. 53(1):47-57.

Commonly Recorded phytoplankton Taxa during the pre and post monsoon study*Pediasium simplex**Closterium sp.**Coscinodiscus sp.**Fragilaria sp.**Ceratium sp.**Spirogyra sp.**Eudorina sp.**Staurastrum sp.**Coelastrum sp.*

Commonly Recorded Zooplankton Taxa during the premonsoon study



Copepods



Mesocyclops sp.



Daphnia sp.



Acanthocyclops



Keratella sp.

Common Benthic Macroinvertebrates Identified during the pre and post monsoon study



Prawn larvae



Crab juvenile



Austrolimnius montanus Larva



Aulodrilus sp.



Thiara scabra



Syllidae sp.



Fish larvae



Gnorimosphaeroma sp.



Prostoma sp.



Tarebia lineata



Parreysia caerulea



Indoplanorbis exustus



Agabus binotatus



Tarebia granifera



Bellamyia crassa



Thiara tuberculata



Corbicula striatella



Parreysia favidens



Bellamyia dissimilis

Annexure 4

| Reach | River Sta | Profile | Q Total | Min Ch El | W.S. Elev | Crit W.S. | Vel Chnl | Flow Area | Top Width | Froude # Chl |
|--------|-----------|---------|---------------------|-----------|-----------|-----------|----------|-------------------|-----------|--------------|
| | | | (m ³ /s) | (m) | (m) | (m) | (m/s) | (m ²) | (m) | |
| Poicha | 1000 | PF 1 | 10 | -3.19 | 9.58 | | 0.01 | 1391.63 | 208.84 | 0 |
| Poicha | 1000 | PF 2 | 20 | -3.19 | 9.67 | | 0.01 | 1409.47 | 209.98 | 0 |
| Poicha | 1000 | PF 3 | 25 | -3.19 | 9.7 | | 0.02 | 1415.87 | 210.39 | 0 |
| Poicha | 1000 | PF 4 | 30 | -3.19 | 9.73 | | 0.02 | 1421.96 | 210.77 | 0 |
| Poicha | 1000 | PF 5 | 35 | -3.19 | 9.75 | | 0.02 | 1427.63 | 211.13 | 0 |
| Poicha | 1000 | PF 6 | 40 | -3.19 | 9.78 | | 0.03 | 1433.03 | 211.47 | 0 |
| Poicha | 1000 | PF 7 | 45 | -3.19 | 9.8 | | 0.03 | 1438.25 | 211.81 | 0 |
| Poicha | 1000 | PF 8 | 50 | -3.19 | 9.83 | | 0.03 | 1443.18 | 212.12 | 0 |
| Poicha | 1000 | PF 9 | 55 | -3.19 | 9.85 | | 0.04 | 1447.68 | 212.4 | 0 |
| Poicha | 1000 | PF 10 | 60 | -3.19 | 9.87 | | 0.04 | 1452.08 | 212.68 | 0.01 |
| Poicha | 1000 | PF 11 | 400 | -3.19 | 11.43 | | 0.22 | 1799.99 | 231.29 | 0.03 |
| Poicha | 1000 | PF 12 | 450 | -3.19 | 11.83 | | 0.24 | 1893.5 | 235.2 | 0.03 |
| Poicha | 1000 | PF 13 | 500 | -3.19 | 11.97 | | 0.26 | 1926.75 | 236.57 | 0.03 |
| Poicha | 1000 | PF 14 | 550 | -3.19 | 12.23 | | 0.28 | 1989.9 | 248.19 | 0.03 |
| Poicha | 1000 | PF 15 | 600 | -3.19 | 12.34 | | 0.3 | 2016.5 | 249.32 | 0.03 |
| | | | | | | | | | | |
| Poicha | 750 | PF 1 | 10 | -2.83 | 9.58 | | 0.01 | 1568.05 | 230.62 | 0 |
| Poicha | 750 | PF 2 | 20 | -2.83 | 9.67 | | 0.01 | 1587.74 | 231.72 | 0 |
| Poicha | 750 | PF 3 | 25 | -2.83 | 9.7 | | 0.02 | 1594.8 | 232.11 | 0 |
| Poicha | 750 | PF 4 | 30 | -2.83 | 9.73 | | 0.02 | 1601.53 | 232.49 | 0 |
| Poicha | 750 | PF 5 | 35 | -2.83 | 9.75 | | 0.02 | 1607.78 | 232.83 | 0 |
| Poicha | 750 | PF 6 | 40 | -2.83 | 9.78 | | 0.02 | 1613.72 | 233.16 | 0 |
| Poicha | 750 | PF 7 | 45 | -2.83 | 9.8 | | 0.03 | 1619.49 | 233.48 | 0 |
| Poicha | 750 | PF 8 | 50 | -2.83 | 9.83 | | 0.03 | 1624.92 | 233.78 | 0 |
| Poicha | 750 | PF 9 | 55 | -2.83 | 9.85 | | 0.03 | 1629.88 | 234.05 | 0 |
| Poicha | 750 | PF 10 | 60 | -2.83 | 9.87 | | 0.04 | 1634.72 | 234.32 | 0 |
| Poicha | 750 | PF 11 | 400 | -2.83 | 11.43 | | 0.2 | 2013.17 | 248.67 | 0.02 |
| Poicha | 750 | PF 12 | 450 | -2.83 | 11.83 | | 0.21 | 2113.48 | 251.94 | 0.02 |
| Poicha | 750 | PF 13 | 500 | -2.83 | 11.97 | | 0.23 | 2149.08 | 253.42 | 0.03 |
| Poicha | 750 | PF 14 | 550 | -2.83 | 12.23 | | 0.25 | 2215.26 | 256.15 | 0.03 |
| Poicha | 750 | PF 15 | 600 | -2.83 | 12.34 | | 0.27 | 2242.69 | 257.27 | 0.03 |
| | | | | | | | | | | |
| Poicha | 500 | PF 1 | 10 | -3.81 | 9.58 | | 0.01 | 1917.91 | 238.83 | 0 |
| Poicha | 500 | PF 2 | 20 | -3.81 | 9.67 | | 0.01 | 1938.31 | 240.01 | 0 |
| Poicha | 500 | PF 3 | 25 | -3.81 | 9.7 | | 0.01 | 1945.63 | 240.42 | 0 |
| Poicha | 500 | PF 4 | 30 | -3.81 | 9.73 | | 0.02 | 1952.59 | 240.82 | 0 |
| Poicha | 500 | PF 5 | 35 | -3.81 | 9.75 | | 0.02 | 1959.07 | 241.19 | 0 |
| Poicha | 500 | PF 6 | 40 | -3.81 | 9.78 | | 0.02 | 1965.23 | 241.54 | 0 |
| Poicha | 500 | PF 7 | 45 | -3.81 | 9.8 | | 0.02 | 1971.2 | 241.88 | 0 |
| Poicha | 500 | PF 8 | 50 | -3.81 | 9.83 | | 0.03 | 1976.82 | 242.2 | 0 |

1415

| | | | | | | | | | | |
|--------|------|-------|-----|-------|-------|--|------|---------|--------|------|
| Poicha | 500 | PF 9 | 55 | -3.81 | 9.85 | | 0.03 | 1981.96 | 242.5 | 0 |
| Poicha | 500 | PF 10 | 60 | -3.81 | 9.87 | | 0.03 | 1986.98 | 242.78 | 0 |
| Poicha | 500 | PF 11 | 400 | -3.81 | 11.43 | | 0.17 | 2382.39 | 262.74 | 0.02 |
| Poicha | 500 | PF 12 | 450 | -3.81 | 11.83 | | 0.18 | 2488.42 | 266.22 | 0.02 |
| Poicha | 500 | PF 13 | 500 | -3.81 | 11.97 | | 0.2 | 2526.01 | 267.44 | 0.02 |
| Poicha | 500 | PF 14 | 550 | -3.81 | 12.23 | | 0.21 | 2595.77 | 269.7 | 0.02 |
| Poicha | 500 | PF 15 | 600 | -3.81 | 12.34 | | 0.23 | 2624.64 | 270.63 | 0.02 |
| | | | | | | | | | | |
| Poicha | 250 | PF 1 | 10 | -1.76 | 9.58 | | 0.01 | 1916.76 | 288.4 | 0 |
| Poicha | 250 | PF 2 | 20 | -1.76 | 9.67 | | 0.01 | 1941.39 | 290.03 | 0 |
| Poicha | 250 | PF 3 | 25 | -1.76 | 9.7 | | 0.01 | 1950.24 | 290.58 | 0 |
| Poicha | 250 | PF 4 | 30 | -1.76 | 9.73 | | 0.02 | 1958.66 | 291.08 | 0 |
| Poicha | 250 | PF 5 | 35 | -1.76 | 9.75 | | 0.02 | 1966.48 | 291.51 | 0 |
| Poicha | 250 | PF 6 | 40 | -1.76 | 9.78 | | 0.02 | 1973.93 | 291.91 | 0 |
| Poicha | 250 | PF 7 | 45 | -1.76 | 9.8 | | 0.02 | 1981.14 | 292.3 | 0 |
| Poicha | 250 | PF 8 | 50 | -1.76 | 9.83 | | 0.03 | 1987.94 | 292.67 | 0 |
| Poicha | 250 | PF 9 | 55 | -1.76 | 9.85 | | 0.03 | 1994.15 | 293 | 0 |
| Poicha | 250 | PF 10 | 60 | -1.76 | 9.87 | | 0.03 | 2000.21 | 293.33 | 0 |
| Poicha | 250 | PF 11 | 400 | -1.76 | 11.43 | | 0.16 | 2478.54 | 320.17 | 0.02 |
| Poicha | 250 | PF 12 | 450 | -1.76 | 11.83 | | 0.17 | 2608.34 | 327.05 | 0.02 |
| Poicha | 250 | PF 13 | 500 | -1.76 | 11.97 | | 0.19 | 2654.55 | 329.23 | 0.02 |
| Poicha | 250 | PF 14 | 550 | -1.76 | 12.23 | | 0.2 | 2740.95 | 336.86 | 0.02 |
| Poicha | 250 | PF 15 | 600 | -1.76 | 12.34 | | 0.22 | 2777.12 | 340.41 | 0.02 |
| | | | | | | | | | | |
| Poicha | 0 | PF 1 | 10 | -0.8 | 9.58 | | 0.01 | 1972.2 | 310.58 | 0 |
| Poicha | 0 | PF 2 | 20 | -0.8 | 9.67 | | 0.01 | 1998.7 | 311.85 | 0 |
| Poicha | 0 | PF 3 | 25 | -0.8 | 9.7 | | 0.01 | 2008.21 | 312.31 | 0 |
| Poicha | 0 | PF 4 | 30 | -0.8 | 9.73 | | 0.01 | 2017.26 | 312.74 | 0 |
| Poicha | 0 | PF 5 | 35 | -0.8 | 9.75 | | 0.02 | 2025.67 | 313.14 | 0 |
| Poicha | 0 | PF 6 | 40 | -0.8 | 9.78 | | 0.02 | 2033.66 | 313.52 | 0 |
| Poicha | 0 | PF 7 | 45 | -0.8 | 9.8 | | 0.02 | 2041.41 | 313.89 | 0 |
| Poicha | 0 | PF 8 | 50 | -0.8 | 9.83 | | 0.02 | 2048.71 | 314.24 | 0 |
| Poicha | 0 | PF 9 | 55 | -0.8 | 9.85 | | 0.03 | 2055.37 | 314.55 | 0 |
| Poicha | 0 | PF 10 | 60 | -0.8 | 9.87 | | 0.03 | 2061.88 | 314.86 | 0 |
| Poicha | 0 | PF 11 | 400 | -0.8 | 11.43 | | 0.16 | 2570.53 | 334.9 | 0.02 |
| Poicha | 0 | PF 12 | 450 | -0.8 | 11.83 | | 0.17 | 2705.59 | 338.64 | 0.02 |
| Poicha | 0 | PF 13 | 500 | -0.8 | 11.97 | | 0.18 | 2753.34 | 339.78 | 0.02 |
| Poicha | 0 | PF 14 | 550 | -0.8 | 12.23 | | 0.19 | 2841.85 | 341.88 | 0.02 |
| Poicha | 0 | PF 15 | 600 | -0.8 | 12.34 | | 0.21 | 2878.39 | 342.75 | 0.02 |
| | | | | | | | | | | |
| Poicha | -250 | PF 1 | 10 | 2.79 | 9.58 | | 0.01 | 1807.66 | 358.4 | 0 |
| Poicha | -250 | PF 2 | 20 | 2.79 | 9.67 | | 0.01 | 1838.21 | 358.77 | 0 |
| Poicha | -250 | PF 3 | 25 | 2.79 | 9.7 | | 0.01 | 1849.14 | 358.91 | 0 |
| Poicha | -250 | PF 4 | 30 | 2.79 | 9.73 | | 0.02 | 1859.52 | 359.04 | 0 |
| Poicha | -250 | PF 5 | 35 | 2.79 | 9.75 | | 0.02 | 1869.17 | 359.15 | 0 |

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| | | | | | | | | | | |
|--------|-------|-------|-----|------|-------|--|------|---------|--------|------|
| Poicha | -250 | PF 6 | 40 | 2.79 | 9.78 | | 0.02 | 1878.34 | 359.27 | 0 |
| Poicha | -250 | PF 7 | 45 | 2.79 | 9.8 | | 0.02 | 1887.21 | 359.37 | 0 |
| Poicha | -250 | PF 8 | 50 | 2.79 | 9.83 | | 0.03 | 1895.56 | 359.48 | 0 |
| Poicha | -250 | PF 9 | 55 | 2.79 | 9.85 | | 0.03 | 1903.18 | 359.57 | 0 |
| Poicha | -250 | PF 10 | 60 | 2.79 | 9.87 | | 0.03 | 1910.62 | 359.66 | 0 |
| Poicha | -250 | PF 11 | 400 | 2.79 | 11.43 | | 0.16 | 2477.79 | 367.42 | 0.02 |
| Poicha | -250 | PF 12 | 450 | 2.79 | 11.83 | | 0.17 | 2625.5 | 369.51 | 0.02 |
| Poicha | -250 | PF 13 | 500 | 2.79 | 11.97 | | 0.19 | 2677.54 | 370.24 | 0.02 |
| Poicha | -250 | PF 14 | 550 | 2.79 | 12.23 | | 0.2 | 2773.84 | 371.59 | 0.02 |
| Poicha | -250 | PF 15 | 600 | 2.79 | 12.34 | | 0.21 | 2813.5 | 372.14 | 0.02 |
| | | | | | | | | | | |
| Poicha | -500 | PF 1 | 10 | 3.13 | 9.58 | | 0.01 | 1365.83 | 369.88 | 0 |
| Poicha | -500 | PF 2 | 20 | 3.13 | 9.67 | | 0.01 | 1397.38 | 370.98 | 0 |
| Poicha | -500 | PF 3 | 25 | 3.13 | 9.7 | | 0.02 | 1408.69 | 371.38 | 0 |
| Poicha | -500 | PF 4 | 30 | 3.13 | 9.73 | | 0.02 | 1419.44 | 371.75 | 0 |
| Poicha | -500 | PF 5 | 35 | 3.13 | 9.75 | | 0.02 | 1429.43 | 372.1 | 0 |
| Poicha | -500 | PF 6 | 40 | 3.13 | 9.78 | | 0.03 | 1438.92 | 372.43 | 0 |
| Poicha | -500 | PF 7 | 45 | 3.13 | 9.8 | | 0.03 | 1448.12 | 372.75 | 0.01 |
| Poicha | -500 | PF 8 | 50 | 3.13 | 9.83 | | 0.03 | 1456.78 | 373.05 | 0.01 |
| Poicha | -500 | PF 9 | 55 | 3.13 | 9.85 | | 0.04 | 1464.68 | 373.32 | 0.01 |
| Poicha | -500 | PF 10 | 60 | 3.13 | 9.87 | | 0.04 | 1472.4 | 373.59 | 0.01 |
| Poicha | -500 | PF 11 | 400 | 3.13 | 11.43 | | 0.19 | 2069.81 | 390.68 | 0.03 |
| Poicha | -500 | PF 12 | 450 | 3.13 | 11.83 | | 0.2 | 2226.92 | 393.22 | 0.03 |
| Poicha | -500 | PF 13 | 500 | 3.13 | 11.97 | | 0.22 | 2282.23 | 394.11 | 0.03 |
| Poicha | -500 | PF 14 | 550 | 3.13 | 12.23 | | 0.23 | 2384.73 | 395.76 | 0.03 |
| Poicha | -500 | PF 15 | 600 | 3.13 | 12.34 | | 0.25 | 2426.9 | 396.43 | 0.03 |
| | | | | | | | | | | |
| Poicha | -750 | PF 1 | 10 | 3.21 | 9.58 | | 0.01 | 1106.56 | 367.96 | 0 |
| Poicha | -750 | PF 2 | 20 | 3.21 | 9.67 | | 0.02 | 1137.93 | 368.77 | 0 |
| Poicha | -750 | PF 3 | 25 | 3.21 | 9.7 | | 0.02 | 1149.17 | 369.06 | 0 |
| Poicha | -750 | PF 4 | 30 | 3.21 | 9.73 | | 0.03 | 1159.84 | 369.34 | 0 |
| Poicha | -750 | PF 5 | 35 | 3.21 | 9.75 | | 0.03 | 1169.76 | 369.59 | 0.01 |
| Poicha | -750 | PF 6 | 40 | 3.21 | 9.78 | | 0.03 | 1179.19 | 369.83 | 0.01 |
| Poicha | -750 | PF 7 | 45 | 3.21 | 9.8 | | 0.04 | 1188.31 | 370.07 | 0.01 |
| Poicha | -750 | PF 8 | 50 | 3.21 | 9.83 | | 0.04 | 1196.91 | 370.29 | 0.01 |
| Poicha | -750 | PF 9 | 55 | 3.21 | 9.85 | | 0.05 | 1204.74 | 370.49 | 0.01 |
| Poicha | -750 | PF 10 | 60 | 3.21 | 9.87 | | 0.05 | 1212.4 | 370.69 | 0.01 |
| Poicha | -750 | PF 11 | 400 | 3.21 | 11.43 | | 0.22 | 1798.46 | 380.99 | 0.03 |
| Poicha | -750 | PF 12 | 450 | 3.21 | 11.83 | | 0.23 | 1951.66 | 383.41 | 0.03 |
| Poicha | -750 | PF 13 | 500 | 3.21 | 11.97 | | 0.25 | 2005.49 | 384.26 | 0.03 |
| Poicha | -750 | PF 14 | 550 | 3.21 | 12.23 | | 0.26 | 2105.39 | 385.83 | 0.04 |
| Poicha | -750 | PF 15 | 600 | 3.21 | 12.33 | | 0.28 | 2146.62 | 391.38 | 0.04 |
| | | | | | | | | | | |
| Poicha | -1000 | PF 1 | 10 | 5.75 | 9.58 | | 0.01 | 900.59 | 417.84 | 0 |
| Poicha | -1000 | PF 2 | 20 | 5.75 | 9.67 | | 0.02 | 936.21 | 418.92 | 0 |

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| | | | | | | | | | | |
|--------|-------|-------|-----|------|-------|--|------|---------|--------|------|
| Poicha | -1000 | PF 3 | 25 | 5.75 | 9.7 | | 0.03 | 948.96 | 419.31 | 0.01 |
| Poicha | -1000 | PF 4 | 30 | 5.75 | 9.73 | | 0.03 | 961.09 | 419.67 | 0.01 |
| Poicha | -1000 | PF 5 | 35 | 5.75 | 9.75 | | 0.04 | 972.35 | 420.01 | 0.01 |
| Poicha | -1000 | PF 6 | 40 | 5.75 | 9.78 | | 0.04 | 983.05 | 420.33 | 0.01 |
| Poicha | -1000 | PF 7 | 45 | 5.75 | 9.8 | | 0.05 | 993.42 | 420.65 | 0.01 |
| Poicha | -1000 | PF 8 | 50 | 5.75 | 9.83 | | 0.05 | 1003.18 | 420.94 | 0.01 |
| Poicha | -1000 | PF 9 | 55 | 5.75 | 9.85 | | 0.05 | 1012.07 | 421.21 | 0.01 |
| Poicha | -1000 | PF 10 | 60 | 5.75 | 9.87 | | 0.06 | 1020.76 | 421.49 | 0.01 |
| Poicha | -1000 | PF 11 | 400 | 5.75 | 11.42 | | 0.24 | 1692.33 | 439.11 | 0.04 |
| Poicha | -1000 | PF 12 | 450 | 5.75 | 11.82 | | 0.24 | 1869.07 | 442.33 | 0.04 |
| Poicha | -1000 | PF 13 | 500 | 5.75 | 11.97 | | 0.26 | 1931.09 | 443.45 | 0.04 |
| Poicha | -1000 | PF 14 | 550 | 5.75 | 12.22 | | 0.27 | 2046.42 | 445.53 | 0.04 |
| Poicha | -1000 | PF 15 | 600 | 5.75 | 12.33 | | 0.29 | 2093.7 | 447.09 | 0.04 |
| | | | | | | | | | | |
| Poicha | -1250 | PF 1 | 10 | 7.83 | 9.58 | | 0.03 | 319.67 | 441.45 | 0.01 |
| Poicha | -1250 | PF 2 | 20 | 7.83 | 9.67 | | 0.06 | 357.25 | 443.19 | 0.02 |
| Poicha | -1250 | PF 3 | 25 | 7.83 | 9.7 | | 0.07 | 370.7 | 443.81 | 0.02 |
| Poicha | -1250 | PF 4 | 30 | 7.83 | 9.73 | | 0.08 | 383.48 | 444.4 | 0.03 |
| Poicha | -1250 | PF 5 | 35 | 7.83 | 9.75 | | 0.09 | 395.35 | 444.95 | 0.03 |
| Poicha | -1250 | PF 6 | 40 | 7.83 | 9.78 | | 0.1 | 406.62 | 445.47 | 0.03 |
| Poicha | -1250 | PF 7 | 45 | 7.83 | 9.8 | | 0.11 | 417.54 | 445.97 | 0.04 |
| Poicha | -1250 | PF 8 | 50 | 7.83 | 9.83 | | 0.12 | 427.81 | 446.44 | 0.04 |
| Poicha | -1250 | PF 9 | 55 | 7.83 | 9.85 | | 0.13 | 437.17 | 446.87 | 0.04 |
| Poicha | -1250 | PF 10 | 60 | 7.83 | 9.87 | | 0.13 | 446.31 | 447.29 | 0.04 |
| Poicha | -1250 | PF 11 | 400 | 7.83 | 11.42 | | 0.35 | 1155.73 | 463.42 | 0.07 |
| Poicha | -1250 | PF 12 | 450 | 7.83 | 11.82 | | 0.34 | 1342.38 | 465.07 | 0.06 |
| Poicha | -1250 | PF 13 | 500 | 7.83 | 11.96 | | 0.36 | 1407.29 | 465.64 | 0.07 |
| Poicha | -1250 | PF 14 | 550 | 7.83 | 12.22 | | 0.36 | 1528.33 | 466.71 | 0.06 |
| Poicha | -1250 | PF 15 | 600 | 7.83 | 12.32 | | 0.38 | 1577.51 | 467.14 | 0.07 |
| | | | | | | | | | | |
| Poicha | -1500 | PF 1 | 10 | 9.01 | 9.58 | | 0.11 | 92.35 | 355.49 | 0.07 |
| Poicha | -1500 | PF 2 | 20 | 9.01 | 9.66 | | 0.16 | 124.14 | 415.35 | 0.09 |
| Poicha | -1500 | PF 3 | 25 | 9.01 | 9.69 | | 0.18 | 136.3 | 422.81 | 0.1 |
| Poicha | -1500 | PF 4 | 30 | 9.01 | 9.72 | | 0.2 | 148.03 | 430 | 0.11 |
| Poicha | -1500 | PF 5 | 35 | 9.01 | 9.74 | | 0.22 | 159.05 | 436.84 | 0.12 |
| Poicha | -1500 | PF 6 | 40 | 9.01 | 9.77 | | 0.24 | 169.65 | 443.31 | 0.12 |
| Poicha | -1500 | PF 7 | 45 | 9.01 | 9.79 | | 0.25 | 180.07 | 451.67 | 0.13 |
| Poicha | -1500 | PF 8 | 50 | 9.01 | 9.81 | | 0.26 | 190.05 | 461.74 | 0.13 |
| Poicha | -1500 | PF 9 | 55 | 9.01 | 9.83 | | 0.28 | 199.24 | 466.97 | 0.13 |
| Poicha | -1500 | PF 10 | 60 | 9.01 | 9.85 | | 0.29 | 208.28 | 469.45 | 0.14 |
| Poicha | -1500 | PF 11 | 400 | 9.01 | 11.4 | | 0.41 | 975.11 | 501.99 | 0.09 |
| Poicha | -1500 | PF 12 | 450 | 9.01 | 11.81 | | 0.38 | 1179.44 | 505 | 0.08 |
| Poicha | -1500 | PF 13 | 500 | 9.01 | 11.95 | | 0.4 | 1249.77 | 506.03 | 0.08 |
| Poicha | -1500 | PF 14 | 550 | 9.01 | 12.21 | | 0.4 | 1381.98 | 507.97 | 0.08 |
| Poicha | -1500 | PF 15 | 600 | 9.01 | 12.31 | | 0.42 | 1435.25 | 508.75 | 0.08 |

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|--------|-------|-------|-----|------|-------|------|------|---------|--------|------|
| | | | | | | | | | | |
| Poicha | -1750 | PF 1 | 10 | 9.1 | 9.52 | | 0.39 | 25.85 | 268.05 | 0.4 |
| Poicha | -1750 | PF 2 | 20 | 9.1 | 9.56 | 9.51 | 0.55 | 36.28 | 305.02 | 0.51 |
| Poicha | -1750 | PF 3 | 25 | 9.1 | 9.57 | 9.52 | 0.65 | 38.42 | 307.65 | 0.59 |
| Poicha | -1750 | PF 4 | 30 | 9.1 | 9.57 | 9.54 | 0.75 | 40.04 | 309.61 | 0.67 |
| Poicha | -1750 | PF 5 | 35 | 9.1 | 9.58 | 9.55 | 0.84 | 41.74 | 311.66 | 0.73 |
| Poicha | -1750 | PF 6 | 40 | 9.1 | 9.58 | 9.56 | 0.92 | 43.68 | 313.98 | 0.78 |
| Poicha | -1750 | PF 7 | 45 | 9.1 | 9.59 | | 0.98 | 45.95 | 316.67 | 0.82 |
| Poicha | -1750 | PF 8 | 50 | 9.1 | 9.6 | | 1.02 | 48.91 | 320.02 | 0.83 |
| Poicha | -1750 | PF 9 | 55 | 9.1 | 9.61 | 9.59 | 1.05 | 52.5 | 322.53 | 0.83 |
| Poicha | -1750 | PF 10 | 60 | 9.1 | 9.62 | 9.6 | 1.07 | 56.31 | 324.87 | 0.82 |
| Poicha | -1750 | PF 11 | 400 | 9.1 | 11.38 | | 0.44 | 916.11 | 555.25 | 0.11 |
| Poicha | -1750 | PF 12 | 450 | 9.1 | 11.8 | | 0.39 | 1145.96 | 557.24 | 0.09 |
| Poicha | -1750 | PF 13 | 500 | 9.1 | 11.94 | | 0.41 | 1223.53 | 557.91 | 0.09 |
| Poicha | -1750 | PF 14 | 550 | 9.1 | 12.2 | | 0.4 | 1370.3 | 559.18 | 0.08 |
| Poicha | -1750 | PF 15 | 600 | 9.1 | 12.3 | | 0.42 | 1428.7 | 559.68 | 0.08 |
| | | | | | | | | | | |
| Poicha | -2000 | PF 1 | 10 | 7.55 | 7.97 | 7.97 | 1.51 | 6.63 | 29 | 1.01 |
| Poicha | -2000 | PF 2 | 20 | 7.55 | 8.22 | | 1.26 | 15.92 | 43.96 | 0.67 |
| Poicha | -2000 | PF 3 | 25 | 7.55 | 8.35 | | 1.15 | 21.78 | 51.2 | 0.56 |
| Poicha | -2000 | PF 4 | 30 | 7.55 | 8.45 | | 1.09 | 27.5 | 56.14 | 0.5 |
| Poicha | -2000 | PF 5 | 35 | 7.55 | 8.55 | | 1.06 | 32.93 | 59.69 | 0.46 |
| Poicha | -2000 | PF 6 | 40 | 7.55 | 8.63 | | 1.04 | 38.34 | 63.08 | 0.43 |
| Poicha | -2000 | PF 7 | 45 | 7.55 | 8.72 | | 1.03 | 43.69 | 66.26 | 0.4 |
| Poicha | -2000 | PF 8 | 50 | 7.55 | 8.79 | | 1.02 | 48.97 | 69.27 | 0.39 |
| Poicha | -2000 | PF 9 | 55 | 7.55 | 8.87 | | 1.01 | 54.23 | 72.15 | 0.37 |
| Poicha | -2000 | PF 10 | 60 | 7.55 | 8.94 | | 1 | 59.83 | 75.12 | 0.36 |
| Poicha | -2000 | PF 11 | 400 | 7.55 | 11.35 | | 0.52 | 762.32 | 588.7 | 0.15 |
| Poicha | -2000 | PF 12 | 450 | 7.55 | 11.78 | | 0.44 | 1019.57 | 624.07 | 0.11 |
| Poicha | -2000 | PF 13 | 500 | 7.55 | 11.92 | | 0.45 | 1106.9 | 624.98 | 0.11 |
| Poicha | -2000 | PF 14 | 550 | 7.55 | 12.18 | | 0.43 | 1273.85 | 626.58 | 0.1 |
| Poicha | -2000 | PF 15 | 600 | 7.55 | 12.29 | | 0.45 | 1339.12 | 627.06 | 0.1 |
| | | | | | | | | | | |
| Poicha | -2250 | PF 1 | 10 | 6.68 | 7.72 | 7.2 | 0.42 | 24.07 | 42.29 | 0.18 |
| Poicha | -2250 | PF 2 | 20 | 6.68 | 8.06 | 7.36 | 0.5 | 39.79 | 52.56 | 0.18 |
| Poicha | -2250 | PF 3 | 25 | 6.68 | 8.19 | 7.43 | 0.53 | 46.88 | 56.65 | 0.19 |
| Poicha | -2250 | PF 4 | 30 | 6.68 | 8.3 | 7.48 | 0.56 | 53.53 | 60.03 | 0.19 |
| Poicha | -2250 | PF 5 | 35 | 6.68 | 8.4 | 7.54 | 0.59 | 59.68 | 62.57 | 0.19 |
| Poicha | -2250 | PF 6 | 40 | 6.68 | 8.49 | 7.58 | 0.61 | 65.66 | 64.95 | 0.19 |
| Poicha | -2250 | PF 7 | 45 | 6.68 | 8.58 | 7.63 | 0.63 | 71.43 | 67.17 | 0.2 |
| Poicha | -2250 | PF 8 | 50 | 6.68 | 8.66 | 7.67 | 0.65 | 76.99 | 69.24 | 0.2 |
| Poicha | -2250 | PF 9 | 55 | 6.68 | 8.74 | 7.7 | 0.67 | 82.46 | 71.22 | 0.2 |
| Poicha | -2250 | PF 10 | 60 | 6.68 | 8.82 | 7.74 | 0.68 | 88.24 | 73.97 | 0.2 |
| Poicha | -2250 | PF 11 | 400 | 6.68 | 11.26 | 9.11 | 0.94 | 423.93 | 217.38 | 0.22 |
| Poicha | -2250 | PF 12 | 450 | 6.68 | 11.71 | 9.23 | 0.81 | 554.14 | 355.98 | 0.21 |

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| | | | | | | | | | | |
|--------|-------|-------|-----|------|-------|------|------|--------|--------|------|
| Poicha | -2250 | PF 13 | 500 | 6.68 | 11.85 | 9.35 | 0.83 | 605.92 | 379.78 | 0.21 |
| Poicha | -2250 | PF 14 | 550 | 6.68 | 12.13 | 9.6 | 0.75 | 732.74 | 530.25 | 0.2 |
| Poicha | -2250 | PF 15 | 600 | 6.68 | 12.24 | 9.69 | 0.76 | 789.37 | 560.3 | 0.2 |

| Reach | River Sta | Profile | Q Total (m3/s) | Min Ch El (m) | W.S. Elev (m) | Crit W.S. (m) | Vel Chnl (m/s) | Flow Area (m2) | Top Width (m) | Froude # Chl |
|---------|-----------|---------|-------------------|------------------|------------------|------------------|-------------------|-------------------|------------------|-----------------|
| Sisodra | 1000 | PF 1 | 10 | 1.2 | 2.86 | | 0.05 | 192.65 | 168.93 | 0.02 |
| Sisodra | 1000 | PF 2 | 20 | 1.2 | 3 | | 0.09 | 216.14 | 176.02 | 0.03 |
| Sisodra | 1000 | PF 3 | 25 | 1.2 | 3.05 | | 0.11 | 225 | 178.55 | 0.03 |
| Sisodra | 1000 | PF 4 | 30 | 1.2 | 3.09 | | 0.13 | 233.08 | 180.83 | 0.04 |
| Sisodra | 1000 | PF 5 | 35 | 1.2 | 3.13 | | 0.15 | 240.54 | 182.91 | 0.04 |
| Sisodra | 1000 | PF 6 | 40 | 1.2 | 3.17 | | 0.16 | 247.74 | 184.89 | 0.04 |
| Sisodra | 1000 | PF 7 | 45 | 1.2 | 3.21 | | 0.18 | 254.57 | 187.1 | 0.05 |
| Sisodra | 1000 | PF 8 | 50 | 1.2 | 3.25 | | 0.19 | 261.39 | 189.27 | 0.05 |
| Sisodra | 1000 | PF 9 | 55 | 1.2 | 3.28 | | 0.21 | 267.92 | 191.33 | 0.06 |
| Sisodra | 1000 | PF 10 | 60 | 1.2 | 3.31 | | 0.22 | 274.21 | 193.29 | 0.06 |
| Sisodra | 1000 | PF 11 | 400 | 1.2 | 4.7 | | 0.7 | 574.93 | 231.69 | 0.14 |
| Sisodra | 1000 | PF 12 | 450 | 1.2 | 4.84 | | 0.74 | 608.32 | 234.31 | 0.15 |
| Sisodra | 1000 | PF 13 | 500 | 1.2 | 4.98 | | 0.78 | 639.64 | 236.76 | 0.15 |
| Sisodra | 1000 | PF 14 | 550 | 1.2 | 5.1 | | 0.82 | 669.86 | 239.11 | 0.16 |
| Sisodra | 1000 | PF 15 | 600 | 1.2 | 5.22 | | 0.86 | 698.83 | 241.33 | 0.16 |
| | | | | | | | | | | |
| Sisodra | 750 | PF 1 | 10 | 0.71 | 2.86 | | 0.06 | 157.14 | 125.72 | 0.02 |
| Sisodra | 750 | PF 2 | 20 | 0.71 | 3 | | 0.11 | 174.48 | 131.1 | 0.03 |
| Sisodra | 750 | PF 3 | 25 | 0.71 | 3.05 | | 0.14 | 180.98 | 133.06 | 0.04 |
| Sisodra | 750 | PF 4 | 30 | 0.71 | 3.09 | | 0.16 | 186.9 | 134.82 | 0.04 |
| Sisodra | 750 | PF 5 | 35 | 0.71 | 3.13 | | 0.18 | 192.35 | 136.42 | 0.05 |
| Sisodra | 750 | PF 6 | 40 | 0.71 | 3.17 | | 0.2 | 197.6 | 137.87 | 0.05 |
| Sisodra | 750 | PF 7 | 45 | 0.71 | 3.2 | | 0.22 | 202.56 | 139.23 | 0.06 |
| Sisodra | 750 | PF 8 | 50 | 0.71 | 3.24 | | 0.24 | 207.5 | 140.56 | 0.06 |
| Sisodra | 750 | PF 9 | 55 | 0.71 | 3.27 | | 0.26 | 212.22 | 141.83 | 0.07 |
| Sisodra | 750 | PF 10 | 60 | 0.71 | 3.3 | | 0.28 | 216.74 | 143.03 | 0.07 |
| Sisodra | 750 | PF 11 | 400 | 0.71 | 4.64 | | 0.91 | 441.04 | 191.58 | 0.19 |
| Sisodra | 750 | PF 12 | 450 | 0.71 | 4.78 | | 0.96 | 467.94 | 197.01 | 0.2 |
| Sisodra | 750 | PF 13 | 500 | 0.71 | 4.91 | | 1.01 | 493.53 | 202.14 | 0.21 |
| Sisodra | 750 | PF 14 | 550 | 0.71 | 5.03 | | 1.06 | 518.65 | 207.28 | 0.21 |
| Sisodra | 750 | PF 15 | 600 | 0.71 | 5.15 | | 1.1 | 543.08 | 212.16 | 0.22 |
| | | | | | | | | | | |
| Sisodra | 500 | PF 1 | 10 | 2.44 | 2.76 | 2.76 | 1.33 | 7.5 | 41.69 | 1 |
| Sisodra | 500 | PF 2 | 20 | 2.44 | 2.88 | 2.88 | 1.41 | 14.15 | 71.28 | 1.01 |
| Sisodra | 500 | PF 3 | 25 | 2.44 | 2.92 | 2.92 | 1.46 | 17.11 | 79.44 | 1 |
| Sisodra | 500 | PF 4 | 30 | 2.44 | 2.95 | 2.95 | 1.52 | 19.69 | 85.42 | 1.01 |
| Sisodra | 500 | PF 5 | 35 | 2.44 | 2.98 | 2.98 | 1.57 | 22.28 | 90.79 | 1.01 |

1420

| | | | | | | | | | | |
|---------|------|-------|-----|-------|------|------|------|---------|--------|------|
| Sisodra | 500 | PF 6 | 40 | 2.44 | 3 | 3 | 1.64 | 24.33 | 92.02 | 1.02 |
| Sisodra | 500 | PF 7 | 45 | 2.44 | 3.03 | 3.03 | 1.68 | 26.8 | 93.47 | 1 |
| Sisodra | 500 | PF 8 | 50 | 2.44 | 3.05 | 3.05 | 1.76 | 28.48 | 94.44 | 1.02 |
| Sisodra | 500 | PF 9 | 55 | 2.44 | 3.07 | 3.07 | 1.8 | 30.51 | 95.61 | 1.02 |
| Sisodra | 500 | PF 10 | 60 | 2.44 | 3.09 | 3.09 | 1.83 | 32.87 | 96.94 | 1 |
| Sisodra | 500 | PF 11 | 400 | 2.44 | 4.35 | | 1.93 | 207.48 | 183.9 | 0.58 |
| Sisodra | 500 | PF 12 | 450 | 2.44 | 4.49 | | 1.92 | 234.15 | 193.9 | 0.56 |
| Sisodra | 500 | PF 13 | 500 | 2.44 | 4.62 | | 1.93 | 259.61 | 199.2 | 0.54 |
| Sisodra | 500 | PF 14 | 550 | 2.44 | 4.75 | | 1.93 | 284.59 | 204.27 | 0.52 |
| Sisodra | 500 | PF 15 | 600 | 2.44 | 4.87 | | 1.94 | 308.79 | 208.07 | 0.51 |
| | | | | | | | | | | |
| Sisodra | 0 | PF 1 | 10 | 1.14 | 1.84 | | 0.22 | 46.29 | 91.83 | 0.1 |
| Sisodra | 0 | PF 2 | 20 | 1.14 | 2.05 | | 0.3 | 66.05 | 101.97 | 0.12 |
| Sisodra | 0 | PF 3 | 25 | 1.14 | 2.12 | | 0.34 | 74 | 105.81 | 0.13 |
| Sisodra | 0 | PF 4 | 30 | 1.14 | 2.19 | | 0.37 | 81.43 | 109.24 | 0.14 |
| Sisodra | 0 | PF 5 | 35 | 1.14 | 2.25 | | 0.4 | 88.4 | 112.24 | 0.14 |
| Sisodra | 0 | PF 6 | 40 | 1.14 | 2.32 | | 0.42 | 95.82 | 115.32 | 0.15 |
| Sisodra | 0 | PF 7 | 45 | 1.14 | 2.38 | | 0.44 | 103.2 | 118.3 | 0.15 |
| Sisodra | 0 | PF 8 | 50 | 1.14 | 2.43 | | 0.46 | 108.42 | 120.36 | 0.16 |
| Sisodra | 0 | PF 9 | 55 | 1.14 | 2.47 | | 0.48 | 113.5 | 122.34 | 0.16 |
| Sisodra | 0 | PF 10 | 60 | 1.14 | 2.51 | | 0.51 | 118.39 | 124.21 | 0.17 |
| Sisodra | 0 | PF 11 | 400 | 1.14 | 4.01 | | 1.12 | 358.2 | 195.2 | 0.26 |
| Sisodra | 0 | PF 12 | 450 | 1.14 | 4.15 | | 1.17 | 386.02 | 201.42 | 0.27 |
| Sisodra | 0 | PF 13 | 500 | 1.14 | 4.28 | | 1.21 | 413.23 | 207.17 | 0.27 |
| Sisodra | 0 | PF 14 | 550 | 1.14 | 4.41 | | 1.25 | 440.1 | 212.7 | 0.28 |
| Sisodra | 0 | PF 15 | 600 | 1.14 | 4.53 | | 1.29 | 466.34 | 217.97 | 0.28 |
| | | | | | | | | | | |
| Sisodra | -250 | PF 1 | 10 | -5.77 | 1.84 | | 0.01 | 767.15 | 155.31 | 0 |
| Sisodra | -250 | PF 2 | 20 | -5.77 | 2.05 | | 0.03 | 799.43 | 158.69 | 0 |
| Sisodra | -250 | PF 3 | 25 | -5.77 | 2.13 | | 0.03 | 811.75 | 160.06 | 0 |
| Sisodra | -250 | PF 4 | 30 | -5.77 | 2.2 | | 0.04 | 822.95 | 161.39 | 0.01 |
| Sisodra | -250 | PF 5 | 35 | -5.77 | 2.26 | | 0.04 | 833.26 | 162.59 | 0.01 |
| Sisodra | -250 | PF 6 | 40 | -5.77 | 2.33 | | 0.05 | 844 | 163.84 | 0.01 |
| Sisodra | -250 | PF 7 | 45 | -5.77 | 2.39 | | 0.05 | 854.47 | 165.05 | 0.01 |
| Sisodra | -250 | PF 8 | 50 | -5.77 | 2.43 | | 0.06 | 861.82 | 165.89 | 0.01 |
| Sisodra | -250 | PF 9 | 55 | -5.77 | 2.48 | | 0.06 | 868.92 | 166.7 | 0.01 |
| Sisodra | -250 | PF 10 | 60 | -5.77 | 2.52 | | 0.07 | 875.67 | 167.47 | 0.01 |
| Sisodra | -250 | PF 11 | 400 | -5.77 | 4.04 | | 0.34 | 1167.95 | 205.96 | 0.05 |
| Sisodra | -250 | PF 12 | 450 | -5.77 | 4.18 | | 0.38 | 1197.33 | 207.06 | 0.05 |
| Sisodra | -250 | PF 13 | 500 | -5.77 | 4.32 | | 0.41 | 1225.35 | 208.1 | 0.05 |
| Sisodra | -250 | PF 14 | 550 | -5.77 | 4.45 | | 0.44 | 1252.36 | 209.11 | 0.06 |
| Sisodra | -250 | PF 15 | 600 | -5.77 | 4.57 | | 0.47 | 1278.17 | 210.06 | 0.06 |
| | | | | | | | | | | |
| Sisodra | -500 | PF 1 | 10 | -2.56 | 1.84 | | 0.02 | 476.83 | 160.15 | 0 |
| Sisodra | -500 | PF 2 | 20 | -2.56 | 2.05 | | 0.04 | 510.1 | 163.54 | 0.01 |

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| | | | | | | | | | | |
|---------|-------|-------|-----|-------|------|------|------|--------|--------|------|
| Sisodra | -500 | PF 3 | 25 | -2.56 | 2.13 | | 0.05 | 522.78 | 164.75 | 0.01 |
| Sisodra | -500 | PF 4 | 30 | -2.56 | 2.2 | | 0.06 | 534.3 | 165.85 | 0.01 |
| Sisodra | -500 | PF 5 | 35 | -2.56 | 2.26 | | 0.06 | 544.88 | 166.85 | 0.01 |
| Sisodra | -500 | PF 6 | 40 | -2.56 | 2.33 | | 0.07 | 555.89 | 167.88 | 0.01 |
| Sisodra | -500 | PF 7 | 45 | -2.56 | 2.39 | | 0.08 | 566.6 | 168.88 | 0.01 |
| Sisodra | -500 | PF 8 | 50 | -2.56 | 2.43 | | 0.09 | 574.1 | 169.58 | 0.02 |
| Sisodra | -500 | PF 9 | 55 | -2.56 | 2.48 | | 0.09 | 581.34 | 170.25 | 0.02 |
| Sisodra | -500 | PF 10 | 60 | -2.56 | 2.52 | | 0.1 | 588.22 | 170.88 | 0.02 |
| Sisodra | -500 | PF 11 | 400 | -2.56 | 4.03 | | 0.46 | 866.24 | 195.81 | 0.07 |
| Sisodra | -500 | PF 12 | 450 | -2.56 | 4.17 | | 0.5 | 893.97 | 198.16 | 0.08 |
| Sisodra | -500 | PF 13 | 500 | -2.56 | 4.31 | | 0.54 | 920.56 | 200.42 | 0.08 |
| Sisodra | -500 | PF 14 | 550 | -2.56 | 4.44 | | 0.58 | 946.35 | 202.59 | 0.09 |
| Sisodra | -500 | PF 15 | 600 | -2.56 | 4.56 | | 0.62 | 971.12 | 204.65 | 0.09 |
| | | | | | | | | | | |
| Sisodra | -750 | PF 1 | 10 | 0.31 | 1.84 | | 0.08 | 127.73 | 122.28 | 0.02 |
| Sisodra | -750 | PF 2 | 20 | 0.31 | 2.05 | | 0.13 | 153.54 | 129.69 | 0.04 |
| Sisodra | -750 | PF 3 | 25 | 0.31 | 2.12 | | 0.15 | 163.61 | 132.46 | 0.04 |
| Sisodra | -750 | PF 4 | 30 | 0.31 | 2.19 | | 0.17 | 172.87 | 134.89 | 0.05 |
| Sisodra | -750 | PF 5 | 35 | 0.31 | 2.26 | | 0.19 | 181.46 | 137.08 | 0.05 |
| Sisodra | -750 | PF 6 | 40 | 0.31 | 2.32 | | 0.21 | 190.49 | 139.34 | 0.06 |
| Sisodra | -750 | PF 7 | 45 | 0.31 | 2.39 | | 0.23 | 199.36 | 141.54 | 0.06 |
| Sisodra | -750 | PF 8 | 50 | 0.31 | 2.43 | | 0.24 | 205.6 | 143.06 | 0.06 |
| Sisodra | -750 | PF 9 | 55 | 0.31 | 2.47 | | 0.26 | 211.65 | 144.51 | 0.07 |
| Sisodra | -750 | PF 10 | 60 | 0.31 | 2.51 | | 0.28 | 217.43 | 145.89 | 0.07 |
| Sisodra | -750 | PF 11 | 400 | 0.31 | 3.99 | | 0.85 | 472.11 | 206.69 | 0.18 |
| Sisodra | -750 | PF 12 | 450 | 0.31 | 4.13 | | 0.9 | 500.55 | 210.74 | 0.19 |
| Sisodra | -750 | PF 13 | 500 | 0.31 | 4.26 | | 0.95 | 528.02 | 214.57 | 0.19 |
| Sisodra | -750 | PF 14 | 550 | 0.31 | 4.38 | | 0.99 | 554.85 | 218.36 | 0.2 |
| Sisodra | -750 | PF 15 | 600 | 0.31 | 4.5 | | 1.03 | 580.78 | 221.97 | 0.2 |
| | | | | | | | | | | |
| Sisodra | -1000 | PF 1 | 10 | 1.18 | 1.84 | 1.48 | 0.29 | 34.3 | 100.74 | 0.16 |
| Sisodra | -1000 | PF 2 | 20 | 1.18 | 2.03 | 1.58 | 0.35 | 57.42 | 129.07 | 0.17 |
| Sisodra | -1000 | PF 3 | 25 | 1.18 | 2.11 | 1.62 | 0.37 | 67.35 | 137.64 | 0.17 |
| Sisodra | -1000 | PF 4 | 30 | 1.18 | 2.18 | 1.66 | 0.39 | 76.86 | 145.68 | 0.17 |
| Sisodra | -1000 | PF 5 | 35 | 1.18 | 2.24 | 1.69 | 0.41 | 86.01 | 153.14 | 0.17 |
| Sisodra | -1000 | PF 6 | 40 | 1.18 | 2.3 | 1.72 | 0.42 | 96.12 | 165.55 | 0.17 |
| Sisodra | -1000 | PF 7 | 45 | 1.18 | 2.36 | 1.75 | 0.42 | 107.11 | 181.77 | 0.17 |
| Sisodra | -1000 | PF 8 | 50 | 1.18 | 2.41 | 1.77 | 0.44 | 114.82 | 184.73 | 0.18 |
| Sisodra | -1000 | PF 9 | 55 | 1.18 | 2.45 | 1.8 | 0.45 | 122.36 | 187.58 | 0.18 |
| Sisodra | -1000 | PF 10 | 60 | 1.18 | 2.48 | 1.82 | 0.46 | 129.59 | 190.28 | 0.18 |
| Sisodra | -1000 | PF 11 | 400 | 1.18 | 3.94 | 2.57 | 0.85 | 468.92 | 274.93 | 0.21 |
| Sisodra | -1000 | PF 12 | 450 | 1.18 | 4.07 | 2.64 | 0.89 | 506.44 | 279.24 | 0.21 |
| Sisodra | -1000 | PF 13 | 500 | 1.18 | 4.2 | 2.7 | 0.92 | 542.55 | 283.32 | 0.21 |
| Sisodra | -1000 | PF 14 | 550 | 1.18 | 4.32 | 2.76 | 0.95 | 577.76 | 287.24 | 0.21 |
| Sisodra | -1000 | PF 15 | 600 | 1.18 | 4.44 | 2.82 | 0.98 | 611.67 | 290.94 | 0.22 |

| Reach | River Sta | Profile | Q Total | Min Ch El | W.S. Elev | Crit W.S. | Vel Chnl | Flow Area | Top Width | Froude # Chl |
|-------------|-----------|---------|---------------------|-----------|-----------|-----------|----------|-------------------|-----------|--------------|
| | | | (m ³ /s) | (m) | (m) | (m) | (m/s) | (m ²) | (m) | |
| Shuklatirth | 1498 | PF 1 | 10 | -1.48 | 0.48 | | 0.04 | 253.92 | 260.8 | 0.01 |
| Shuklatirth | 1498 | PF 2 | 20 | -1.48 | 0.6 | | 0.07 | 284.78 | 277.65 | 0.02 |
| Shuklatirth | 1498 | PF 3 | 25 | -1.48 | 0.65 | | 0.08 | 298.6 | 285.03 | 0.03 |
| Shuklatirth | 1498 | PF 4 | 30 | -1.48 | 0.7 | | 0.1 | 315.18 | 299.29 | 0.03 |
| Shuklatirth | 1498 | PF 5 | 35 | -1.48 | 0.75 | | 0.11 | 328.01 | 311.29 | 0.03 |
| Shuklatirth | 1498 | PF 6 | 40 | -1.48 | 0.79 | | 0.12 | 342.2 | 321.36 | 0.04 |
| Shuklatirth | 1498 | PF 7 | 45 | -1.48 | 0.83 | | 0.13 | 354.08 | 329.58 | 0.04 |
| Shuklatirth | 1498 | PF 8 | 50 | -1.48 | 0.86 | | 0.14 | 365.42 | 337.56 | 0.04 |
| Shuklatirth | 1498 | PF 9 | 55 | -1.48 | 0.89 | | 0.15 | 376.63 | 345.27 | 0.04 |
| Shuklatirth | 1498 | PF 10 | 60 | -1.48 | 0.93 | | 0.15 | 387.78 | 356.54 | 0.05 |
| Shuklatirth | 1498 | PF 11 | 400 | -1.48 | 2.06 | | 0.44 | 900.04 | 561.82 | 0.11 |
| Shuklatirth | 1498 | PF 12 | 450 | -1.48 | 2.15 | | 0.47 | 952.33 | 565.11 | 0.12 |
| Shuklatirth | 1498 | PF 13 | 500 | -1.48 | 2.24 | | 0.5 | 1001.86 | 568.22 | 0.12 |
| Shuklatirth | 1498 | PF 14 | 550 | -1.48 | 2.32 | | 0.52 | 1049.41 | 570.81 | 0.12 |
| Shuklatirth | 1498 | PF 15 | 600 | -1.48 | 2.4 | | 0.55 | 1095.16 | 572.71 | 0.13 |
| | | | | | | | | | | |
| Shuklatirth | 1301 | PF 1 | 10 | -0.79 | 0.48 | | 0.07 | 143.4 | 235.43 | 0.03 |
| Shuklatirth | 1301 | PF 2 | 20 | -0.79 | 0.6 | | 0.12 | 171.38 | 259.05 | 0.05 |
| Shuklatirth | 1301 | PF 3 | 25 | -0.79 | 0.64 | | 0.14 | 184.2 | 269.51 | 0.05 |
| Shuklatirth | 1301 | PF 4 | 30 | -0.79 | 0.7 | | 0.15 | 199.69 | 280.54 | 0.06 |
| Shuklatirth | 1301 | PF 5 | 35 | -0.79 | 0.74 | | 0.17 | 211.46 | 288.41 | 0.06 |
| Shuklatirth | 1301 | PF 6 | 40 | -0.79 | 0.79 | | 0.18 | 224.39 | 296.82 | 0.07 |
| Shuklatirth | 1301 | PF 7 | 45 | -0.79 | 0.82 | | 0.19 | 235.19 | 305.68 | 0.07 |
| Shuklatirth | 1301 | PF 8 | 50 | -0.79 | 0.86 | | 0.2 | 245.53 | 314.58 | 0.07 |
| Shuklatirth | 1301 | PF 9 | 55 | -0.79 | 0.89 | | 0.22 | 255.78 | 320.93 | 0.08 |
| Shuklatirth | 1301 | PF 10 | 60 | -0.79 | 0.92 | | 0.23 | 265.88 | 327.06 | 0.08 |
| Shuklatirth | 1301 | PF 11 | 400 | -0.79 | 2.04 | | 0.49 | 813.64 | 649.12 | 0.14 |
| Shuklatirth | 1301 | PF 12 | 450 | -0.79 | 2.13 | | 0.52 | 873.65 | 652.23 | 0.14 |
| Shuklatirth | 1301 | PF 13 | 500 | -0.79 | 2.22 | | 0.54 | 930.43 | 655.15 | 0.14 |
| Shuklatirth | 1301 | PF 14 | 550 | -0.79 | 2.3 | | 0.56 | 984.95 | 658.46 | 0.15 |
| Shuklatirth | 1301 | PF 15 | 600 | -0.79 | 2.38 | | 0.58 | 1037.52 | 661.91 | 0.15 |
| | | | | | | | | | | |
| Shuklatirth | 1022 | PF 1 | 10 | -0.46 | 0.48 | | 0.08 | 127.97 | 252.9 | 0.04 |
| Shuklatirth | 1022 | PF 2 | 20 | -0.46 | 0.59 | | 0.13 | 156.27 | 262.7 | 0.05 |
| Shuklatirth | 1022 | PF 3 | 25 | -0.46 | 0.64 | | 0.15 | 168.67 | 267.06 | 0.06 |
| Shuklatirth | 1022 | PF 4 | 30 | -0.46 | 0.69 | | 0.16 | 183.63 | 275.98 | 0.06 |
| Shuklatirth | 1022 | PF 5 | 35 | -0.46 | 0.73 | | 0.18 | 194.79 | 283.52 | 0.07 |
| Shuklatirth | 1022 | PF 6 | 40 | -0.46 | 0.77 | | 0.19 | 207.15 | 290.19 | 0.07 |
| Shuklatirth | 1022 | PF 7 | 45 | -0.46 | 0.81 | | 0.21 | 217.25 | 295.51 | 0.08 |

1423

| | | | | | | | | | | |
|-------------|------|-------|-----|-------|------|--|------|---------|--------|------|
| Shuklatirth | 1022 | PF 8 | 50 | -0.46 | 0.84 | | 0.22 | 226.79 | 300.93 | 0.08 |
| Shuklatirth | 1022 | PF 9 | 55 | -0.46 | 0.87 | | 0.23 | 236.19 | 310.61 | 0.09 |
| Shuklatirth | 1022 | PF 10 | 60 | -0.46 | 0.9 | | 0.24 | 245.65 | 325.56 | 0.09 |
| Shuklatirth | 1022 | PF 11 | 400 | -0.46 | 2 | | 0.49 | 824.41 | 620.2 | 0.13 |
| Shuklatirth | 1022 | PF 12 | 450 | -0.46 | 2.09 | | 0.51 | 881.45 | 623.73 | 0.14 |
| Shuklatirth | 1022 | PF 13 | 500 | -0.46 | 2.18 | | 0.53 | 935.4 | 625.85 | 0.14 |
| Shuklatirth | 1022 | PF 14 | 550 | -0.46 | 2.26 | | 0.56 | 987.12 | 627.87 | 0.14 |
| Shuklatirth | 1022 | PF 15 | 600 | -0.46 | 2.34 | | 0.58 | 1036.9 | 629.82 | 0.14 |
| | | | | | | | | | | |
| Shuklatirth | 471 | PF 1 | 10 | -0.44 | 0.48 | | 0.05 | 219.99 | 392.58 | 0.02 |
| Shuklatirth | 471 | PF 2 | 20 | -0.44 | 0.58 | | 0.08 | 261.76 | 395.06 | 0.03 |
| Shuklatirth | 471 | PF 3 | 25 | -0.44 | 0.63 | | 0.09 | 279.62 | 396.11 | 0.03 |
| Shuklatirth | 471 | PF 4 | 30 | -0.44 | 0.68 | | 0.1 | 301.06 | 397.37 | 0.04 |
| Shuklatirth | 471 | PF 5 | 35 | -0.44 | 0.72 | | 0.11 | 316.33 | 398.26 | 0.04 |
| Shuklatirth | 471 | PF 6 | 40 | -0.44 | 0.76 | | 0.12 | 333.07 | 399.24 | 0.04 |
| Shuklatirth | 471 | PF 7 | 45 | -0.44 | 0.8 | | 0.13 | 346.32 | 400.01 | 0.04 |
| Shuklatirth | 471 | PF 8 | 50 | -0.44 | 0.83 | | 0.14 | 358.59 | 400.72 | 0.05 |
| Shuklatirth | 471 | PF 9 | 55 | -0.44 | 0.86 | | 0.15 | 370.43 | 401.41 | 0.05 |
| Shuklatirth | 471 | PF 10 | 60 | -0.44 | 0.88 | | 0.16 | 381.78 | 402.07 | 0.05 |
| Shuklatirth | 471 | PF 11 | 400 | -0.44 | 1.93 | | 0.47 | 855.9 | 691.95 | 0.13 |
| Shuklatirth | 471 | PF 12 | 450 | -0.44 | 2.02 | | 0.49 | 919.01 | 699.81 | 0.14 |
| Shuklatirth | 471 | PF 13 | 500 | -0.44 | 2.11 | | 0.51 | 979.09 | 706.93 | 0.14 |
| Shuklatirth | 471 | PF 14 | 550 | -0.44 | 2.19 | | 0.53 | 1037.12 | 713.34 | 0.14 |
| Shuklatirth | 471 | PF 15 | 600 | -0.44 | 2.27 | | 0.55 | 1093.31 | 719.27 | 0.14 |
| | | | | | | | | | | |
| Shuklatirth | 228 | PF 1 | 10 | -1.19 | 0.48 | | 0.04 | 274.41 | 384.17 | 0.01 |
| Shuklatirth | 228 | PF 2 | 20 | -1.19 | 0.58 | | 0.06 | 315.08 | 388.12 | 0.02 |
| Shuklatirth | 228 | PF 3 | 25 | -1.19 | 0.63 | | 0.08 | 332.49 | 389.75 | 0.03 |
| Shuklatirth | 228 | PF 4 | 30 | -1.19 | 0.68 | | 0.08 | 353.5 | 391.7 | 0.03 |
| Shuklatirth | 228 | PF 5 | 35 | -1.19 | 0.72 | | 0.09 | 368.43 | 393.09 | 0.03 |
| Shuklatirth | 228 | PF 6 | 40 | -1.19 | 0.76 | | 0.1 | 384.85 | 394.6 | 0.03 |
| Shuklatirth | 228 | PF 7 | 45 | -1.19 | 0.79 | | 0.11 | 397.83 | 395.8 | 0.04 |
| Shuklatirth | 228 | PF 8 | 50 | -1.19 | 0.82 | | 0.12 | 409.84 | 396.9 | 0.04 |
| Shuklatirth | 228 | PF 9 | 55 | -1.19 | 0.85 | | 0.13 | 421.45 | 397.97 | 0.04 |
| Shuklatirth | 228 | PF 10 | 60 | -1.19 | 0.88 | | 0.14 | 432.59 | 398.99 | 0.04 |
| Shuklatirth | 228 | PF 11 | 400 | -1.19 | 1.9 | | 0.45 | 880.27 | 613.26 | 0.12 |
| Shuklatirth | 228 | PF 12 | 450 | -1.19 | 1.99 | | 0.48 | 936.11 | 630.64 | 0.13 |
| Shuklatirth | 228 | PF 13 | 500 | -1.19 | 2.08 | | 0.51 | 989.63 | 633.9 | 0.13 |
| Shuklatirth | 228 | PF 14 | 550 | -1.19 | 2.16 | | 0.53 | 1041.09 | 635.8 | 0.13 |
| Shuklatirth | 228 | PF 15 | 600 | -1.19 | 2.24 | | 0.55 | 1090.62 | 637.63 | 0.13 |
| | | | | | | | | | | |
| Shuklatirth | 0 | PF 1 | 10 | -2.4 | 0.48 | | 0.03 | 363.48 | 332.09 | 0.01 |
| Shuklatirth | 0 | PF 2 | 20 | -2.4 | 0.58 | | 0.05 | 400.8 | 389.39 | 0.02 |
| Shuklatirth | 0 | PF 3 | 25 | -2.4 | 0.63 | | 0.06 | 418.18 | 390.78 | 0.02 |
| Shuklatirth | 0 | PF 4 | 30 | -2.4 | 0.68 | | 0.07 | 439.18 | 392.45 | 0.02 |

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|-------------|------|-------|-----|-------|------|--|------|---------|--------|------|
| Shuklatirth | 0 | PF 5 | 35 | -2.4 | 0.72 | | 0.08 | 454.06 | 393.63 | 0.02 |
| Shuklatirth | 0 | PF 6 | 40 | -2.4 | 0.76 | | 0.09 | 470.43 | 394.92 | 0.02 |
| Shuklatirth | 0 | PF 7 | 45 | -2.4 | 0.79 | | 0.09 | 483.34 | 395.94 | 0.03 |
| Shuklatirth | 0 | PF 8 | 50 | -2.4 | 0.82 | | 0.1 | 495.28 | 396.87 | 0.03 |
| Shuklatirth | 0 | PF 9 | 55 | -2.4 | 0.85 | | 0.11 | 506.82 | 397.78 | 0.03 |
| Shuklatirth | 0 | PF 10 | 60 | -2.4 | 0.88 | | 0.12 | 517.87 | 398.64 | 0.03 |
| Shuklatirth | 0 | PF 11 | 400 | -2.4 | 1.89 | | 0.4 | 994.04 | 542.73 | 0.09 |
| Shuklatirth | 0 | PF 12 | 450 | -2.4 | 1.98 | | 0.43 | 1041.98 | 548.43 | 0.1 |
| Shuklatirth | 0 | PF 13 | 500 | -2.4 | 2.06 | | 0.46 | 1088.03 | 555.03 | 0.1 |
| Shuklatirth | 0 | PF 14 | 550 | -2.4 | 2.14 | | 0.49 | 1132.69 | 561.08 | 0.11 |
| Shuklatirth | 0 | PF 15 | 600 | -2.4 | 2.22 | | 0.51 | 1176.01 | 566.63 | 0.11 |
| | | | | | | | | | | |
| Shuklatirth | -220 | PF 1 | 10 | -1.73 | 0.48 | | 0.04 | 280.21 | 280.37 | 0.01 |
| Shuklatirth | -220 | PF 2 | 20 | -1.73 | 0.58 | | 0.06 | 310.33 | 295.04 | 0.02 |
| Shuklatirth | -220 | PF 3 | 25 | -1.73 | 0.62 | | 0.08 | 323.52 | 299.87 | 0.02 |
| Shuklatirth | -220 | PF 4 | 30 | -1.73 | 0.68 | | 0.09 | 339.69 | 305.68 | 0.03 |
| Shuklatirth | -220 | PF 5 | 35 | -1.73 | 0.72 | | 0.1 | 351.27 | 310.32 | 0.03 |
| Shuklatirth | -220 | PF 6 | 40 | -1.73 | 0.76 | | 0.11 | 364.19 | 315.52 | 0.03 |
| Shuklatirth | -220 | PF 7 | 45 | -1.73 | 0.79 | | 0.12 | 374.47 | 319.6 | 0.04 |
| Shuklatirth | -220 | PF 8 | 50 | -1.73 | 0.82 | | 0.13 | 384.09 | 325.04 | 0.04 |
| Shuklatirth | -220 | PF 9 | 55 | -1.73 | 0.85 | | 0.14 | 393.51 | 330.76 | 0.04 |
| Shuklatirth | -220 | PF 10 | 60 | -1.73 | 0.88 | | 0.15 | 402.68 | 338.91 | 0.04 |
| Shuklatirth | -220 | PF 11 | 400 | -1.73 | 1.87 | | 0.46 | 862.7 | 548.4 | 0.12 |
| Shuklatirth | -220 | PF 12 | 450 | -1.73 | 1.95 | | 0.49 | 910.28 | 554.06 | 0.12 |
| Shuklatirth | -220 | PF 13 | 500 | -1.73 | 2.04 | | 0.52 | 955.87 | 558.99 | 0.13 |
| Shuklatirth | -220 | PF 14 | 550 | -1.73 | 2.12 | | 0.55 | 999.99 | 563.61 | 0.13 |
| Shuklatirth | -220 | PF 15 | 600 | -1.73 | 2.19 | | 0.58 | 1042.71 | 567.97 | 0.14 |
| | | | | | | | | | | |
| Shuklatirth | -485 | PF 1 | 10 | -2.05 | 0.48 | | 0.03 | 300.22 | 210 | 0.01 |
| Shuklatirth | -485 | PF 2 | 20 | -2.05 | 0.58 | | 0.06 | 322.76 | 226.51 | 0.02 |
| Shuklatirth | -485 | PF 3 | 25 | -2.05 | 0.62 | | 0.08 | 332.81 | 229.75 | 0.02 |
| Shuklatirth | -485 | PF 4 | 30 | -2.05 | 0.68 | | 0.09 | 345.13 | 233.65 | 0.02 |
| Shuklatirth | -485 | PF 5 | 35 | -2.05 | 0.71 | | 0.1 | 353.9 | 236.83 | 0.03 |
| Shuklatirth | -485 | PF 6 | 40 | -2.05 | 0.76 | | 0.11 | 363.85 | 251.8 | 0.03 |
| Shuklatirth | -485 | PF 7 | 45 | -2.05 | 0.79 | | 0.12 | 372.1 | 263.68 | 0.03 |
| Shuklatirth | -485 | PF 8 | 50 | -2.05 | 0.82 | | 0.13 | 380.03 | 276.4 | 0.04 |
| Shuklatirth | -485 | PF 9 | 55 | -2.05 | 0.84 | | 0.14 | 388.04 | 289.99 | 0.04 |
| Shuklatirth | -485 | PF 10 | 60 | -2.05 | 0.87 | | 0.15 | 396.02 | 301.43 | 0.04 |
| Shuklatirth | -485 | PF 11 | 400 | -2.05 | 1.84 | | 0.48 | 832.85 | 595.58 | 0.13 |
| Shuklatirth | -485 | PF 12 | 450 | -2.05 | 1.93 | | 0.51 | 883.44 | 599.46 | 0.13 |
| Shuklatirth | -485 | PF 13 | 500 | -2.05 | 2.01 | | 0.54 | 931.82 | 603.15 | 0.14 |
| Shuklatirth | -485 | PF 14 | 550 | -2.05 | 2.08 | | 0.56 | 978.56 | 606.7 | 0.14 |
| Shuklatirth | -485 | PF 15 | 600 | -2.05 | 2.16 | | 0.59 | 1023.78 | 609.38 | 0.14 |
| | | | | | | | | | | |
| Shuklatirth | -750 | PF 1 | 10 | -1 | 0.48 | | 0.04 | 234.14 | 235.88 | 0.01 |

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| | | | | | | | | | | |
|-------------|-------|-------|-----|------|------|------|------|--------|--------|------|
| Shuklatirth | -750 | PF 2 | 20 | -1 | 0.58 | | 0.08 | 258.91 | 242.89 | 0.02 |
| Shuklatirth | -750 | PF 3 | 25 | -1 | 0.62 | | 0.09 | 269.6 | 245.81 | 0.03 |
| Shuklatirth | -750 | PF 4 | 30 | -1 | 0.68 | | 0.11 | 282.67 | 249.19 | 0.03 |
| Shuklatirth | -750 | PF 5 | 35 | -1 | 0.71 | | 0.12 | 291.91 | 251.55 | 0.04 |
| Shuklatirth | -750 | PF 6 | 40 | -1 | 0.75 | | 0.13 | 302.15 | 254.13 | 0.04 |
| Shuklatirth | -750 | PF 7 | 45 | -1 | 0.78 | | 0.15 | 310.19 | 256.15 | 0.04 |
| Shuklatirth | -750 | PF 8 | 50 | -1 | 0.81 | | 0.16 | 317.6 | 257.45 | 0.05 |
| Shuklatirth | -750 | PF 9 | 55 | -1 | 0.84 | | 0.17 | 324.75 | 258.54 | 0.05 |
| Shuklatirth | -750 | PF 10 | 60 | -1 | 0.87 | | 0.18 | 331.6 | 261.25 | 0.05 |
| Shuklatirth | -750 | PF 11 | 400 | -1 | 1.79 | | 0.61 | 656.89 | 538.93 | 0.18 |
| Shuklatirth | -750 | PF 12 | 450 | -1 | 1.87 | | 0.64 | 701.49 | 542.23 | 0.18 |
| Shuklatirth | -750 | PF 13 | 500 | -1 | 1.95 | | 0.67 | 744.12 | 542.86 | 0.18 |
| Shuklatirth | -750 | PF 14 | 550 | -1 | 2.03 | | 0.7 | 785.1 | 543.45 | 0.19 |
| Shuklatirth | -750 | PF 15 | 600 | -1 | 2.1 | | 0.73 | 824.64 | 544.03 | 0.19 |
| | | | | | | | | | | |
| Shuklatirth | -1011 | PF 1 | 10 | 0.15 | 0.47 | 0.31 | 0.18 | 54.1 | 289.02 | 0.14 |
| Shuklatirth | -1011 | PF 2 | 20 | 0.15 | 0.57 | 0.35 | 0.24 | 83.89 | 305.97 | 0.15 |
| Shuklatirth | -1011 | PF 3 | 25 | 0.15 | 0.61 | 0.36 | 0.26 | 96.97 | 314.35 | 0.15 |
| Shuklatirth | -1011 | PF 4 | 30 | 0.15 | 0.67 | 0.38 | 0.26 | 114.25 | 360.53 | 0.15 |
| Shuklatirth | -1011 | PF 5 | 35 | 0.15 | 0.7 | 0.39 | 0.27 | 127.45 | 375.81 | 0.15 |
| Shuklatirth | -1011 | PF 6 | 40 | 0.15 | 0.74 | 0.41 | 0.28 | 143.09 | 411.06 | 0.15 |
| Shuklatirth | -1011 | PF 7 | 45 | 0.15 | 0.77 | 0.41 | 0.29 | 155.8 | 425.96 | 0.15 |
| Shuklatirth | -1011 | PF 8 | 50 | 0.15 | 0.8 | 0.43 | 0.3 | 167.77 | 437.95 | 0.15 |
| Shuklatirth | -1011 | PF 9 | 55 | 0.15 | 0.83 | 0.44 | 0.31 | 179.59 | 450.18 | 0.15 |
| Shuklatirth | -1011 | PF 10 | 60 | 0.15 | 0.85 | 0.45 | 0.31 | 191.12 | 461.35 | 0.16 |
| Shuklatirth | -1011 | PF 11 | 400 | 0.15 | 1.73 | 0.86 | 0.6 | 661.65 | 597.5 | 0.18 |
| Shuklatirth | -1011 | PF 12 | 450 | 0.15 | 1.81 | 0.9 | 0.63 | 710.55 | 598.58 | 0.19 |
| Shuklatirth | -1011 | PF 13 | 500 | 0.15 | 1.89 | 0.93 | 0.66 | 757.44 | 599.62 | 0.19 |
| Shuklatirth | -1011 | PF 14 | 550 | 0.15 | 1.96 | 0.96 | 0.69 | 802.58 | 600.61 | 0.19 |
| Shuklatirth | -1011 | PF 15 | 600 | 0.15 | 2.04 | 1 | 0.71 | 846.18 | 601.57 | 0.19 |

Images of habitat profile (Pre-monsoon)**Site-I (Garudeshwar)**

| | |
|--|---|
| Elevation (msl.) | 60.57 m. |
| Width of channel (wetted) | 300 m. |
| Width of channel (Bank to bank) | 800 m. |
| Depth (Av.) | 3.5 m. |
| Water velocity | 130 cm/sec. |
| Substrate composition | Boulders 25%, coarse sand 45%, gravels 10%, clay and others 20%. |
| Deep pools | 2 nos. identified with average depth of 18.5 ft. |
| Riparian vegetation | Trees 45%, Herbs 15%, Shrubs 25%, grass land 15% |
| GPS Coordinates | N 21.887099, E 73.656058 |
| Other information | Check dam constructed, Ritual activities by the local people were visualized, temple exist. No pollution sources were recorded. |

Site-II (Poicha)



| | |
|--|--|
| Elevation (msl.) | 36 m. |
| Width of channel (wetted) | 300 m. |
| Width of channel (Bank to bank) | 800 m. |
| Depth (Av.) | 3.26 m. |
| Water velocity | 110 cm./sec. |
| Substrate composition | Coarse sand 25%, gravels 15%, cobbles 10% clay and others 50%. |
| Deep pools | 1 no (depth 12 m.) |
| Riparian vegetation | Trees 40%, Herbs 20%, Shrubs 25%, grass land 15% |
| GPS Coordinates | N 21.975716, E 73.458628 |
| Other information | Pollution source not recorded, bank soil erosion observed, instream cover not found. |

Site-III (Sisodra)



| | |
|--|---|
| levation (msl.) | 37.3 m. |
| Width of channel (wetted) | 200 m. |
| Width of channel (Bank to bank) | 800 m. |
| Depth (Av.) | 3.9 m. |
| Water velocity | 75 cm./sec. |
| Substrate composition | Small gravels 15%, sand 35%, clay and others 50% |
| Deep pools | Not recorded |
| Riparian vegetation | Trees 35%, shrubs 15%, herbs 15%, grass land 25% |
| GPS Coordinates | N 21.913903, E 73.347048 |
| Other information | Ritual activities visualized, sources of pollution not found. |

Site-IV (Lilod)



| | |
|--|---|
| Elevation (msl.) | 29.5 m. |
| Width of channel (wetted) | 500 m. |
| Width of channel (Bank to bank) | 700 m. |
| Depth (Av.) | 9.6 m. |
| Water velocity | 85 cm./sec. |
| Substrate composition | Sandy clay and others 100% |
| Deep pools | Recorded (1 no. with 30 m. depth) |
| Riparian vegetation | Trees 40%, shrubs 10%, herbs 15%, grass land 35% |
| GPS Coordinates | N 21.878093, E 73.233343 |
| Other information | Temple exist, no significant pollution discharge source identified. |

Site-V (Jhanor)



| | |
|--|---|
| Elevation (msl.) | 20 m. |
| Width of channel (wetted) | 450 m. |
| Width of channel (Bank to bank) | 700 m. |
| Depth (Av.) | 5.46 m. |
| Water velocity | 32 cm. /sec. |
| Substrate composition | Sandy clay |
| Deep pools | Not recorded |
| Riparian vegetation | Trees 20%, shrubs 25%, herbs 15%, grass land 40% |
| GPS Coordinates | N 21.8388, E 73.134 |
| Other information | Water lifting pump installed in the bank of the river, no pollution sources were found. |

Site-VI (Shuklatirth)



| | |
|--|--|
| Elevation (msl.) | 36.9 m. |
| Width of channel (wetted) | 400 m. |
| Width of channel (Bank to bank) | 700 m. |
| Depth (Av.) | 4.7 m. |
| Water velocity | 47 cm. / sec. |
| Substrate composition | Sandy clay |
| Deep pools | Not recorded |
| Riparian vegetation | Trees 15%, shrubs 25%, herbs 20%, grass land and others 40% |
| GPS Coordinates | N 21.747727, E 73.123398 |
| Other information | Ritual activities observed as the site considered as one of the holiest shrines. |

Site-VII (Bharuch)



| | |
|--|--|
| Elevation (msl.) | 15.9 m. |
| Width of channel (wetted) | 700 m. |
| Width of channel (Bank to bank) | 1000 m. |
| Depth (Av.) | 11.46 m. |
| Water velocity | 35 cm./sec. |
| Substrate composition | Clay and organic materials |
| Deep pools | Not recorded |
| Riparian vegetation | Trees 20%, shrubs 25%, herbs 20%, grass land and others 35% |
| GPS Coordinates | N 21.690182, E 73.00644 |
| Other information | Urban area, city sewage being discharged into the river, railway and road bridge constructed over the river. |

Site-VIII (Sakkarpura)



| | |
|--|---|
| Elevation (msl.) | 14.8 m. |
| Width of channel (wetted) | 500 m. |
| Width of channel (Bank to bank) | 700 m. |
| Depth (Av.) | 5.2 m. |
| Water velocity | 45 cm./sec. |
| Substrate composition | Sandy clay |
| Deep pools | Not recorded |
| Riparian vegetation | Trees 25%, shrubs 15%, herbs 10%, grass land and others 50% |
| GPS Coordinates | N 21.682, E 73.907 |
| Other information | Water lifting pump installed in the shoreline of the river, no instream cover was recorded. |

Site-IX (Bhadbhut)



| | |
|--|---|
| Elevation (msl.) | 17.47 m. |
| Width of channel (wetted) | 900 m. |
| Width of channel (Bank to bank) | 1200 m. |
| Depth (Av.) | 7.76 m. |
| Water velocity | 56 cm./sec. (Synchronized with the tidal effect) |
| Substrate composition | Sandy clay |
| Deep pools | Not recorded |
| Riparian vegetation | Rich riparian vegetation (Trees, shrubs, herbs, grass land and others) |
| GPS Coordinates | N 21.680952, E 73.845297 |
| Other information | Island formed in the middle of the river, Temples are located on the bank of the river, barrage under construction. |

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Images of habitat (post-monsoon)



Site-1 (Garudeshwar)



Site-2 (Poicha)

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Site-3 (Sisodra)

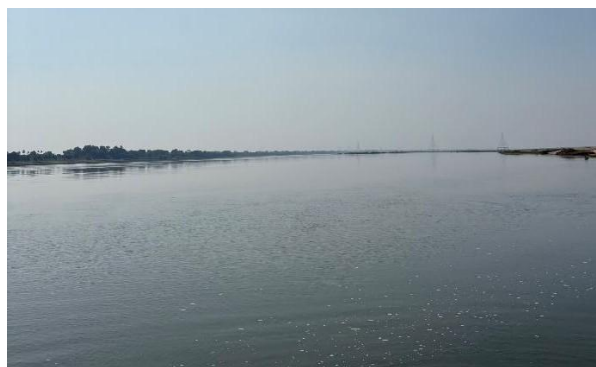


Site-4 (Lilod)

1437

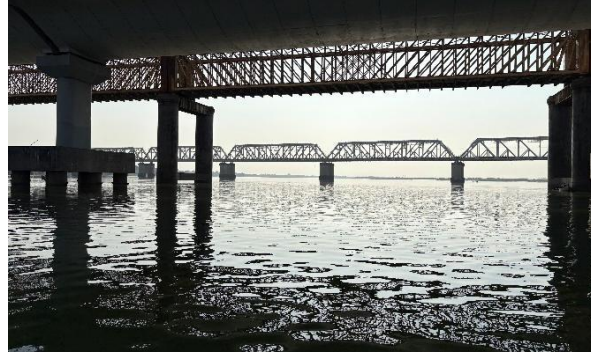


Site-5 (Jhanor)



Site-6 (Shuklatirth)

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Site-7 (Bharuch)



Site-8 (Sakkarpura)

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Site-9 (Bhadbhut)

Images of field activities



