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INDRAYANI RIVER

Assessment of Biodiversity and Ecological Health



Ecological Society, Pune

Study period: December 2025 to March 2026

Contents

1. Introduction.....	1
2. Purpose of the Assessment.....	1
3. Project Team.....	1
4. Study Area.....	2
4.1 Confluences and other important places.....	3
5. Rapid Assessment.....	3
5.1 Methodology – Rapid Assessment.....	3
5.2 Results – Rapid Assessment.....	4
5.3 Seasonal limitations of the surveys.....	6
6. Floral Diversity Assessment.....	7
6.1 Methodology – Floral Diversity Assessment.....	7
6.2 Data Analysis – Floral Diversity Assessment.....	8
6.3 Results & Discussion – Floral Diversity Assessment.....	8
7. Bird Diversity Assessment.....	13
7.1 Methodology – Bird Diversity Assessment.....	13
7.2 Data Analysis – Bird Diversity Assessment.....	14
7.3 Results & Discussion – Bird Diversity Assessment.....	14
7.4 Photographs.....	17
8. Butterflies and Odonates.....	19
8.1 Methodology.....	19
8.2 Results.....	20
9. Fish.....	22
9.1 Methodology.....	22
9.2 Observations.....	24
9.3 Mahseer Conservation in the Indrayani River.....	27
9.4 Recurring Fish Kill Incidents in the Indrayani River.....	27
10. Macroinvertebrate Diversity & Water Chemistry.....	28
10.1 Introduction.....	28
10.2 Methodology.....	28
10.3 Results.....	30
10.4 Discussion.....	32
11. Assessment of Ecological Health of Habitats.....	33
12. Summary of Study Findings.....	37
13. Recommendations, Guidelines and Models for Restoration and Conservation.....	38
13.1 The Indrayani needs a different approach from the Mula and Mutha.....	38
13.2 Immediate management actions.....	39
13.3 Protecting existing biodiversity: a tiered approach.....	39
13.4 Restoring degraded stretches.....	40

13.5 Protecting wetlands and floodplains.....	40
13.6 Improving water quality beyond sewage treatment.....	41
13.7 Conservation as flood management.....	41
13.8 Community involvement and governance.....	42
13.9 Monitoring framework.....	42
13.10 Restoration models: global precedents and their relevance.....	43
13.11 Summary of priority actions.....	43
14. Way Forward.....	44
15. Acknowledgements.....	44
References.....	46
Annexure 1: Consolidated list of floral species (rapid and detailed assessments).....	49
Annexure 2: Floral species documented in the detailed floral assessment.....	54
Annexure 3: Checklist of regeneration in the 10 detailed-assessment stretches.....	56
Annexure 4: Checklist of bird species.....	57
Annexure 5: Site-wise macroinvertebrate results.....	61
Annexure 6: Checklists of butterflies and odonates.....	77
Annexure 7: Habitats recorded at each location in the rapid assessment.....	78

1. Introduction

The Indrayani River originates in the northern Western Ghats of India at Kurwande Village (18.7310N & 73.3820E) near Lonavala, Pune District, Maharashtra. The river flows eastward from Kurwande Village near Lonavala in Pune District, to meet the Bhima River at Tulapur. It is one of the tributaries of Bhima River, which in turn is a major tributary of the Krishna River system. The Indrayani River is highly revered in Maharashtra as the birthplace of the Warkari spiritual movement. Historically and culturally, its sacred banks connect the revered pilgrimage towns of Dehu and Alandi, drawing millions of devotees during the annual Wari.

Over the years, rapid urbanization, changes in land-use patterns, agriculture expansion, altered hydrological regimes, and increasing anthropogenic disturbances have significantly disrupted natural river processes and have adversely impacted riparian ecology and ecosystem services. However, as compared to other rivers of the Bhima catchment like the Mula, Mutha and Pawana which flow through the Pune and Pimpri-Chinchwad cities and their suburbs, the banks of the Indrayani are less urbanized. The rapid expansion of Pimpri-Chinchwad however has now reached the Indrayani and has led to disturbance on its banks and influx of untreated sewage.

2. Purpose of the Assessment

Currently, comprehensive studies that provide insights into the existing state of the river ecosystem are unavailable. In the absence of such reports, evaluating the potential effects of increasing urbanisation on the ability of the river to retain its ecological functions is impossible.

This study aims to assess floral and faunal diversity as well as make an assessment of the health and diversity of aquatic and riparian habitats. This will help inform urban planning in the vicinity of the river while conserving critical habitats and ensuring ecologically sensitive development along the river.

3. Project Team

Kedar Champhekar, Kedar Bhagwat and Prajakta Mahajan led the study under the guidance of Ajay Phatak.

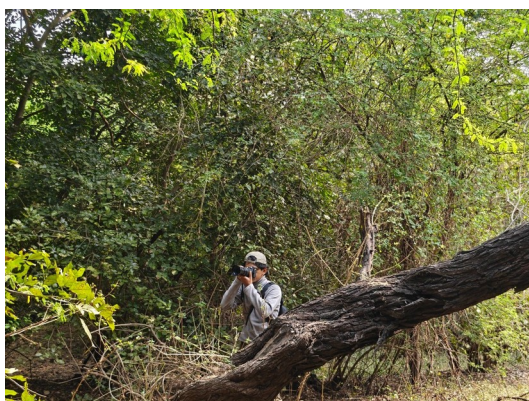
Services of area specific experts were availed - Monali Shah for flora and habitat assessment, Chinmay Sonawane for butterflies and odonate assessment, Aditya Soman for fish survey and Shiraj Jakhalekar and Shruti Paripatyadar for aquatic invertebrates. Avifaunal assessment was carried out by Kedar Champhekar. Water sample testing was carried out by UNIK Lab, Pune. We also thank Sayali Patwardhan, Kalyan Mane and Sucheta Mahajan for their assistance during the study. Special thanks to Pune River Revival and Jeevitnadi for their support.



The field team on the river bed



Bird survey on the river bank



Photographing birds in riverine woodland



Surveying beside a hyacinth-covered stretch

Figure 3.1: The study team in the field

4. Study Area

A 41 km stretch of the Indrayani River from Dehu town to the Bhima-Indrayani confluence at Tulapur was selected. Along this stretch there is rapid urbanisation and industrialization which is affecting the river. There are also proposed plans for development of a riverfront in a section of this stretch. Studying the ecological health of this stretch will highlight the challenges faced by the river ecosystem and will help formulate development plans along the river. A total of 67 river locations exhibiting significant vegetation were selected with the help of Google Earth images.

This stretch of the river is home to the important religious towns of Dehu and Alandi. Between these towns there is significant urbanisation along the southern bank, which is a part of Pimpri-Chinchwad Municipal Corporation. On the north bank there is an industrial belt from Khalumbre to Chimbali, which is a part of the larger Chakan industrial area.

East of Dhanore village up to Tulapur the river flows through a more rural landscape with agriculture being the primary land use along the river. However, 2-5 km south of the river bank along this stretch is an area of extensive stone quarrying that extends almost 6 km. The quarrying is being carried out in an area of low hills which are a part of the catchment of the Indrayani.

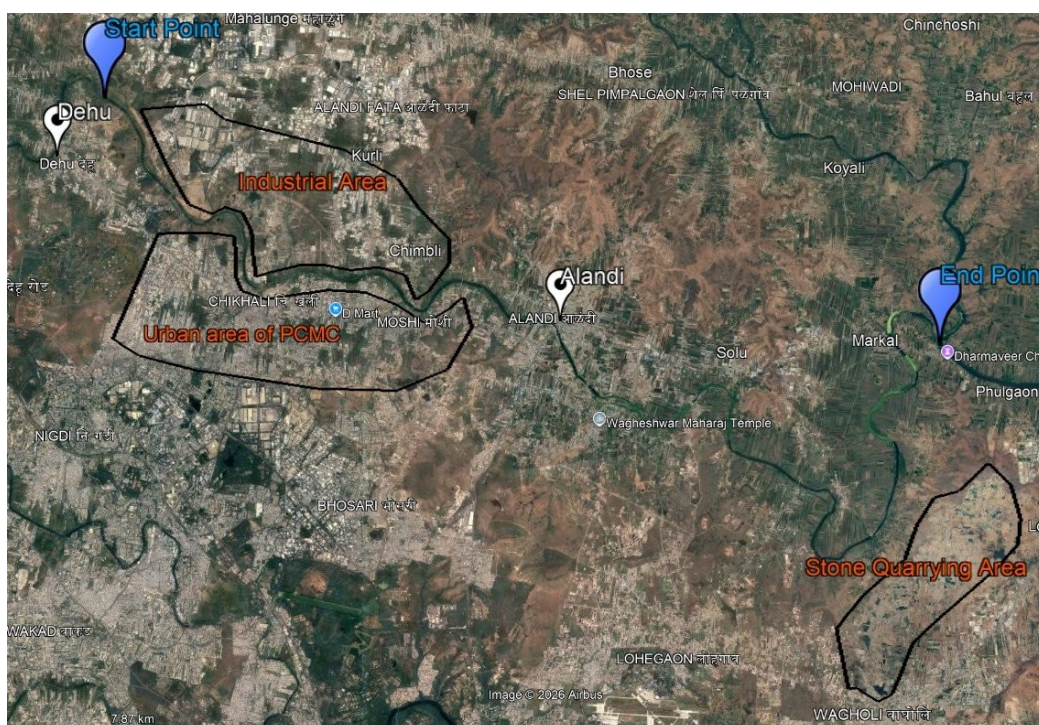


Figure 4.1: Study area

4.1 Confluences and other important places

Confluences, where streams and rivers meet, are ecologically important. They bring together water, sediment and nutrients from different sources and usually hold a greater variety of habitats and species than the reaches on either side. Two confluences lie within the study stretch. At W7, near Pimpri, the Ram stream joins the Indrayani; this stretch has been altered by temple development and is invaded by subabul (*Leucaena latisiliqua*). At Tulapur (E1) the Indrayani meets the Bhima at the Sangam, beside the Sangameshwar temple and the samadhi of Chhatrapati Sambhaji Maharaj, a place of great historical and cultural importance. The confluence stretch has dense riparian vegetation dominated by karanj, and a very large banyan (*Ficus benghalensis*) estimated to be more than 200 years old (Section 6.3.3). Sampling site 11, just above the confluence, had the highest diversity of aquatic invertebrates found in this study, including pollution-sensitive mayfly larvae (Section 10).

Upstream of the study area, the Sudha river joins the Indrayani near Dehu, and Pakshi Teerth, an island in the river at Dehu, is important from both a cultural and a biodiversity point of view (Jeevitnadi, pers. comm.). These places lie outside the 41 km stretch surveyed and were not assessed in this study; they are recommended for survey in Section 14.

5. Rapid Assessment

5.1 Methodology - Rapid Assessment

A total of 67 locations from Dehu to Tulapur, up to the Indrayani-Bhima confluence, exhibiting significant vegetation were initially identified using Google Earth imagery. A rapid field survey was conducted across 59 of these locations from 5 November to 19 November 2025. At each location, a random transect of variable length (not fixed in advance) was walked through the riparian zone to record flora including trees, shrubs, herbs, climbers, grasses, and aquatic plants. The dominance of each flora species was visually assessed, and the overall floral composition was systematically documented. Bird species observed at each location were also documented. In addition, physical features such as feeder streams and springs, rocky outcrops, sandbars, mudflats, marshy areas, grassy patches, wetlands, and riverine islands were recorded along the riverbank.

5.2 Results - Rapid Assessment

Table 5.2 a) Floral composition observed in rapid assessment

Habit/Taxon	Total no. of species	Native	Non-native	Riparian	Remarks
Trees	62	48	14	13	
Shrubs	31	19	12	3	
Herbs	29	21	8	12	
Climbers	20	15	5	2	
Grasses	24	21	3	2	Includes one species of Bamboo
Sedges	1	-	-	-	
Aquatic Plants	2	-	-	-	

Table 5.2 b) Distinctive riparian features observed in the rapid assessment (number of the 59 locations surveyed)

Feeder Streams and Springs	Rocky Outcrops	Sandbars and Mudflats
15	6	19

Marshy areas, grassy patches, wetlands and meanders were also seen across the study area.

Habitats recorded at each location. The rapid-survey notes for each of the 59 locations surveyed were used to list the habitats present, grouped into river bank habitats, river bed habitats and water inflows (Table 5.2 c). In all, 14 habitat types were recorded. The habitats found at each location are listed in Annexure 7.

Table 5.2 c) Habitats recorded during the rapid assessment

Zone	Habitat	Number of locations (of 59)
River bank	Riparian woodland (dense or good riparian vegetation)	23
River bank	Narrow strip of riparian trees	15
River bank	Mixed or degraded vegetation	21
River bank	Old, mature trees	20
River bank	Floodplain (including grassy floodplain)	10
River bank	Wetland	3
River bed	Sandbars	13
River bed	Mudflats	8
River bed	Rocky outcrops	6
River bed	Islands	3
River bed	Meanders	4
Water inflows	Feeder streams	14
Water inflows	Springs	2
Water inflows	Confluences (Ram stream at W7; Bhima at E1)	2

Of the 59 stretches surveyed, 30 were assessed as ecologically rich, based on field observation of vegetation cover, habitat heterogeneity, the variety of microhabitats and the presence of old, mature trees.

The study recorded multiple anthropogenic stressors, including agricultural encroachment, debris dumping, solid waste disposal, sewage discharge, construction activities, and the accumulation of plastic waste along the riverbanks.

Agricultural encroachment. The rapid survey found that most stretches are encroached by farmland. At 26 of the 59 locations, fields (often sugarcane) run right up to the bank, leaving only a narrow strip of trees or none at all. The many riparian species still found in these strips suggest that a wider riverine forest once stood here. Clearing the bank for cultivation removes the riparian buffer, increases bank erosion and lets fertiliser and pesticide runoff flow straight into the river.

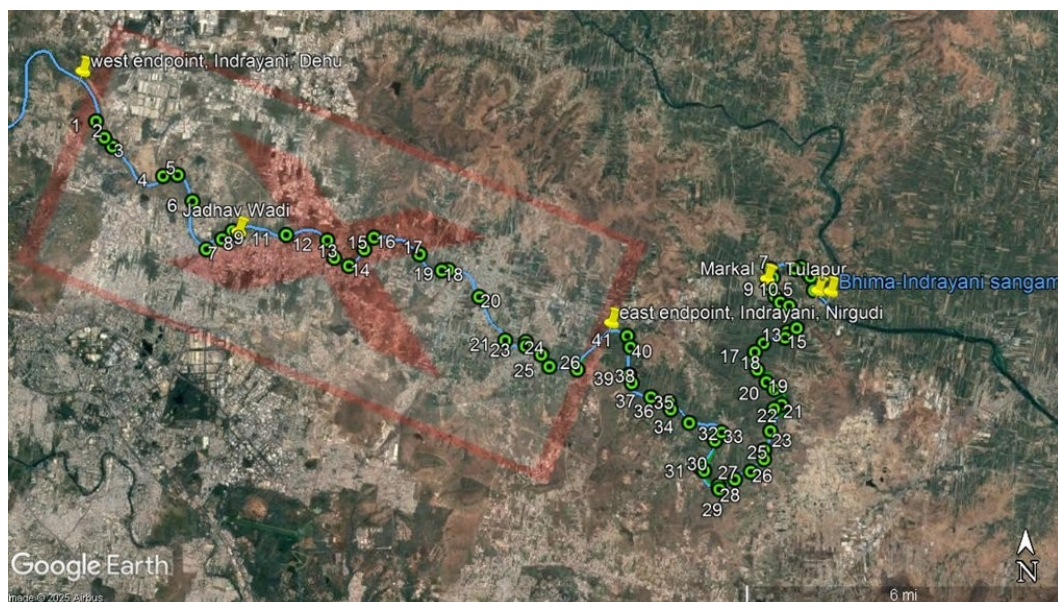


Figure 5.1: All locations from Dehu to Tulapur

Figure 5.2 shows the range of riverbank and in-channel habitats found along the Indrayani.



Riparian forest



Reserve Forest boundary pillar at E30



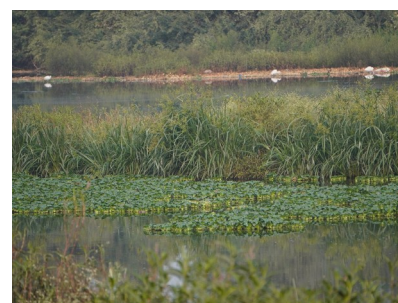
Riparian forest interior



Tree-lined banks



Large river island



Sandbars with vegetation



Rocky outcrops



Rocky bed with small rocky islands



Shallow pools



Tributary stream forming a wetland



Grassy banks



Riparian scrub with shindi palms

Figure 5.2: Habitats along the Indrayani River

5.3 Seasonal limitations of the surveys

All field surveys were carried out in the dry season: the rapid survey in November 2025 and the detailed surveys between January and March 2026. The findings are therefore a dry-season baseline, and should be read with the following limitations in mind.

- **Ground flora:** by November most monsoon herbs and grasses had flowered, set seed and dried, and by January–February the ground layer was largely dry. Seasonal herbs, grasses and aquatic plants that appear

only during and just after the monsoon could not be recorded or mapped, so the ground-flora lists and diversity values understate the true richness of the banks.

- **Associated biodiversity:** because the seasonal ground flora and monsoon wetlands were missed, the insects and other fauna that depend on them were also under-recorded. Amphibians and reptiles were not surveyed.
- **Butterflies and odonates** peak after the monsoon; the winter surveys recorded fewer species than a post-monsoon survey would (Section 8).
- **Birds** were counted in winter, so wintering migrants are included but birds that breed on the river in the monsoon and summer may be under-recorded.
- **Water and fish:** water quality was sampled once, in late winter, and fish were recorded only from fishers' catches and fish markets.

Surveys in all seasons are needed for a complete picture of the river's biodiversity (Section 14).

6. Floral Diversity Assessment

6.1 Methodology - Floral Diversity Assessment

Out of the 30 stretches found to be ecologically rich, 10 stretches were selected for detailed floral study, based on ease of access and the presence of dense, mature vegetation observed during the rapid survey. The selected stretches, W6, W22, W23, E5, E6, E18, E21, E30, E40 and E41 were studied in detail to assess their ecological characteristics and biodiversity.

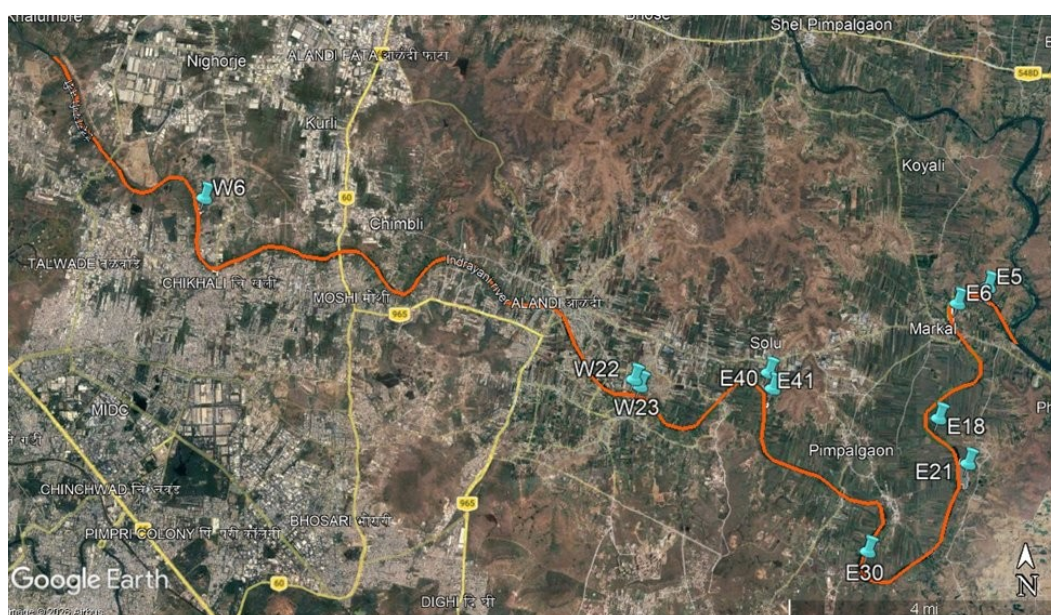


Figure 6.1: Locations of the 10 stretches selected for detailed floral assessment

The survey was conducted from 29 January to 12 February 2026. Detailed vegetation sampling was carried out using a stratified sampling approach with nested quadrats. A total of 45 quadrats were laid across 10 selected stretches. Quadrat sizes were standardized as (10 m × 10 m) for trees, (5 m × 5 m) for shrubs and climbers, and (1 m × 1 m) for herbs, sedges, and grasses. The girth at breast height (GBH) and height of each tree were recorded; GBH was used to calculate basal area, which gives the relative dominance component of the IVI. Canopy cover at each quadrat was visually assessed. Flora species were identified using field guides (Ingalthalikar 2003, 2007, 2014; Yadav 2010; Potdar et al. 2012; Krishen 2013).

6.2 Data Analysis - Floral Diversity Assessment

Ecological indicators evaluated are species diversity, including species richness, frequency, density, abundance and Importance Value Index (IVI). Dominant species were identified as those with the highest IVI values within each community, while rare species were those with the lowest IVI values. Standard methods of Curtis and McIntosh (1950) and Mueller-Dombois and Ellenberg (1974) were used to analyse density, frequency and abundance. IVI was calculated as the sum of relative density, relative frequency and relative dominance (maximum 300).

The Shannon-Wiener Index (H') (Shannon 1948) assessed species diversity in a community. Simpson's dominance index (D) measured species dominance and rarity of the tree species in the riparian ecosystem and Simpson's Diversity Index ($1-D$) (Simpson 1949) measured diversity with emphasis on dominance. Pielou's evenness index (J) (Pielou 1966) measured how evenly individuals are spread across species. Several indices are reported because each weights the data differently: Shannon's index is more sensitive to rare species, Simpson's indices to the most common ones. Reporting them together also allows comparison with other riparian studies that use one or the other.

6.3 Results & Discussion - Floral Diversity Assessment

6.3.1 Taxonomic Composition

Detailed study of riparian forest along Indrayani River documented a total of 70 plant species during surveys belonging to 67 genera and 35 families. Among these Fabaceae was the most dominant family with 9 species followed by Asteraceae (8) species and Acanthaceae (4). The consolidated list of all floral species found in the rapid and detailed surveys is given in Annexure 1. The list of all floral species documented in the detailed floral diversity assessment is given in Annexure 2.

Shrubs were the most species-rich growth form (34 species), followed by trees (19), herbs including sedges (9), climbers (4) and grasses (4). The split of each growth form into native, non-native, riparian and invasive species is given in Table 6.3.1.

Based on nativity, 58 species were native (83%) while 12 species were non-native (17%). Native species were dominant across most habit categories particularly shrubs (88%) and trees (79%). In contrast, non-native species showed higher representation in the herbaceous layer (33%). Herbaceous ground cover was notably affected by invasive species. *Alternanthera ficoidea* and *Synedrella nodiflora* were the most abundant species in the herb quadrats (see Section 6.3.2).

Riparian species accounted for 28 species (40%) contributing significantly to vegetation structure. Riparian species were most prominent particularly in herbs (67%), followed by trees (58%) and shrubs (29%) indicating their crucial role in maintaining riparian ecosystem integrity.

Table 6.3.1: Taxonomic composition

Vegetation layer	Total species	Native	Non-native	Riparian	Invasive
Trees	19	15	4	11	2
Shrub	34	30	4	10	3
Climber	4	4	0	1	0
Herbs	9	6	3	6	3
Grass	4	3	1	0	0
TOTAL	70	58	12	28	8
%	100	83	17	40	11

The abundance and distribution patterns of the riparian vegetation along the Indrayani River varied across growth forms. Among trees, *Pongamia pinnata* (51%) and *Vachellia nilotica* (16%) were the most abundant species, occurring in 73% and 63% of quadrats respectively (frequency), i.e. distributed widely across the study area. Among shrubs, *Plumbago zeylanica* (22%) and *Sida acuta* (10%) were abundant; *Plumbago zeylanica* occurred in 53% of quadrats, whereas *Sida acuta* showed a patchy distribution. In the herbaceous layer, *Alternanthera ficoidea* was the most abundant species (51%) and occurred in 82% of quadrats.

The riparian tree species such as *Terminalia arjuna*, *Syzygium salicifolium*, *Salix tetrasperma*, *Ficus hispida*, and *Cordia dichotoma* that are typically characteristic of the riverine ecosystem were found to be rare within the study area. Among these, mature and tall individuals of *Terminalia arjuna* were extremely scarce and were recorded only at a single stretch (W6). Notably, this species was not observed along other rivers within the Pune region. Additionally, *Ficus heterophylla* was recorded only once (in stretch W1) in rapid surveys indicating its very limited distribution within the study area. *Balanites aegyptiaca* is a characteristic species of desert, arid, and semi-arid dryland regions. It typically occurs along dry riverbanks and in riparian zones, where it can tolerate periodic flooding of up to two months. During the study, this species was found to be abundant only in two stretches. *Capparis divaricata*, another species associated with dry deciduous forests, was recorded at only one stretch. This distribution pattern may indicate that the Indrayani River was likely more seasonal in the past, with periods of reduced or intermittent flow, as reflected by the occurrence of dryland-associated species.

Endemism analysis revealed the presence of two species (2.85%) endemic to the Indian subcontinent, *Syzygium salicifolium* and *Combretum ovalifolium*, highlighting the ecological significance of the riparian zone for conserving native biodiversity.

6.3.2 Vegetation Structure

Tree layer: A total of 644 trees were sampled in the study area, among them *Pongamia pinnata* showed the greatest abundance with 326 individuals, followed by *Vachellia nilotica* with 102 individuals.

Based on the IVI (Table 6.3.2 a), *Pongamia pinnata* had the highest IVI (99.87) followed by *Vachellia nilotica* (76.18) and *Holoptelea integrifolia* (22.64). *Ficus hispida* (0.96) had the lowest IVI. *Pongamia pinnata* was the most abundant species while *Ficus hispida* was found to be the rarest species. The high IVI values indicate that *Pongamia pinnata* is the most dominant species followed by *Vachellia nilotica*. Both are native, riparian and flood-tolerant species, reflecting their adaptive advantage in the riverine environment. Other co-dominant species include *Holoptelea integrifolia*, *Prosopis juliflora*, *Azadirachta indica*, and *Phoenix sylvestris*, with *Prosopis juliflora* being an invasive species impacting native tree composition.

Table 6.3.2 a: IVI for tree species

Sr. No	Botanical name	Common name	Family	IVI	Native/Non-native/ Invasive	Riparian
1	<i>Pongamia pinnata</i>	Karanj	Fabaceae	99.87	Native	Yes
2	<i>Vachellia nilotica</i>	Babhul	Fabaceae	76.18	Native	Yes
3	<i>Holoptelea integrifolia</i>	Wawal	Ulmaceae	22.64	Native	Yes - generalist species found in association with riparian species
4	<i>Prosopis juliflora</i>	Vedi Babhul	Fabaceae	16.4	Invasive and Non-native	Yes - highly generalist species also found invading river floodplains
5	<i>Azadirachta indica</i>	Neem	Meliaceae	14.2	Native	No
6	<i>Phoenix sylvestris</i>	Shindi	Arecaceae	13.04	Native	Yes
7	<i>Leucaena leucocephala</i>	Subabhul	Fabaceae	9.49	Invasive and Non-native	Yes - highly generalist species also found invading riparian habitats
8	<i>Terminalia arjuna</i>	Arjun	Combretaceae	8.31	Native	Yes

Sr. No	Botanical name	Common name	Family	IVI	Native/Non-native/ Invasive	Riparian
9	<i>Ziziphus mauritiana</i>	Bor	Rhamnaceae	7.47	Native	No
10	<i>Ficus racemosa</i>	Umbar	Moraceae	6.77	Native	Yes
11	<i>Balanites aegyptiaca</i>	Hinganbet	Zygophyllaceae	6.19	Native	Occasionally seen in riparian habitats
12	<i>Tamarindus indica</i>	Chinch	Fabaceae	5.53	Non-native	Yes - generalist species that also thrives along rivers
13	<i>Samanea saman</i>	Rain tree	Fabaceae	3.97	Non-native	Yes - generalist - seen in riparian forests in its native range
14	<i>Pithecellobium dulce</i>	Vilayati chinch	Fabaceae	3.59	Non-native (naturalised)	Yes - generalist also seen thriving in riparian habitats
15	<i>Syzygium salicifolium</i>	Paan Jambhul	Myrtaceae	1.92	Native	Yes
16	<i>Salix tetrasperma</i>	Walunj	Salicaceae	1.39	Native	Yes
17	<i>Mitragyna parviflora</i>	Kalam	Rubiaceae	1.12	Native	Yes - generalist but also found as an associated species in riparian zones
18	<i>Cordia dichotoma</i>	Bhokar	Boraginaceae	0.96	Native	Yes - generalist, can be found associated with riparian species
19	<i>Ficus hispida</i>	Dedh umbar	Moraceae	0.96	Native	Yes
Total				300		

The dominance–diversity curve (Figure 6.2) shows a sharp initial decline followed by a flatter portion indicating that a few species are highly dominant while the remaining species are more evenly distributed across the riparian community.

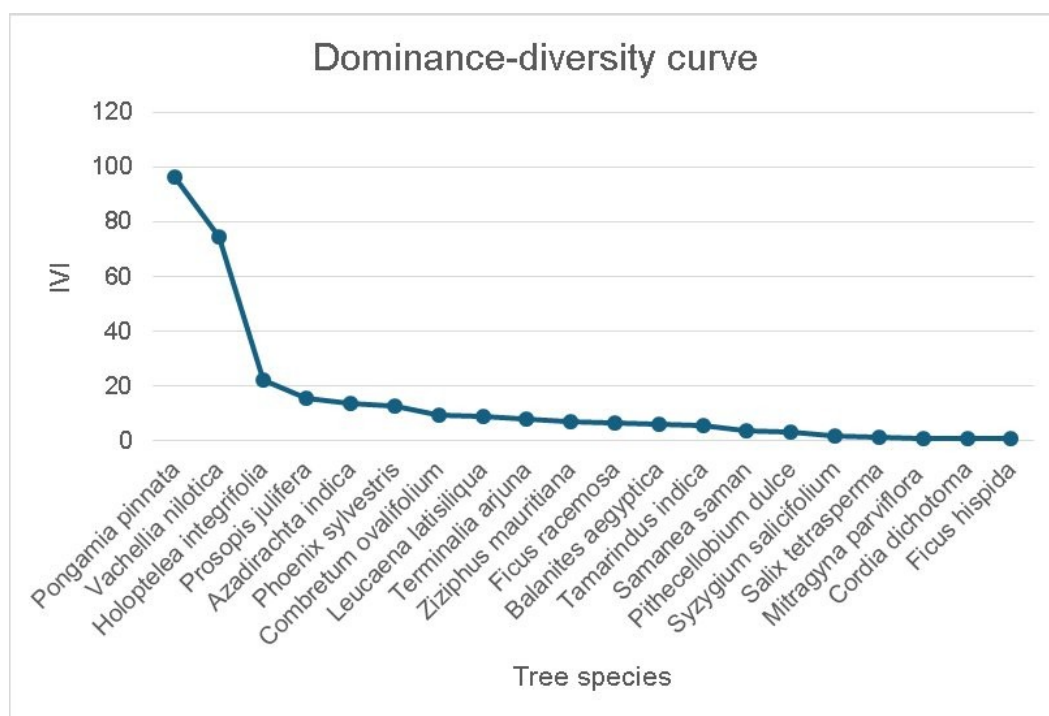


Figure 6.2: Dominance–diversity curve for tree species

Diversity indices (Table 6.3.2 b) indicate good species richness, moderate diversity, high dominance and lower evenness among tree species reflecting their uneven distribution. A few specialized species, particularly *Pongamia pinnata* and *Vachellia nilotica* are well adapted to riparian conditions, including periodic flooding, waterlogging,

sediment deposition, and other disturbances along the riverbank, which contributes to their dominance in the tree layer.

Shrub and climber layer: A total of 1,321 individuals were sampled in the shrub and climber layer. *Plumbago zeylanica* was the most abundant species with 298 individuals followed by *Sida acuta* (132), *Cyathocline purpurea* (110), *Dicliptera paniculata* (101) and *Colocasia esculenta* (98).

Diversity indices (Table 6.3.2 b) indicate high species richness, high diversity, low dominance, and high evenness within this layer, indicating a structurally stable and well-balanced riparian community.

Herb and grass layer: The ground cover was dominated by invasive species particularly *Alternanthera ficoidea* and *Synedrella nodiflora*. Out of 1,134 individuals sampled, 575 were *Alternanthera ficoidea* and 261 were *Synedrella nodiflora*. Both these species are non-native and invasive, significantly influencing the composition of the herbaceous layer.

Diversity indices for this layer (Table 6.3.2 b: $H' = 1.49$, $D = 0.32$, $J = 0.58$) are close to those of the tree layer ($H' = 1.68$, $D = 0.29$, $J = 0.57$). Both layers are dominated by a few species. The difference is in which species dominate: native riparian trees in the tree layer, and two invasive herbs in the ground layer.

Table 6.3.2 b: Vegetation diversity indices

Vegetation layer	Species richness (S)	Shannon's index (H')	Simpson's dominance (D)	Simpson's diversity index (1-D)	Pielou's evenness (J)
Trees	19	1.68	0.29	0.71	0.57
Shrub & climber	38	2.77	0.09	0.91	0.76
Herbs & grass	13	1.49	0.32	0.68	0.58
Regeneration	18	1.83	0.20	0.80	0.63

Box 6.1: Understanding the diversity indices

Shannon diversity and evenness: The Shannon Index is a measure of the diversity and evenness of species in a community. Evenness means that the abundances of all the species are similar, that is that the species are evenly distributed. A Shannon Index value of 0 means the community has just one species. Highly diverse and healthy communities usually have a Shannon Index value between 3.5 to 4.5. Pielou's Evenness measures how equally individuals are distributed across species. The value ranges from 0 to 1 where 1 means individuals are perfectly evenly distributed across species.

Simpson diversity and dominance: The Simpson Diversity Index also is a measure of diversity and evenness; it calculates the probability that two individuals randomly selected from a community will belong to different species. The Simpson Index is weighted more towards dominant species and its value ranges from 0 to 1, with higher values indicating higher diversity. Simpson Dominance measures how strongly a few species dominate a community. The higher the diversity, the lower the value of Simpson's Dominance Index.

Importance Value Index (IVI): IVI combines how common a tree species is (relative density), how widely it occurs (relative frequency) and how much space its trunks occupy (relative dominance, from basal area). The three relative values are added, so IVI for all species together totals 300. The higher a species' IVI, the more it dominates the stand.

The quadrat data also reveal that the combined presence of trees, shrubs, climbers, herbs, and grasses across transects reflects a substantial vertical and horizontal structural diversity within riparian zones. However, the dominance of disturbance-tolerant and invasive herbs in the ground layer suggests that the riparian zone is under anthropogenic and environmental pressure.

Regeneration: We documented regeneration of tree species across all quadrats (Annexure 3). Regeneration of 17 tree species (718 saplings) and one liana, *Combretum ovalifolium* (76 saplings), was recorded. *Pongamia pinnata*

exhibited a very good regeneration rate with 235 individuals (30%) occurring in 56% of quadrats, while *Phoenix sylvestris* had 237 individuals (30%) occurring in 36% of quadrats. Together, these species accounted for 60% of the total regeneration. Both species are riparian, indicating hydrological and soil conditions that currently support natural regeneration. Whether the community is moving toward a more stable, native-dominated state cannot be judged from a single survey; repeat surveys of the same quadrats would be needed. Non-native species contributing to regeneration included *Pithecellobium dulce* (9.5%), *Leucaena leucocephala* (7.3%) and *Prosopis juliflora* (1.25%). Non-native saplings should be monitored over time to see whether these species are spreading. At present they form a small share (about 18%) of regeneration, so native species make up most of the regenerating layer.

Although *Vachellia nilotica* was one of the dominant adult tree species in the study area, no regeneration of this species was observed among the saplings. The absence of its saplings in this survey may indicate a future shift in community composition; this should be checked in repeat surveys.

Tree density and canopy cover: The tree density of the 10 stretches sampled in the detailed assessment was estimated at 1,367 individuals per hectare, while canopy cover was visually estimated at 60–70%, indicating moderately dense vegetation. Extrapolating this density across the combined area of the 67 stretches initially selected for the rapid assessment gives an estimated total of approximately 1.2 lakh (about 119,700) trees in these stretches.

Key finding – flora: Overall, the floral diversity assessment shows that the Indrayani riparian zone supports a predominantly native riparian flora (83% of species native) with a limited presence of non-native trees and shrubs. The herb layer, however, is dominated by invasive species, which needs management.

6.3.3 Old-growth, mature trees

Old, tall and mature trees were recorded at 20 of the 59 stretches surveyed (W6, W15, W18, W22, W23, W24, E1, E5, E6, E11, E14, E18, E19, E20, E21, E27, E28, E30, E40 and E41). They include karanj (*Pongamia pinnata*), neem (*Azadirachta indica*), babhul (*Vachellia nilotica*), shindi (*Phoenix sylvestris*), umbar (*Ficus racemosa*), arjun (*Terminalia arjuna*), vaval (*Holoptelea integrifolia*), chinch (*Tamarindus indica*), bhokar (*Cordia dichotoma*) and rain tree (*Samanea saman*). Arjun was found only at W6.

Of the 644 trees measured in the detailed survey of 10 stretches, 89 had a girth at breast height (GBH) of more than 100 cm. Ten trees measured during the surveys had a GBH of 200 cm or more (Table 6.3.3). The largest is a banyan (*Ficus benghalensis*) at the Indrayani–Bhima confluence at Tulapur (E1), estimated to be more than 200 years old.

Table 6.3.3: Trees with a girth at breast height of 200 cm or more

Scientific name	Common name	GBH (cm)	Stretch
<i>Ficus benghalensis</i>	Wad (banyan)	more than 400	E1
<i>Tamarindus indica</i>	Chinch	400	W18
<i>Ficus racemosa</i>	Umbar	335	W6
<i>Samanea saman</i>	Rain tree	325	W23
<i>Holoptelea integrifolia</i>	Vaval	305	W23
<i>Vachellia nilotica</i>	Babhul	301	W18
<i>Terminalia arjuna</i> (3 trees)	Arjun	240, 225, 213	W6
<i>Phoenix sylvestris</i>	Shindi	200	E18

Old trees like these are of high ecological value. Their hollows, loose bark and broad crowns shelter birds, bats, reptiles and insects; they produce large quantities of flowers, fruit and seed; and their roots anchor the bank. They

cannot be replaced by planting within a human lifetime, so they should be mapped and protected individually (Section 14).



Old banyan (wad)



Mature riverbank tree



Measuring girth at breast height



Large old tree in riverine woodland



Mature riverbank tree with peeling bark



Old multi-stemmed tree

Figure 6.3: Old, mature trees along the Indrayani

7. Bird Diversity Assessment

7.1 Methodology - Bird Diversity Assessment

Eleven of the 30 shortlisted locations were selected for bird diversity assessment, based on the diversity of habitat and of birds assessed during the rapid survey. Thirty-one point counts of 15 minutes each were taken across these 11 stretches of the river (Ralph et al. 1995; Bibby et al. 2000), a design also used in recent riverine bird surveys in the Western Ghats (Raj et al. 2023).

Eighteen point counts covered aquatic habitats, that is open water, islands and aquatic vegetation on the edges. An area of 50 m by 50 m was considered for the count.

Thirteen counts were taken in terrestrial riparian habitats on the river banks consisting of scrub, grassy patches, riverine forest, plantations as well as small streams and seasonal wetlands. For the terrestrial counts a circular area of 25 m in diameter was considered. Sampling spanned a total of 7 hours and 45 minutes.

In addition to the point counts, all birds encountered during the field visits in between the point counts were also documented. Birds were identified using Grimmett et al. (2011) and the Merlin Bird ID app (Cornell Lab of Ornithology 2025), and observations were recorded on eBird (Sullivan et al. 2009). Names follow the eBird/Clements checklist (Clements et al. 2024).

7.2 Data Analysis - Bird Diversity Assessment

Ecological indicators evaluated are species diversity, including species richness, frequency, density and relative abundance (Bibby et al. 2000; Magurran 2004). Dominant species were identified as those with the highest frequency or relative abundance. Bird species were also classified as being primarily terrestrial or primarily associated with aquatic or riparian habitats, similar to the grouping of water-dependent and water-associated birds used by Raj et al. (2024). Conservation status follows the IUCN Red List and State of India's Birds 2023 (SoIB 2023). The Shannon-Wiener Index (H') and Simpson's Diversity Index (1-D) were also calculated as measures of diversity and evenness (Shannon 1948; Simpson 1949; Magurran 2004; Box 6.1). All these values were calculated separately for terrestrial and aquatic counts so as to understand the bird community specific to the aquatic habitat and the bird community associated with the terrestrial habitats on the river banks.

7.3 Results & Discussion - Bird Diversity Assessment

7.3.1 Species Richness

In all, 107 species of birds were documented during the survey (full list in Annexure 4), of which 66 were terrestrial species associated primarily with terrestrial habitats on the river banks, and 41 species associated primarily with aquatic habitats. However, the boundary between these groups is not rigid, as some species such as the White-breasted Waterhen, which are primarily aquatic, also make use of terrestrial habitats. Also, some species that belong to terrestrial bird orders were considered aquatic if they are mainly seen in association with riverine or other wetland habitats (e.g. wagtails).

7.3.2 Community Composition

Terrestrial birds

The Ashy Prinia was the most common terrestrial bird with a 100% frequency, which means it was recorded in all the samples. It was followed by other common birds like Asian Green Bee-eater, Asian Tit, Barn Swallow, Baya Weaver and Black Drongo. The Barn Swallow is a migratory species that arrives in large numbers and is often seen in habitats that are close to water. These were also the most dominant species seen in the terrestrial habitats as evident from their relative abundances. The Red-whiskered Bulbul was an exception and was encountered in only one sample but in high numbers. Migratory warblers like the Greenish Warbler and Sykes's and Blyth's Reed Warblers were also quite common and were seen in more than 30% of the samples.

Aquatic birds

The most common aquatic bird was the Indian Pond Heron, followed by the Red-wattled Lapwing, Little Cormorant, the migratory Wood Sandpiper, and Black-winged Stilt. These are all generalist aquatic birds seen at a variety of wetland habitats. The Black-winged Stilt is an indicator of higher organic pollution and was seen at half the locations sampled.

Box 7.1: Black-winged Stilt as an indicator of organic pollution

Black-winged Stilts feed on blood-worms, also called chironomid (*Chironomus*) larvae, which are the larvae of non-biting midges. They also feed on Tubifex worms. Shorebirds in salt pans concentrate where chironomid larvae are most abundant (Sánchez et al. 2006), and on an urban stretch of the Ganga at Patna, Black-winged Stilts foraged mainly at eutrophic sites with high densities of *Chironomus* larvae and *Tubifex* (Shahbaz et al. 2026). Both of these are found in water that has high levels of organic nutrients, indicating pollution from domestic sewage and agricultural runoff. Black-winged Stilts were found to be one of the common species in this study, indicating organic pollution of the Indrayani River. The study of macroinvertebrates (Chapter 10) also shows presence of chironomid larvae at all 11 locations that were sampled, providing more biological evidence of organic pollution.

The River Tern was seen across 40% of sites, which is a good sign since, while once common, it is now considered Vulnerable by the IUCN (International Union for Conservation of Nature) (BirdLife International 2020a). Its numbers have declined due to widespread habitat destruction caused by erosion and sand mining. The study area features many locations with sandbars and river islands which River Terns prefer for nesting.

Seven of the recorded species are in Schedule I of the Wild Life (Protection) Act, 1972 (as amended in 2022), the highest level of legal protection: River Tern, Eurasian Spoonbill, Greater Spotted Eagle, Western Marsh Harrier, Shikra, Small Minivet and Indian Peafowl. Almost all the other species are in Schedule II; only the House Crow and Rock Pigeon are not scheduled (Annexure 4).

Flocks of the migratory Ruddy Shelduck were observed at a third of the locations. These large ducks winter in wetlands across India. They prefer shallow, slow-moving rivers and pools with good aquatic vegetation. These ducks were seen mostly in locations where the river is wide and shallow and has shallow pools and flat banks with vegetation.

A large flock of Asian Woolly-necked Storks was seen at one location where there were many islands and sand bars in the river. These storks prefer quiet locations away from disturbance to rest and feed, and these river islands provide them with suitable habitat. The Asian Woolly-necked Stork is listed as Near Threatened by the IUCN (BirdLife International 2020b), and the Greater Spotted Eagle, also recorded during the survey, as Vulnerable (BirdLife International 2021).

A large heronry was found on an island in the middle of the river at stretch W23. The ground was plastered with bird droppings and scattered with white feathers, probably of egrets, showing that the island is used as a nesting or roosting colony. Such colonies are easily abandoned when disturbed, and construction was recorded at this stretch (Table 11.3), so the island needs specific protection.

Overall, aquatic bird species richness was good (41 species); however, there was a lack of diversity of ducks. Only one resident species, the Indian Spot-billed Duck, and one migratory species, the Ruddy Shelduck, were seen. The reason could be pollution and invasion by water hyacinth, which reduces aquatic invertebrate and vegetation diversity and makes it difficult for ducks to navigate the water.

7.3.3 Diversity Indices

The Shannon Diversity Index for terrestrial birds is 3.28 and Simpson's Diversity Index is 0.95. For aquatic birds the Shannon Diversity Index is 2.97 and Simpson's Index is 0.93 (see Box 6.1 for what these indices mean).

The values indicate good diversity of terrestrial birds and moderate diversity of aquatic species. There is a very good diversity of terrestrial habitats along the river which are relatively undisturbed. This is a likely reason for the high terrestrial bird diversity. Although there is also a wide variety of aquatic habitats, water pollution, invasive aquatic plants and solid waste are major and widespread factors affecting aquatic birds and probably explain the lower aquatic bird diversity.

Key finding – birds: Overall the Indrayani shows good bird diversity; however, aquatic bird diversity is lower than terrestrial bird diversity. Likely reasons are heavy water pollution in the urban stretch of the river and large areas covered with water hyacinth and *Pistia*. Many of the shallow wetlands on the banks are also choked with plastic waste, affecting habitat health. All these factors can affect the diversity of aquatic macroinvertebrates and vegetation available for birds to feed on. Choking of the waterways with invasives and solid waste also makes it difficult for birds to navigate the river and find food. This is concerning and can have long-term effects on aquatic bird diversity. Further studies are necessary to establish the effect of these disturbances on bird diversity.

7.4 Photographs



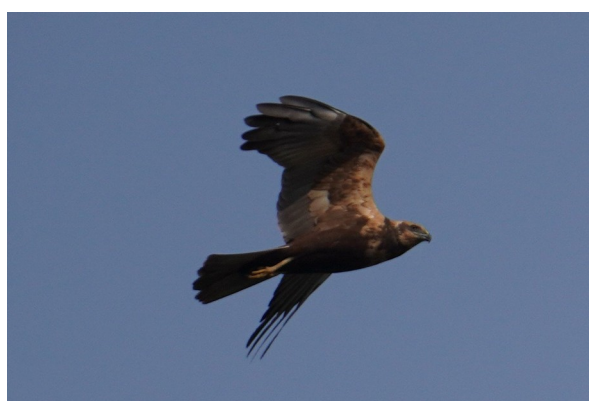
River Tern (Schedule I)



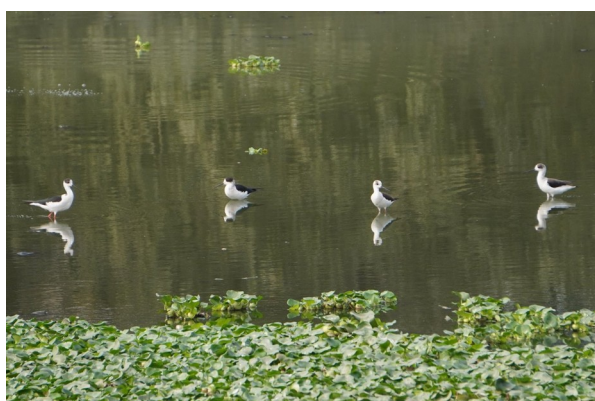
Ruddy Shelduck



Asian Woolly-necked Stork



Western Marsh Harrier (Schedule I)



Black-winged Stilt



Indian Pond Heron



Painted Stork



Glossy Ibis



Black-headed Ibis



Grey Heron



Great Cormorant



Little Cormorant



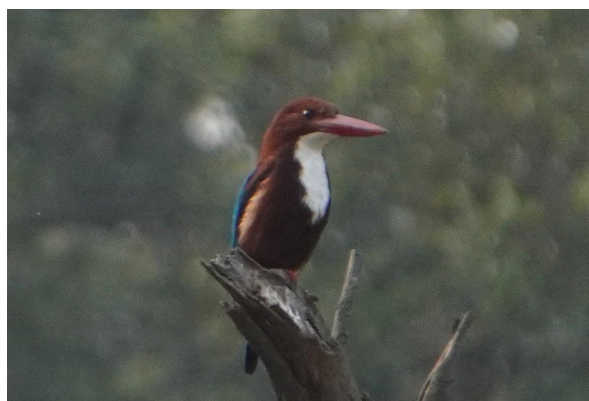
Indian Spot-billed Duck



Wood Sandpiper (with Black-winged Stilt)



Red-wattled Lapwing



White-throated Kingfisher



Pied Kingfisher



White-browed Wagtail

Figure 7.1: Some of the bird species recorded along the Indrayani River during the survey (photographs: Kedar Champhekar)

8. Butterflies and Odonates

8.1 Methodology

We conducted field surveys over six days between 8:00 and 14:00 hours for approximately 36 hours, sampling twelve quadrats positioned at various locations along and adjacent to the Indrayani River in Pune district. All observations were made in the field using cameras for photographic documentation. Specimens were identified to the finest taxonomic level possible using standard field guides and online resources, particularly iNaturalist. This non-invasive approach allowed us to assess insect diversity without collecting specimens. Because many locations

had to be covered in a short time, survey times ranged from 8:00 to 14:00 and were not standardised across sites; time of day may have influenced the counts.

8.2 Results

8.2.1 Butterfly Diversity and Composition



Figure 8.1: Butterfly species recorded in each survey (A1–A6), grouped by family; large dots = recorded

Our surveys produced 49 records (a species recorded in a survey) of 22 species across four families: Lycaenidae, Nymphalidae, Pieridae, and Hesperidae. The butterfly community was clearly dominated by Lycaenidae and Nymphalidae, each contributing nine species, while Pieridae added three species and Hesperidae one species.

One of the recorded butterflies, the Tailless Lineblue (*Prosotas dubiosa*), is listed in Schedule II of the Wild Life (Protection) Act, 1972 (as amended in 2022). None of the other species recorded is scheduled. The full checklist is in Annexure 6.

Species richness per survey ranged from 5 species (first survey) to 10 species (third and fourth surveys) (Figure 8.2). Given the small sample, no conclusion about changes in riparian conditions over the study period can be drawn from this.

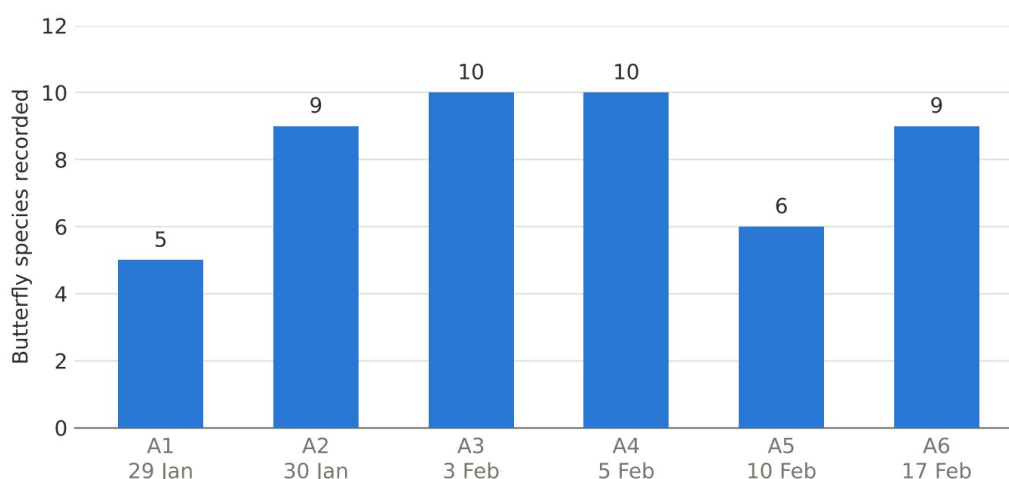


Figure 8.2: Number of butterfly species recorded in each survey

8.2.2 Odonata Diversity and Composition

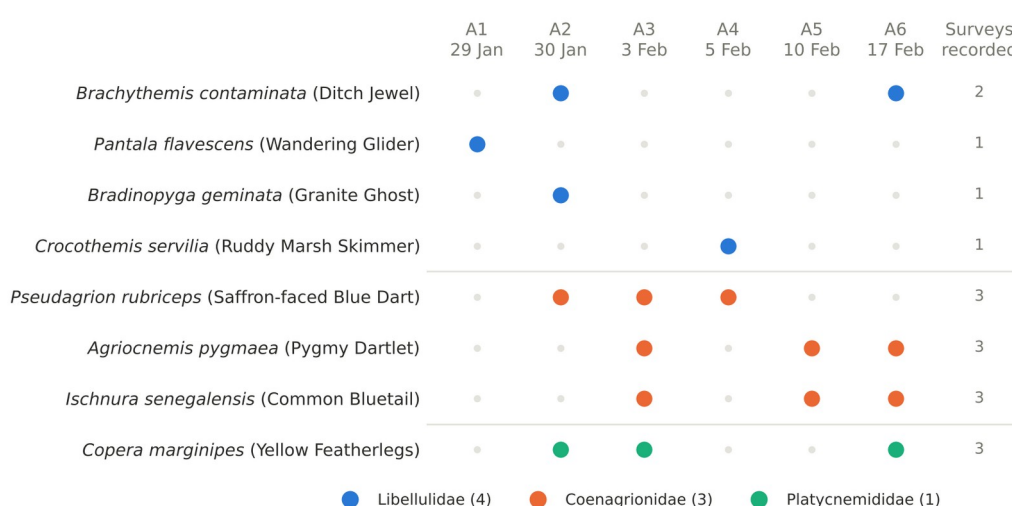


Figure 8.3: Odonate species recorded at each survey site (A1–A6), grouped by family; large dots = recorded

In contrast to butterflies, the Odonata community showed more pronounced spatial heterogeneity. Our survey documented 4 dragonfly and 4 damselfly species from three families — Libellulidae (4 species), Coenagrionidae (3 species), and Platycnemididae (1 species) — with a total of 17 records across six sampling sites. *Copera marginipes* and *Ischnura senegalensis* were each recorded from three different locations, while species such as *Pantala flavescens*, *Bradinopyga geminata* and *Crocothemis servilia* appeared at only one or two sites.

None of the odonates recorded is listed in any schedule of the Wild Life (Protection) Act, 1972 (as amended in 2022). The full checklist is in Annexure 6.

Species richness at individual sites varied substantially, with sites A2, A3, and A6 supporting four species each, whereas site A1 yielded only a single species. Because sampling time and area were not standardised across sites, these differences cannot be attributed to specific environmental factors; the survey is best read as a checklist. Differences in water velocity, substrate, riparian cover and water quality may play a role and merit a standardised study.

Overall the odonate diversity was low. One reason is that the survey was done in the winter season; in the neighbouring Mula and Mutha river basins, odonate diversity and abundance peak in the post-monsoon period (Kulkarni & Subramanian 2013). Another reason could be water quality. The water is highly polluted in many locations and is also covered with water hyacinth and *Pistia*. This lowers the oxygen levels in the water and makes

it difficult for odonate larvae to survive. A more comprehensive survey is required to explore odonate diversity and its relation to ecological health on the Indrayani River.

9. Fish

A rapid survey was undertaken along the banks of the Indrayani River from 24 February 2026 to 16 March 2026 to document the fish (ichthyofaunal) diversity of the study stretch in Pune district, Maharashtra.



Figure 9: One of the river stretches where surveys were done

9.1 Methodology

A total of 7 river stretches from near Nighoje village ($18^{\circ}42'16.36''\text{N}$ $73^{\circ}48'23.76''\text{E}$) to near Moi village ($18^{\circ}41'21.92''\text{N}$ $73^{\circ}49'36.43''\text{E}$), and from Bhavadi village ($18^{\circ}37'24.06''\text{N}$ $73^{\circ}58'38.02''\text{E}$) to Tulapur village ($18^{\circ}38'45.43''\text{N}$ $73^{\circ}59'02.68''\text{E}$) were covered in the survey. Four local fish markets as well as weekly markets were surveyed on the basis of references from community members citing the sale of fishes caught from the surveyed river stretches in these markets. Of these, only one market, in Bagwan Vasti in Markal village, had catches available from the Indrayani River. A general questionnaire was filled out while interacting with local fishermen and people selling fishes in the market. Part of the checklist data came from this questionnaire survey, since direct field sampling was not possible. The questionnaire included general questions on the amount of catch per season and changes in catches over the years, the number of years respondents had been in the business, which species were seen or caught and which were the most abundant.

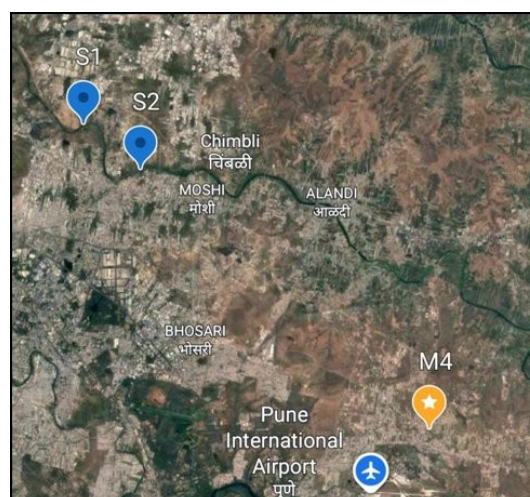
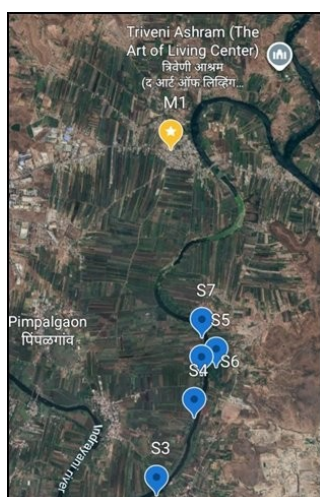


Figure 9.1 a (left) and Figure 9.1 b (right): Survey locations in Google Earth

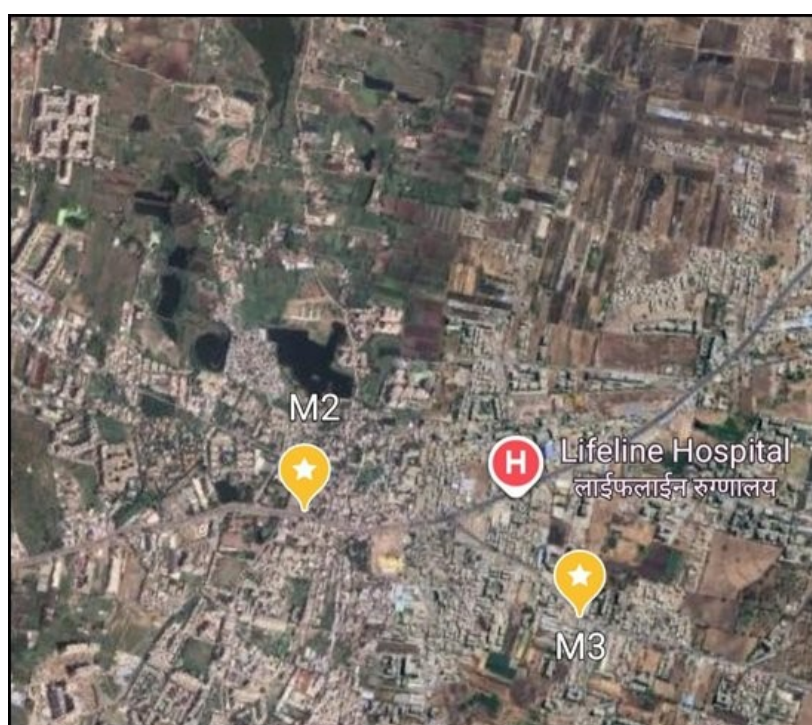


Figure 9.1 c: Survey locations in Google Earth

Figures 9.1 a, 9.1 b and 9.1 c show the locations added in the Google Earth file created to document where surveys were carried out. Locations with blue tags labelled 'S1', 'S2', 'S3' etc. are the river stretches where the surveys were conducted (S stands for stretch). Locations with yellow tags labelled 'M1', 'M2', 'M3' etc. are the local markets where the surveys were conducted (M stands for market). The markets were at Markal ($18^{\circ}40'22.16''\text{N}$ $73^{\circ}58'45.72''\text{E}$), Lohagaon ($18^{\circ}36'08.73''\text{N}$ $73^{\circ}55'44.74''\text{E}$) and Wagholi ($18^{\circ}34'51.53''\text{N}$ $73^{\circ}58'50.32''\text{E}$; $18^{\circ}34'42.57''\text{N}$ $73^{\circ}59'33.57''\text{E}$).



Figure 9.1 d: Fisherman at one of the river stretches

9.2 Observations

Table 9.2: Checklist of fish species documented during the rapid survey

Sr. no.	Family	Species	IUCN status	WPA schedule
01	Anguillidae / Mastacembalidae	<i>Anguillidae</i> (Rafinesque, 1810) / <i>Mastacembalidae</i> (Swainson, 1839)		Not scheduled
02	Bagridae	<i>Mystus</i> sp. (Scopoli, 1777)		Not scheduled
03	Channidae	<i>Channa punctata</i> (Bloch, 1793)	LC	Not scheduled
04	Cichlidae	<i>Oreochromis</i> sp. (Günther, 1889)		Not scheduled
05	Cyprinidae	<i>Garra mulya</i> (Sykes, 1839)	LC	Not scheduled
06		<i>Systomus sarana</i> (F. Hamilton, 1822)	LC	Not scheduled
07	Heteropneustidae	<i>Heteropneustes fossilis</i> (Bloch, 1794)	LC	Not scheduled
08	Labeoninae	<i>Labeo calbasu</i> (F. Hamilton, 1822)	LC	Not scheduled
09		<i>Labeo catla</i> (F. Hamilton, 1822)	LC	Not scheduled
10		<i>Labeo rohita</i> (F. Hamilton, 1822)	LC	Not scheduled
11	Notopteridae	<i>Notopterus notopterus</i> (Pallas, 1769)	LC	Not scheduled
12	Poeciliidae	<i>Poecilia reticulata</i> (W. Peters, 1859)	LC	Not scheduled



Figure 9.2 a: Aerial view of one of the river stretches

Twelve species from 9 families and 8 genera were documented, of which 9 species are listed as Least Concern on the IUCN Red List of Threatened Species. *Oreochromis* sp. and *P. reticulata* are introduced as well as invasive. *Oreochromis* sp. was the most abundant species in this survey. Full species identification of *Oreochromis* was not possible due to the existence of possible hybrid individuals.



Figure 9.2 b: *Oreochromis* sp. freshly caught by fishermen

Previously published data report several other species of the genus *Labeo* in the Indrayani River, such as *Gymnostomus ariza* (F. Hamilton, 1807) (formerly *Labeo ariza*), *L. boggut* (Sykes, 1839), and *L. porcellus* (Heckel, 1844). Species of the genus *Mystus* (Bagridae) reported are *M. bleekeri* (Day, 1877), *M. seengtee* (Sykes, 1839), *M. malabaricus* (Jerdon, 1849), and *M. cavasius* (Hamilton, 1822). *Oreochromis mossambicus* (Peters, 1852) has been recorded previously. *Channa marulius* (Hamilton, 1822) and *C. gachua* (F. Hamilton, 1822) are reported along with *C. punctata* (Dahanukar et al., 2012).



Figure 9.2 c: *Channa punctata* from a local fish market

Location S1 offers suitable habitat for small fishes such as barbs, minnows, danios and loaches. None were recorded, as this survey relied mainly on market catches, but S1 is flagged as a priority site for direct sampling. Previous publications mention barbs such as *Puntius amphibius* (Valenciennes, 1842), *Pethia conchonius* (F. Hamilton, 1822), *Puntius sophore* (F. Hamilton, 1822) and *Pethia ticto* (F. Hamilton, 1822); danios such as *Devario aequipinnatus* (McClelland, 1839) and *D. malabaricus* (Jerdon, 1849); minnows such as *Parapsilorhynchus tentaculatus* (Annandale, 1919); and loaches such as *Paracanthocobitis mooreh* (Sykes, 1839), *Nemacheilus rueppellii* (Sykes, 1839), *N. anguilla* (Annandale, 1919), *Schistura denisonii* (Day, 1867) and *Lepidocephalichthys thermalis* (Valenciennes, 1846) (Dahanukar et al., 2012).



Figure 9.2 d: *Labeo* sp. from a local fish market

All of the river stretches are adjacent to agricultural fields. All of them have polluted water, including sewage and garbage. Basalt gravel was visible in a few stretches. All of the stretches have dominant growth of the invasive Water Hyacinth (*Pontederia crassipes*) and Water Lettuce (*Pistia* sp.) on the surface of the water. Some stretches had stunted flow due to the overgrowth of Water Hyacinth. One stretch had bridge construction work going on during the survey. Other stretches had slow-flowing water.



Figure 9.2 e: Water hyacinth and sewage at one of the stretches

9.3 Mahseer Conservation in the Indrayani River

The Deccan Mahseer (*Tor khudree*) is a flagship fish of Western Ghats rivers. It was once assessed as Endangered on the IUCN Red List and is now listed as Least Concern following conservation efforts (de Alwis Goonatilake et al. 2020). If the condition of rivers such as the Indrayani continues to decline, it is at risk of becoming threatened again. Local accounts indicate that its numbers in the Indrayani were already falling by the 1970s (Deccan Herald, n.d.). Conservation efforts in the catchment include Tata Power's long-running Mahseer breeding programme at Walwan near Lonavala (Deccan Herald, n.d.) and the release of hatchery-reared fingerlings into the Indrayani at Dehu by the Friends of Nature Association (India's Endangered 2012). No Mahseer were recorded in the present survey, although Mahseer were among the fish killed at Dehu in 2019 (Section 9.4).

Conservation of the Deccan Mahseer in this region has a long history. In the early 1970s the Maharashtra State Fisheries Department, under its then Director C.V. Kulkarni, worked with Tata Power to develop artificial breeding of the species at Lonavala. The Tata Power hatchery at Walwan has since released about seven million Mahseer fingerlings into rivers and reservoirs over more than four decades, and Mahseer were again reported in the Indrayani in 2019 (Ogale 2002; The Bridge Chronicle 2019a). Anand Doh on the Indrayani is also recognised as a site of in-situ Mahseer conservation (Jeevitnadi, pers. comm.). These government and institutional efforts deserve recognition and support: hatchery-raised fish can establish in the river only if the water-quality problems documented in Chapter 10 are solved and deep pools such as Anand Doh are protected as refuges.

Stocking alone cannot sustain the species. Mahseer need clean, well-oxygenated flowing water, rocky substrates for spawning and unobstructed passage along the river. Pollution, invasive aquatic vegetation, bunds and loss of natural channel form all reduce the survival of released fish. Long-term conservation therefore needs habitat restoration, pollution control and adequate environmental flows alongside scientifically monitored restocking.

9.4 Recurring Fish Kill Incidents in the Indrayani River

Fish kills have been reported on the Indrayani. In June 2019, several thousand dead fish were found near Dehu: reports put the number at about 4,000, mostly Mahseer (The Hindu 2019), or about 7,000, mostly mrigal carp with some rohu, catla, tilapia and Mahseer (The Bridge Chronicle 2019b). The Maharashtra Pollution Control Board attributed the deaths to untreated sewage lowering dissolved oxygen during low summer flows.

Repeated kills reduce breeding populations and favour pollution-tolerant and invasive species over sensitive native fish. The conditions recorded in this study (untreated sewage, high BOD and COD, eutrophication and dense

floating vegetation) are the conditions that trigger such events. Preventing them will require sewage treatment, control of industrial discharge, continuous water-quality monitoring and adequate environmental flows.



Figure 9.4: News reports of a mass fish death in the Indrayani River at Dehu ahead of Ashadhi Wari (left: Pune Times Mirror; right: The Pune News)

10. Macroinvertebrate Diversity & Water Chemistry

10.1 Introduction

The consequences of organic pollution in river systems are significant. High levels of organic contaminants deplete dissolved oxygen, disrupt the chemical balance of the water, and create conditions that are harmful to aquatic organisms. This process leads to nutrient imbalances and eutrophication, which in turn result in a loss of biodiversity. The cumulative effects of these pressures cause a decline in ecosystem functionality, disrupting food webs, reducing species diversity, and destabilising the ecosystem as a whole.

Traditionally, the quality of aquatic habitats is assessed by measuring physical and chemical parameters of water, including temperature, pH, dissolved oxygen, and pollutant levels. However, these tests alone do not provide a complete picture of ecosystem health. The diversity of aquatic invertebrates, along with the data on the presence and abundance of key ecological indicator species, provides a valuable and often more sensitive measure of water quality. Aquatic invertebrates serve as reliable indicators of ecological stress due to their close relationship with environmental conditions. Their presence, abundance, and community composition can reveal changes in water quality long before chemical imbalances become apparent.

10.2 Methodology

10.2.1 Study Sites

Eleven sampling sites along the 41 km study stretch of the Indrayani River (from Talawade, near Dehu, to Tulapur) were selected based on the degree of urbanisation, activities on the banks (such as agriculture and industry), and accessibility. The average distance between adjacent sampling sites was maintained at 3–4 km. The sampling sites are shown in Figure 10.2.1.

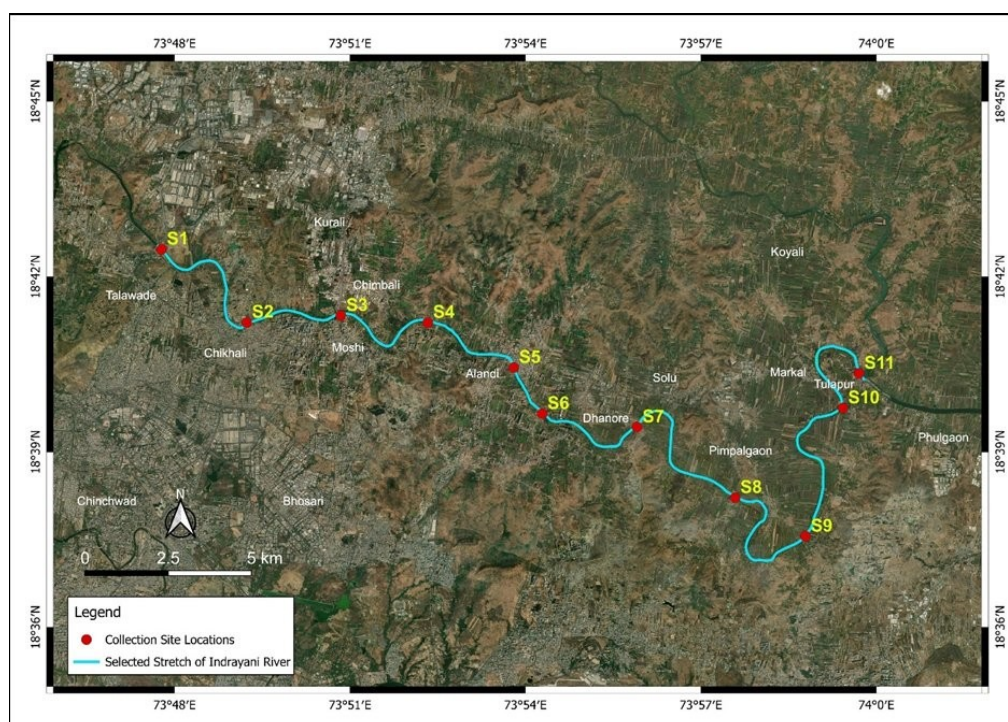


Figure 10.2.1: Map of sampling sites along the selected stretch of Indrayani River

10.2.2 Sampling and Identification Methods

Water samples were collected for chemical and microbiological testing from all eleven sites. For microbiological analysis, samples were collected in sterile containers. All the water samples were transported in an insulated box with chilled ice packs and were handed to the laboratory on the same day for further testing. The qualitative parameters of the waterbody (such as odour and colour of water, depth, flow, type of substratum, eutrophication conditions, apparent sources of pollution, etc.) were also noted and documented on-site, to assess the state of the waterbody.

Aquatic macroinvertebrates were sampled from all eleven sites using an extendable hand net (mesh size = 1 mm). An area of about 5 sq m was sampled at each site. The macroinvertebrates were collected by disturbing the sediment, by scraping the rock surfaces, from submerged or floating plants, from the water column and also from the water surface (Figure 10.2.2).

Macroinvertebrate samples were examined in the laboratory under a stereomicroscope and were photographed with a camera attachment. Macroinvertebrates were identified to the genus/family level using standard literature and online resources, and their occurrence, relative abundance in the sample, and ecological roles were noted.



Figure 10.2.2: Sampling methods

10.3 Results

10.3.1 Water Chemistry Analysis

Water samples from different sites showed variable readings.

1. The pH remains in the acceptable range of 6.5–8.5.
2. All samples showed the presence of faecal coliforms. Samples S2 to S8, which were collected from an urbanised stretch of the river, showed extreme contamination with faecal coliforms (>1600 MPN/100ml, with 1600 being the upper limit of testing). This highlights the discharge of an enormous volume of untreated sewage into the river in this urbanised stretch. Faecal coliforms should remain under 500 MPN/100ml for bathing purposes and should be undetectable in drinking water according to the BIS norms.
3. Elevated values of nitrates and orthophosphates indicate the discharge of untreated domestic waste in the form of black and grey water, decaying organic matter and surface run-offs from urban areas and agricultural fields. Nitrates and orthophosphates serve as macronutrients for plants, and their enrichment leads to eutrophication of the water body, resulting in excessive growth of invasive vegetation such as water hyacinth.
4. The BOD and COD values for all sites exceed the permissible limit of 3 mg/L (bathing water) and 30 mg/L (for wastewater) according to BIS norms. For most sites, the recorded values are 2-3 times higher than the permissible limits. At Site 3, a six-fold spike is seen as compared to the permissible limits. This highlights the extent of organic pollution in the selected stretch of the Indrayani River. According to the CPCB report on polluted river stretches (CPCB 2025), the Moshi to Alandi stretch of the Indrayani has been recognised as Priority Class III for restoration.

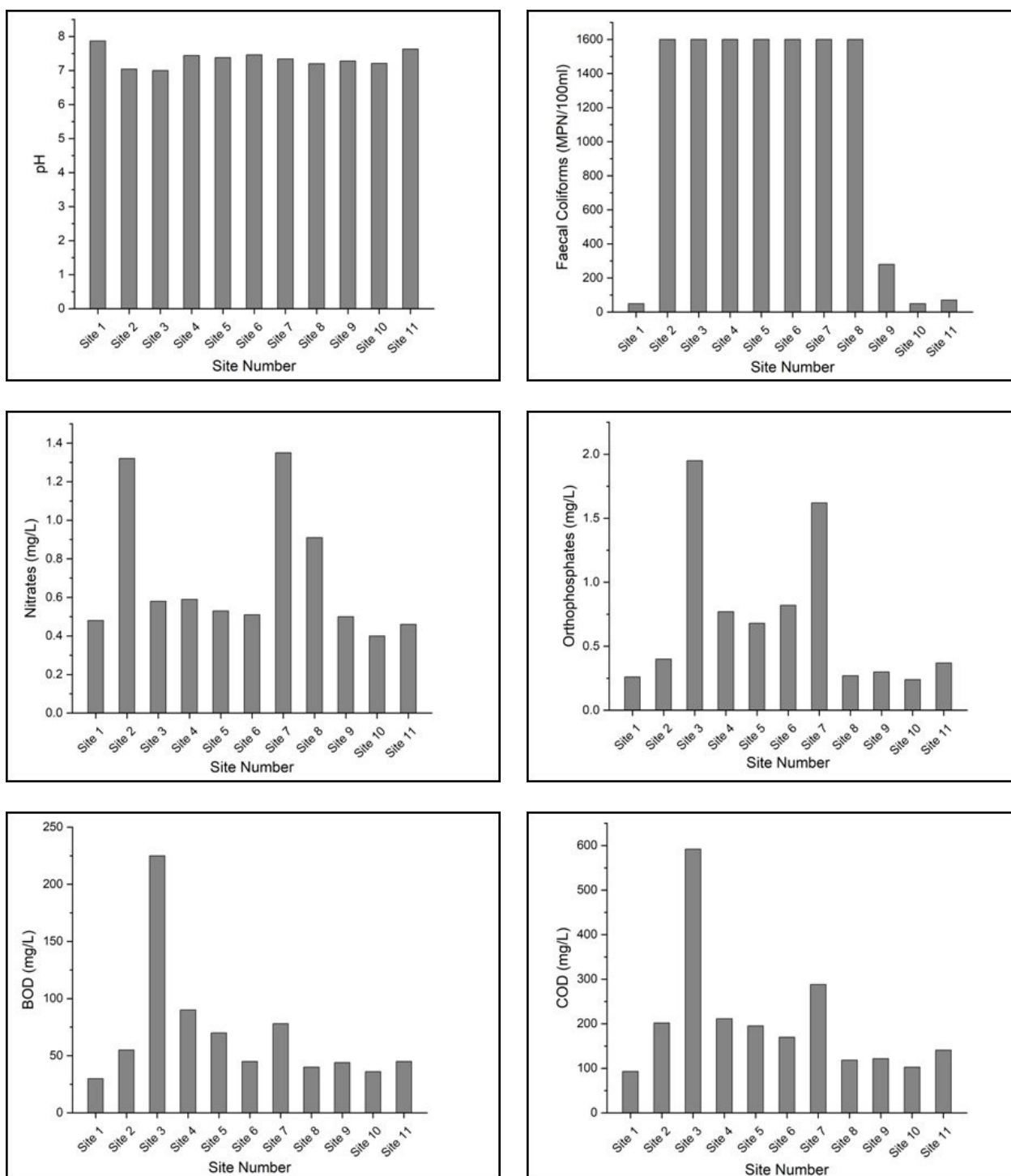


Figure 10.3.1: Graphs showing values of water quality parameters at different sites

10.3.2 Diversity of Macroinvertebrates

Species richness ranged from 3 species at Site 5 (Alandi) to 24 species at Site 11 (Tulapur). Pollution-sensitive indicators (mayfly and caddisfly larvae, freshwater sponge) were found only at Sites 1, 6, 10 and 11. Site-by-site descriptions, photographs and species checklists are given in Annexure 5.

Table 10.3.2: Summary of macroinvertebrate diversity across sites

Site	Location	Species	Taxa (groups)	Sensitive indicators recorded
1	Talawade	12	6	Freshwater sponge, mayfly and caddisfly larvae

Site	Location	Species	Taxa (groups)	Sensitive indicators recorded
2	Chikhali-Moi	5	3	None
3	Moshi	13	7	None
4	Moshi-Dudulgaon	6	4	None
5	Alandi	3	1	None
6	Charholi	8	6	Mayfly larvae (Caenidae)
7	Nirgudi-Dhanore	12	6	None
8	Wadgaon Shinde	7	3	None
9	Bhawadi	10	6	None
10	Markal-Tulapur	20	8	Mayfly larvae (Baetidae)
11	Tulapur (near Bhima confluence)	24	10	Mayfly larvae (Baetidae, Caenidae)

10.4 Discussion

10.4.1 Macroinvertebrate Diversity and Ecology of the Indrayani River



Figure 10.4.1 a: Number of species recorded at each site

Different sites along the 41 km study stretch of the Indrayani River showed variable species diversity. The highest number of species was found at Site 11 near the confluence of the Indrayani and Bhima rivers, where the habitat quality was relatively better. The lowest number of species was recorded at Site 5 in the town of Alandi, where habitat quality was severely degraded. The overall diversity pattern was influenced by the quality of habitats, availability of microhabitats and resources, and pollution levels.

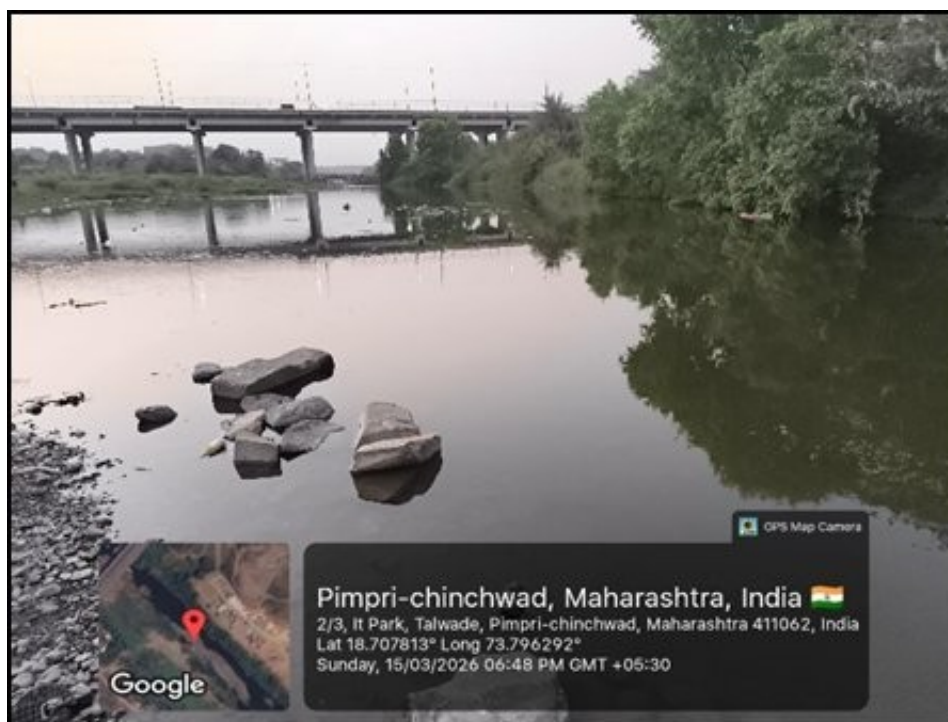


Figure 10.4.1 b: Ecological roles and the number of species occupying them at each site

The changing diversity is also reflected in the ecological roles performed by macroinvertebrate groups. More diverse sites exhibit a greater number of ecological roles and feeding guilds, as well as more species per role. As water and habitat quality degrade, biological diversity and the diversity of ecological roles also decline. This greatly disturbs food webs at multiple trophic levels, impairs energy flow, and disrupts ecosystem functioning. To maintain the balance of the ecosystem, all ecological roles must be occupied by organisms with optimal diversity.

10.4.2 Recommendations for improvement

Based on the assessment of the macroinvertebrates from the Indrayani River, we propose the following recommendations:

1. There is heavy discharge of untreated sewage, especially in the urban stretch of the river, which is increasing faecal coliform levels, nitrate levels, and BOD readings. This is detrimental to the biodiversity and the ecological health of the river. Decentralised sewage/wastewater treatment plants should be installed at multiple places and all the wastewater that enters the river channel should be treated before its discharge. New residential complexes should have functional sewage treatment plants.
2. The industrial waste entering the river should be treated effectively and pollution control regulations should be followed strictly.
3. Solid waste should be periodically collected from the river. Floating barriers to trap the solid waste can be used.

11. Assessment of Ecological Health of Habitats

For qualitative assessment of ecological health of 30 selected river stretches, the following parameters were considered:

1. Habitat diversity: Habitat diversity is very important for the ecological health of a river. The more the types of habitats on a river - riparian forests, mud flats, emergent vegetation, islands etc. - the greater the diversity of flora and fauna it will support. Higher biodiversity generally translates to greater ecological health and resilience.

2. **Floral diversity:** The diversity and types of flora in a river reflect the habitat diversity and health of the ecosystem. Diverse vegetation like riparian trees, submerged vegetation, rooted and emergent vegetation, floating vegetation, seasonal vegetation on river banks etc. supports an equally diverse fauna. Aquatic vegetation also carries out important ecological functions like erosion control, water quality regulation, providing habitats to fauna etc.
3. **Bird diversity:** Bird diversity directly reflects the health and diversity of habitats on a river. A wide variety of habitats support different kinds of aquatic birds like waders, swimmers, divers, dabblers etc. and also a wide diversity of terrestrial birds that prefer habitats on the banks of the rivers. This diversity is a direct indication of the health of the river.

The three parameters were scored using a rating scale of 0 to 5, where higher values indicate better ecological conditions. The maximum possible score for each stretch was 15. Based on percentage score each stretch was assigned to one of three ecological grades. This is a rapid, qualitative scoring method developed by the study team to compare stretches within this assessment, similar in approach to visual habitat scoring in rapid bioassessment protocols (Barbour et al. 1999). It is not a standardised index, and scores are relative rather than absolute. Special features (streams, springs, rocky outcrops, sandbars and mudflats) were recorded separately (Table 11.2) rather than added to the score, so that the grades reflect diversity alone.

Grade 1 (High ecological value, score > 70%): high habitat diversity, greater diversity of flora and fauna, and more physical river features. Stretches: W22, E18, W6, E21, E40, W24, E30, W23. E30 includes a 10-acre (about 4 ha) riparian forest that is a notified Reserve Forest.

Grade 2 (Medium ecological value, score 50–70%): moderate ecological value and a good number of physical river features. Stretches: E32, E28, E6, E41, E5, W9, W8, W4, E27, E26, W10, E34, W1, E20, W3.

Grade 3 (Low ecological value, score < 50%): lower ecological value and fewer physical features. Stretches: W13, W25, E4, E1, E2, W15, E14.

Table 11.1: Qualitative assessment of stretches

S.No	Stretch number	Habitat diversity	Flora diversity	Bird diversity	Score	Percent Score
1	W22	4	5	5	14	93.33
2	E18	5	5	3	13	86.67
3	W6	4	5	4	13	86.67
4	E21	5	5	3	13	86.67
5	E40	4	5	3	12	80.00
6	W24	4	4	4	12	80.00
7	E30	4	5	3	12	80.00
8	W23	3	4	4	11	73.33
9	E32	3	3	4	10	66.67
10	E28	3	4	3	10	66.67
11	E6	3	5	2	10	66.67
12	E41	3	5	2	10	66.67
13	E5	4	4	2	10	66.67
14	W9	3	2	4	9	60.00
15	W8	3	1	5	9	60.00
16	W4	4	4	1	9	60.00
17	E27	2	4	3	9	60.00
18	E26	3	4	1	8	53.33
19	W10	3	1	4	8	53.33
20	E34	3	1	4	8	53.33

S.No	Stretch number	Habitat diversity	Flora diversity	Bird diversity	Score	Percent Score
21	W1	2	3	3	8	53.33
22	E20	3	3	2	8	53.33
23	W3	1	4	3	8	53.33
24	W13	2	4	1	7	46.67
25	W25	2	1	4	7	46.67
26	E4	2	3	2	7	46.67
27	E1	2	3	2	7	46.67
28	E2	2	3	1	6	40.00
29	W15	1	3	2	6	40.00
30	E14	1	4	1	6	40.00

Table 11.1 shows that all 30 stretches score 40% or more: eight score above 70% (Grade 1), 15 score 50–70% (Grade 2) and seven score below 50% (Grade 3). Most of the selected locations therefore retain a good level of ecological health. Even the stretches scoring below 50% can be restored and protected to improve their condition. This also shows that the Indrayani has a large diversity of habitats along its length and that the level of disturbance is still relatively low, so there is both scope and an urgent need for protection.

Presence of special features.

Springs and streams, rocky outcrops, sandbars and mudflats were the special features that were documented along the selected locations.

Presence of streams and springs indicate a healthy and functioning river basin and hydrogeology. Streams and springs also provide unique habitats for aquatic flora and fauna. They also contribute to river flows significantly, especially in the dry season.

Rocky outcrops, sandbars and mudflats provide important habitats for birds to roost and nest. The River Tern, for example, was once common but is now Vulnerable (IUCN), largely because the sandbars it nests on have been destroyed. Many resident and migratory birds use these habitats as safe spaces to roost and nest. Their presence is critical to the avian diversity of a river.

Presence of streams, springs, rocky outcrop and sandbar/mud flats were assessed using a binary scale, with 1 indicating presence and 0 indicating absence. One stretch E40 showed presence of all 4 features. Among the 30 stretches, springs were observed only at E40, where nine natural springs and four streams were recorded. A live spring was also found during the rapid survey at E29 (Bhawadi), which was not among the 30 stretches. Stretch E18 showed the presence of three features. Fourteen stretches showed two features and eight showed one. Six of the 30 stretches showed none of these features.

Table 11.2: Presence of Critical Habitat

S.No	Stretch number	Stream	Spring	Rocky outcrop	Sand bar & Mud flats
1	E18	1	0	1	1
2	E40	1	1	1	1
3	W22	0	0	1	1
4	W6	1	0	0	1
5	W23	0	0	1	1
6	E32	1	0	0	1
7	W9	1	0	0	1
8	W8	1	0	0	1
9	E26	0	0	1	1

S.No	Stretch number	Stream	Spring	Rocky outcrop	Sand bar & Mud flats
10	W4	1	0	0	1
11	W10	1	0	0	1
12	E34	1	0	0	1
13	W13	1	0	0	1
14	W25	0	0	1	1
15	E4	1	0	0	1
16	W24	1	0	0	1
17	E30	0	0	0	1
18	E28	0	0	0	1
19	E6	0	0	0	1
20	E41	0	0	0	1
21	E5	0	0	0	1
22	W1	1	0	0	0
23	E20	0	0	0	1
24	E2	1	0	0	0
25	E21	0	0	0	0
26	E27	0	0	0	0
27	W3	0	0	0	0
28	E1	0	0	0	0
29	W15	0	0	0	0
30	E14	0	0	0	0

The disturbances at each stretch were also documented. Solid waste, invasive species, dumping of debris, encroachment and construction on river banks were the main disturbances. Disturbances were recorded at 10 of the 30 stretches; none were recorded at the other 20.

Beyond these 30 stretches, the rapid survey found farmland running up to the bank at 26 of the 59 locations surveyed (Section 5.2), and large dumps of plastic, industrial scrap and household waste at several places on the banks (Figure 11.1).

Table 11.3: Disturbances

S.No	Stretch number	Disturbance
1	E18	Solid waste, Invasive species
2	W8	Solid waste, Invasive species
3	W22	Sewage, Dumping of debris
4	E5	Invasive species
5	W25	Invasive species
6	E20	Invasive species
7	W10	Encroachment
8	W15	Encroachment
9	W13	Dumping of debris
10	W23	Construction
11	E40	None recorded
12	W6	None recorded

S.No	Stretch number	Disturbance
13	W24	None recorded
14	E21	None recorded
15	E30	None recorded
16	E32	None recorded
17	E28	None recorded
18	E6	None recorded
19	W9	None recorded
20	E41	None recorded
21	E26	None recorded
22	W4	None recorded
23	E34	None recorded
24	E4	None recorded
25	E27	None recorded
26	W3	None recorded
27	E1	None recorded
28	E2	None recorded
29	E14	None recorded
30	W1	None recorded



Clothes and waste dumped around a tree on the bank



Plastic and industrial scrap dumped near the river



Mixed waste dumped on the bank

Figure 11.1: Solid waste and debris dumped on the river banks

This shows a lower level of disturbance as compared to other rivers in the Pune urban region. However disturbances are seen especially in urban areas and, if not managed now, will cause irreversible damage to the river ecology.

Although these stretches differ in ecological value, most are in relatively good condition. It is recommended that these 30 stretches should be protected from further disturbances. The disturbances identified in Table 11.3 should be managed or removed to maintain the ecological integrity of these river stretches.

12. Summary of Study Findings

1. **Vegetation:** The riparian zone hosts a structurally complex, species-rich plant community dominated by native trees and shrubs, with high vertical and horizontal diversity. Regeneration is dominated by native

riparian species, reflecting suitable hydrology and soil conditions. The herb layer is dominated by invasive species; repeat surveys are needed to judge long-term trends.

2. **Avifauna:** Bird diversity is correspondingly high, including long-distance migrants (Ruddy Shelduck, Sandpipers) and the River Tern (IUCN Vulnerable), indicating good habitat quality with conservation potential. However, sewage pollution, solid waste, and water hyacinth proliferation have suppressed aquatic bird diversity, particularly migratory duck species typical of similar riverine habitats.
3. **Butterflies:** Twenty-two species from four families were recorded, with 5–10 species per survey. A quantified post-monsoon survey during peak season is recommended for a fuller assessment.
4. **Odonates:** Eight species were recorded and diversity was low, likely due to water pollution and hyacinth cover. A comprehensive, season-wise quantitative study is recommended.
5. **Fish:** Catch diversity was poor (12 species), dominated by the invasive, pollution-tolerant tilapia (*Oreochromis* sp.); barbs, minnows and loaches were not recorded. This, together with elevated sewage indicators in urbanized stretches, points to water quality and habitat degradation. Detailed fish sampling is recommended to quantify diversity loss.
6. **Habitat health:** Of the 30 assessed stretches, eight scored above 70%, 17 scored 60% or more and all scored at least 40%, indicating good overall ecological condition at most sites.
7. **Threats:** Sewage influx, solid waste, dumping, and invasive species are the primary stressors on the ecosystem. Loss of riparian vegetation and channel modification also expose banks to erosion during monsoon floods.
8. **Overall assessment:** The Indrayani riparian zone remains ecologically robust and under comparatively less pressure than other rivers in the Pune Metropolitan Region, though timely intervention is needed to prevent degradation similar to that seen in the Mula and Mutha rivers.

13. Recommendations, Guidelines and Models for Restoration and Conservation

13.1 The Indrayani needs a different approach from the Mula and Mutha

Unlike other rivers in the Pune Metropolitan Region, the Indrayani is **still ecologically functional**. All 30 stretches assessed for habitat health scored 40% or more, and eight scored above 70%. The river retains springs (nine at E40 and one at E29), streams, rocky outcrops, sandbars, mudflats and riverine islands. It supports 169 plant taxa, 107 bird species, 22 butterfly and eight odonate species, and a stressed but functioning macroinvertebrate community. The river carries flow throughout the year, as a minimum flow is mandated.

The river therefore calls for a **pre-emptive conservation strategy**, with restoration focused on the degraded pockets: chiefly the Moshi–Alandi urban stretch (CPCB Priority Class III for organic pollution, 2025) and other sites with sewage inflow, faecal coliform spikes or invasive monocultures. Protecting a functioning river is far cheaper and more effective than restoring a degraded one. The recommendations below follow one logic: protect what works, restore what is failing, and govern the river so that the balance does not tip.

Conservation on the Indrayani is also **flood management**. The features valued in this report (floodplains, wetlands, sandbars, riparian vegetation and meanders) are the same features that will determine flood risk for Dehu, Alandi, the PCMC fringe and Tulapur as intense rainfall events become more frequent.

13.2 Immediate management actions

These are low-cost, urgent actions, several of which can start this financial year within existing municipal and irrigation budgets.

A. Stop waste and debris at source. Construction and demolition (C&D) debris, solid waste and dumping were recorded at several stretches (including E18, W8 and W22). Rather than repeated clean-ups, dumping should be traced to its sources (contractors, wards, informal collection points) and enforced under the Solid Waste Management Rules, 2016 and the C&D Waste Management Rules, 2016. PCMC and the Gram Panchayats should designate and publicise legal C&D disposal sites near the river corridor, since illegal dumping is driven largely by the lack of legal alternatives.

B. Intercept and treat sewage, worst stretches first. Water quality and macroinvertebrate data agree that untreated sewage is the main driver of degradation, most acute in the Moshi–Alandi corridor. A two-track approach is recommended:

- Intercept *trunk sewage* in urban stretches and route it to municipal STPs, designing the interceptors correctly now, while pollutant loads are still relatively low.
- Mandate *decentralised treatment* (root-zone systems, DEWATS) for new residential and industrial developments within a defined buffer of the river, particularly in the Chakan industrial belt and the expanding PCMC periphery, where trunk sewers will lag behind construction.

C. Fund invasive-species control every year, not once. Water hyacinth (*Pontederia crassipes*) and *Pistia* choke several stretches and visibly slow the flow. Terrestrial invasives (*Prosopis juliflora*, *Lantana camara*, *Leucaena leucocephala*, *Parthenium hysterophorus*, *Synedrella nodiflora*, *Alternanthera ficoidea*) dominate ground cover at degraded sites. One-off clearances fail because these species return within one or two monsoons. A **standing annual budget line** is needed, with clearance before the monsoon (April–May, before seed dispersal) and after it (October–November, to remove new growth), using mechanical removal rather than herbicides within 50 m of the channel. Combined with pollution control at source, regular clearance can largely free the river of these invasives within a few years.

D. Halt agricultural encroachment on the banks. Farmland reaches the water's edge at 26 of the 59 locations surveyed. Demarcate the riparian buffer and floodplain on the ground, stop further clearing of the bank for cultivation, and work with farmers to restore a strip of native riverbank trees along field edges.

13.3 Protecting existing biodiversity: a tiered approach

The 30 assessed stretches should be managed in three tiers based on their Table 11.1 scores, giving agencies a clear order of priority when resources are limited.

Tier	Stretches (from Table 11.1)	Ecological value	Management
Tier 1: Biodiversity anchor zones (score >70%)	W22, E18, W6, E21, E40, W24, E30, W23	High habitat, flora and bird diversity; E40 has all four special features, including nine natural springs; E30 includes a 10-acre (about 4 ha) riparian forest that is a notified Reserve Forest	Strict protection from construction and encroachment; priority for notification under the Biological Diversity Act, 2002, or as deemed forests
Tier 2: Consolidation zones (score 50–70%)	E32, E28, E6, E41, E5, W9, W8, W4, E27, E26, W10, E34, W1, E20, W3	Moderate to good value, generally less disturbed	Protect current condition; targeted invasive removal; watch for encroachment; restore where possible

Tier	Stretches (from Table 11.1)	Ecological value	Management
Tier 3: Active restoration zones (score <50%, or disturbed)	W13, W25, E4, E1, E2, W15, E14; plus W22 (sewage, dumping) and W10 (encroachment)	Lower scores, but recoverable	Priority for debris clearance, native replanting and, where encroachment is documented, legal reclamation of the riverbank

Protect special features. Springs, rocky outcrops, sandbars and mudflats matter far more than their area suggests. Sandbars are nesting habitat for the River Tern (*Sterna aurantia*, IUCN Vulnerable), which has declined as sandbars elsewhere were lost to sand mining and channel hardening. The nine springs at E40, and a live spring at E29, show that groundwater still feeds the river. Quarrying, borewells or hard embankments in its recharge area should be treated as threats to the river's hydrology, not just to local ecology. The heronry island at W23 (Section 7.3.2) needs the same protection from disturbance. At E30, a 10-acre (about 4 ha) riparian forest is already a notified Reserve Forest, which makes it of great conservation importance and a reference site for what riverine forest along the Indrayani can be.

13.4 Restoring degraded stretches

Restoration of Tier 3 stretches should follow a fixed sequence, because planting on a site that is still being degraded simply produces failed plantations:

1. **Remove the stressor first:** clear debris, remove encroachments and intercept sewage before any planting.
2. **Remove invasives and stabilise the soil**, especially where *Prosopis juliflora* or *Leucaena* has displaced deeper-rooted, more flood-resilient native trees.
3. **Replant with native riparian species recorded in this assessment:** *Salix tetrasperma*, *Terminalia arjuna*, *Syzygium cumini*, *Syzygium salicifolium*, *Pongamia pinnata*, *Vachellia nilotica*, *Ficus racemosa*, *Ficus hispida*, *Holoptelea integrifolia*, *Phoenix sylvestris* and *Cordia dichotoma*. Using local species avoids the common failure of generic "riverbank" planting lists.
4. **Budget for 3–5 years of maintenance**, including watering, weeding and replacement of dead saplings. Plantings left unattended often suffer heavy losses in the first year.

Keystone native trees. Some native trees do far more for the riverbank ecosystem than their numbers suggest, and restoration should protect and replant them deliberately. Arjun (*Terminalia arjuna*) is a native tree of river and stream banks in India, including Maharashtra; its spreading roots bind stream banks and it is planted to control bank erosion (Orwa et al. 2009). Its tall, wide crown provides nesting and roosting sites, and it has been described as a keystone species of riparian forest (Sekar et al. 2025). On the Indrayani it survives only at W6, where three trees have a girth of 213–240 cm; these trees should be protected and used as a seed source. Hinganbet (*Balanites aegyptiaca*), a hardy native tree that was abundant in the rapid survey, tolerates drought and poor soils; its thorny cover shelters a grass understorey and buffers the microclimate of the bank (Jeevitnadi, pers. comm.). Protecting and replanting these species, together with walunj (*Salix tetrasperma*), jambhul (*Syzygium cumini*) and karanj, will make the restored banks more resilient to drought, heat and floods.

13.5 Protecting wetlands and floodplains

Construction and encroachment should be prohibited in wetlands and floodplains. To be enforceable, this needs:

- **Formal floodplain demarcation:** Blue Line (active channel and frequent-flood zone, no construction) and Red Line (flood fringe, restricted development) boundaries for the full 41 km stretch, based on hydrological modelling. These lines should be agreed urgently, and in any case before any development proposal for the river (one is already planned) is finalised.

- **Notification of significant wetlands** under the Wetlands (Conservation and Management) Rules, 2017, especially the seasonal wetlands and marshes recorded in the rapid assessment. Because they hold water only part of the year, these are easily misclassified as vacant or low-lying land and filled for construction.
- **No hard engineering of the floodplain edge** (retaining walls, concrete embankments) except where already committed for public safety, since hard edges remove the floodplain's capacity to store floodwater.

13.6 Improving water quality beyond sewage treatment

Even well-run STPs have bypass events and power interruptions, and diffuse runoff from farmland (seen in high nitrate levels near agricultural stretches) is not captured by point-source treatment. The river therefore also needs nature-based treatment:

- **Constructed wetlands or reed beds** at the stream and drain outfalls with the highest pollutant loads (Chapter 10), using species suited to nutrient uptake such as *Typha* and *Phragmites*, or the native *Ludwigia* and *Cyperus* already recorded along the river.
- **Floating treatment wetlands** in stretches dominated by water hyacinth: a managed, regularly harvested floating system can keep some of the nutrient-removal benefit without the flow blockage and oxygen depletion caused by uncontrolled mats.
- **Riparian buffer strips** of native vegetation, at least 30 m wide where feasible, along farmland stretches to intercept fertiliser and pesticide runoff before it reaches the river.

13.7 Conservation as flood management

13.7.1 Why flood risk is changing

The Indrayani rises in the high-rainfall Western Ghats near Lonavala and drains a basalt catchment. Once its thin weathered layer is saturated, basalt absorbs little water, so heavy rain turns quickly into runoff. At the same time, more of the region's monsoon rain is arriving in short, intense bursts. The 2019 Mula–Mutha floods in Pune, driven by extreme rainfall combined with reservoir releases on a heavily built-up floodplain, show the consequences. The Indrayani faces the same climate, but has not yet lost its floodplain: this is the opportunity this report identifies.

13.7.2 How this report's findings link to flood risk

1. **Floodplains and wetlands store floodwater.** An open floodplain acts as a temporary reservoir that lowers flood peaks downstream. Every hectare built on removes that storage permanently, so encroachment upstream (near Dehu or Chakan) raises flood levels downstream (Alandi, Tulapur), even without any change in rainfall.
2. **Riparian vegetation slows floodwater.** Vegetation reduces flow speed and erosion. Deep-rooted native trees (*Salix tetrasperma*, *Terminalia arjuna*, *Vachellia nilotica*, *Pongamia pinnata*) are less likely than shallow-rooted invasive stands (*Prosopis*, *Leucaena*) to be uprooted and carried as flood debris, so native replanting also reduces flood hazard.
3. **Waste and invasive mats raise flood levels.** A channel partly blocked by solid waste, debris or water hyacinth carries less water, so the same flow rises higher. Waste and invasive control is therefore flood-channel maintenance as well as ecology.
4. **Sandbars and channel complexity spread flood energy.** A varied channel with sandbars, mudflats and multiple flow paths dissipates energy. Straightening or hardening the channel for "flood control" usually increases flow speed and downstream peaks, as the Kissimmee River case (Section 13.10) shows.

13.7.3 What this means for the proposed riverfront development

Riverfront development is proposed for a 20.6 km section of the 41 km stretch surveyed. **Any reduction in floodplain width or channel complexity in that section will raise flood levels for a given flow, and the effect will carry downstream to Alandi and Tulapur regardless of safeguards within the project.** A joint ecological and hydrological impact assessment, combining the habitat tiers in Section 13.3 with HEC-RAS or equivalent flood modelling for current and design-storm scenarios, should be a precondition for approving any riverfront development, not a parallel or later exercise.

13.7.4 Practical measures

- **Adopt "room for the river" as a planning principle:** where the floodplain is still open, as along most of this stretch, keep it open rather than building levees that move the flood problem downstream.
- **Update flood hazard maps with current extreme-rainfall data** (IMD/IITM analyses for the Western Ghats–Deccan transition) and use them for the Blue and Red Line demarcation.
- **Protect the E40 and E29 springs and other groundwater inputs** as points where groundwater and river connect, not only as biodiversity features.
- **Integrate this plan with the flood and disaster management plans of PCMC and the Irrigation Department,** so that habitat protection zones and flood hazard zones are mapped as one geography.

13.8 Community involvement and governance

Community stewardship. People's Biodiversity Registers (PBRs) under the Biological Diversity Act, 2002 should be started for the Gram Panchayats and urban wards along the river, using this assessment as the baseline. Local colleges can carry out seasonal monitoring (bird counts, invasive-cover mapping, water-quality checks), extending the data record cheaply and building informed local support for the river.

Inter-agency coordination. The pressures identified here span at least five agencies: the Forest Department, the Maharashtra Pollution Control Board, the Maharashtra State Biodiversity Board, PCMC and the Irrigation Department, as well as disaster management authorities. A standing River Basin Committee with all of them, meeting quarterly with this report's monitoring indicators as a standing agenda item, would prevent each agency treating the river as someone else's responsibility. PCMC and the Alandi and Dehu councils could also use the River Cities Alliance (NMCG–NIUA), which Pune has already joined, to prepare an Urban River Management Plan for the Indrayani, with this report's monitoring indicators built into it.

Biodiversity Management Committees (BMCs). Tier 1 stretches are strong candidates for notification as Biodiversity Heritage Sites or deemed forests, or for BMC-led management under the Biological Diversity Act, giving local bodies a statutory role in their protection.

13.9 Monitoring framework

- **Annual:** water quality at the 11 sampling sites; invasive-cover mapping using satellite or drone imagery; solid-waste and encroachment checks at the 10 disturbed stretches.
- **Every two years:** repeat the habitat-health scoring (Table 11.1) for all 30 stretches to track movement between tiers.
- **Every five years:** repeat the full baseline assessment (flora, birds, fish, macroinvertebrates, butterflies and odonates).
- **Continuous:** groundwater level and quality near E40 and other springs and streams.

All monitoring data should go to the River Basin Committee, so that ecological and flood-risk monitoring are read together.

13.10 Restoration models: global precedents and their relevance

Model	Approach	Relevance to the Indrayani	Caution
Kissimmee River, Florida, USA	Reversal of 1960s channelisation by re-meandering the river and reconnecting its floodplain	A cautionary lesson: channelisation for flood control increased flood risk and destroyed habitat, and took decades and great expense to reverse. The Indrayani's unchannelised state is an asset to protect	The reversal cost far more than the original work; the lesson is prevention, not a template to copy
Isar River, Munich, Germany	Urban renaturation: concrete banks removed, gravel bars and braided channel restored, public access added	A model for the Moshi–Alandi and Chakan-adjacent stretches: restoration and public use are compatible when the channel itself is restored	Munich had far lower pollution loads; sewage interception must come first here
Rhine Action Programme	Basin-wide, multi-country pollution reduction and habitat reconnection after the 1986 Sandoz chemical spill	Mainly a governance model: a shared, binding framework across jurisdictions	Needs decades of political commitment; the River Basin Committee is a first step
Yamuna Biodiversity Park, Delhi	Restoration of degraded floodplain with researched native species and phased planting	The most directly transferable model, working within Indian regulatory and funding conditions	Relied on Delhi Development Authority land control; the Indrayani's mixed land ownership will need negotiation with PCMC, landowners and Gram Panchayats

The common lesson is that **it is far cheaper, faster and more effective to prevent degradation of a functioning river than to restore it afterwards**. This assessment shows that, for the Indrayani, that window is still open.

13.11 Summary of priority actions

Priority	Action	Timeframe	Primary responsibility
1	Stop C&D and solid-waste dumping at identified sources	Immediate	PCMC, Gram Panchayats
2	Intercept and treat sewage in the Moshi–Alandi (Priority Class III) corridor	1–3 years	PCMC, MPCB
3	Set up an annual invasive-species management budget (pre- and post-monsoon)	Immediate, recurring	Forest Dept., PCMC, Ecological Society (technical support)
4	Formally tier and notify the 30 stretches; protect Tier 1 anchors	6–12 months	Forest Dept., MSBB
5	Blue Line/Red Line floodplain demarcation for the full 41 km stretch	1–2 years, before riverfront project	Irrigation Dept., PCMC, hydrology consultants
6	Joint ecological–hydrological impact assessment before any riverfront development	Before project	PCMC, Irrigation Dept.
7	Native-species planting in Tier 3 stretches, after stressors are removed	2–3 years	Forest Dept., Ecological Society, local colleges
8	Constructed wetlands or reed beds at high-pollution outfalls	2–4 years	MPCB, PCMC
9	Establish a River Basin Committee for inter-agency coordination	6–12 months	District Administration (convening)

Priority	Action	Timeframe	Primary responsibility
10	Launch PBRs and BMC processes with college and citizen participation	1 year	Gram Panchayats, MSBB, Ecological Society
11	Establish a recurring monitoring cycle	Ongoing from Year 1	Ecological Society, MPCB, Irrigation Dept.

14. Way Forward

This assessment is a dry-season baseline for 41 km of the river. To build a complete conservation strategy for the Indrayani, the following studies are recommended.

1. **Map biodiversity in all seasons.** Repeat the vegetation, bird, butterfly, odonate and aquatic surveys in the monsoon, post-monsoon and summer seasons, and add amphibians and reptiles, which were not covered.
2. **Map all springs and their biodiversity.** Locate every spring along the river, starting with the nine springs at E40 and the spring at E29; record their flow through the year and the plants and animals that depend on them; and map their recharge and discharge areas so that these can be protected.
3. **Map the confluencing streams and their status.** Feeder streams were recorded at 14 locations. Each should be traced through its catchment, its flow, water quality and encroachment recorded, and its confluence with the river surveyed.
4. **Survey important places outside the study area,** including the Sudha-Indrayani confluence and Pakshi Teerth island at Dehu, and Anand Doh.
5. **Carry out a full fish survey** using standard sampling methods across seasons, including the status of the Deccan Mahseer.
6. **Map and protect old, mature trees individually,** beginning with the 20 stretches where they were recorded (Section 6.3.3).
7. **Extend the assessment to the whole river,** from its source at Kurwande to Tulapur, so that the Indrayani can be managed as one system.

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Annexure 1: Consolidated list of floral species (rapid and detailed assessments)

Consolidated list of all floral species documented during rapid and detailed floral assessments. Key: N = native to the Indian subcontinent, NN = non-native, I = invasive; Occurrence: A = abundant, M = moderate, R = rare.

Sr.No	Botanical name	Local name	Habit	Native (N)/Non-native (NN)/Invasive (I)	Habitat	Occurrence
1	<i>Ailanthus excelsa</i>	Maharukh	Tree	N		R
2	<i>Albizia procera</i>	Kinai	Tree	N		M
3	<i>Annona reticulata</i>	Ramfal	Tree	NN		R
4	<i>Annona squamosa</i>	Sitafal	Tree	NN		A
5	<i>Artocarpus heterophyllus</i>	Fanas	Tree	N	Planted	R
6	<i>Azadirachta indica</i>	Neem	Tree	N		M
7	<i>Balanites aegyptiaca</i>	Hinganbet	Tree	N		A
8	<i>Bauhinia racemosa</i>	Aapata	Tree	N		M
9	<i>Butea monosperma</i>	Palas	Tree	N		R
10	<i>Ceiba pentandra</i>	Dev sawar	Tree	NN, I		R
11	<i>Cocos nucifera</i>	Naral	Tree	N		R
12	<i>Cordia dichotoma</i>	Bhokar	Tree	N	Riparian	M
13	<i>Dalbergia lanceolaria</i>	Fanashi	Tree	N		R
14	<i>Dalbergia sissoo</i>	Shisoo	Tree	N		R
15	<i>Delonix regia</i>	Gulmohar	Tree	NN		R
16	<i>Dolichandrone falcata</i>	Medhshingi	Tree	N		R
17	<i>Ehretia laevis</i>	Aajan	Tree	N		R
18	<i>Erythrina indica</i>	Pangara	Tree	N		R
19	<i>Erythrina stricta</i>	Kate pangara	Tree	N		R
20	<i>Eucalyptus spp.</i>	Nilgiri	Tree	NN		R
21	<i>Ficus benghalensis</i>	Vad	Tree	N		M
22	<i>Ficus heterophylla</i>	Datir	Tree	N	Riparian	R
23	<i>Ficus hispida</i>	Dhed umbar	Tree	N	Riparian	R
24	<i>Ficus racemosa</i>	Umbar	Tree	N	Riparian	A
25	<i>Ficus religiosa</i>	Pimpal	Tree	N		A
26	<i>Gliricidia sepium</i>	Undirmar	Tree	NN, I		M
27	<i>Gmelina arborea</i>	Shivan	Tree	N		R
28	<i>Grevillea robusta</i>	Silver oak	Tree	NN		R
29	<i>Grewia asiatica</i>	Falsa	Tree	N		R
30	<i>Grewia tiliifolia</i>	Dhaman	Tree	N		R
31	<i>Holoptelea integrifolia</i>	Waval	Tree	N	Riparian	A
32	<i>Lannea coromandelica</i>	Moi	Tree	N		R

Sr.No	Botanical name	Local name	Habit	Native (N)/Non-native (NN)/Invasive (I)	Habitat	Occurrence
33	<i>Leucaena leucocephala</i>	Subabhul	Tree	NN, I		A
34	<i>Limonia acidissima</i>	Kavath	Tree	N	Planted	R
35	<i>Mangifera indica</i>	Aamba	Tree	N	Planted	A
36	<i>Melia azedarach</i>	Bakana neem	Tree	N		R
37	<i>Muntingia calabura</i>	Singapur cherry	Tree	NN		R
38	<i>Neolamarckia cadamba</i>	Kadamb	Tree	N	Riparian	R
39	<i>Phoenix sylvestris</i>	Shindi	Tree	N	Riparian	A
40	<i>Phyllanthus acidus</i>	Aawala	Tree	N	Planted	R
41	<i>Pithecellobium dulce</i>	Vilayati chinch	Tree	NN		A
42	<i>Pongamia pinnata</i>	Karanj	Tree	N	Riparian	A
43	<i>Prosopis juliflora</i>	Vedi babhul	Tree	NN, I		A
44	<i>Salix tetrasperma</i>	Valunj	Tree	N	Riparian	M
45	<i>Samanea saman</i>	Rain tree	Tree	NN		M
46	<i>Santalum album</i>	Chandan	Tree	N		M
47	<i>Senegalia catechu</i>	Khair	Tree	N		M
48	<i>Senna siamea</i>	Kashid	Tree	NN		M
49	<i>Spathodea campanulata</i>	Pichkari	Tree	NN		R
50	<i>Stereospermum spp.</i>	Padal	Tree	N	Riparian	R
51	<i>Syzygium cumini</i>	Jambhul	Tree	N	Riparian	M
52	<i>Syzygium salicifolium</i>	Paanjambhul	Tree	N	Riparian	M
53	<i>Tamarindus indica</i>	Chinch	Tree	N	Planted	M
54	<i>Tectona grandis</i>	Sag	Tree	N	Planted	R
55	<i>Terminalia arjuna</i>	Arjun	Tree	N	Riparian	R
56	<i>Terminalia catappa</i>	Khota badam	Tree	NN		R
57	<i>Thespesia populnea</i>	Parosa pimpal	Tree	N		R
58	<i>Trema orientalis</i>	Ghol	Tree	N		R
59	<i>Vachellia leucophloea</i>	Hivar	Tree	N		M
60	<i>Vachellia nilotica</i>	Babhul	Tree	N	Riparian	A
61	<i>Ziziphus mauritiana</i>	Bor	Tree	N		M
62	<i>Ziziphus oenoplia</i>	Buragi	Tree	N	Riparian	R
63	<i>Ziziphus xylopyrus</i>	Ghatbor	Tree	N		R
64	<i>Abelmoschus ficulneus</i>	Jangali bhendi	Shrub	N		R
65	<i>Ageratum conyzoides</i>	Ranmodi	Shrub	NN, I		A
66	<i>Barleria cristata</i>	Kate koranti	Shrub	N		R
67	<i>Calotropis gigantea</i>	Rui	Shrub	N		M
68	<i>Cascabela thevetia</i>	Bitti	Shrub	NN, I		R
69	<i>Chromolaena odorata</i>	Raanmari	Shrub	NN, I		A
70	<i>Cosmos sulphureus</i>	Cosmos	Shrub	NN, I		M

Sr.No	Botanical name	Local name	Habit	Native (N)/Non-native (NN)/Invasive (I)	Habitat	Occurrence
71	<i>Crotalaria pallida</i>	Khulkhula	Shrub	N		M
72	<i>Euphorbia tirucalli</i>	Tridhari nivadung	Shrub	N		R
73	<i>Euphorbia heterophylla</i>	Dudhi	Shrub	NN		M
74	<i>Flueggea leucopyrus</i>	Pandharfali	Shrub	N		A
75	<i>Hibiscus panduriformis</i>	Yellow hibiscus	Shrub	N		M
76	<i>Hygrophila auriculata</i>	Talimkhana	Shrub	N	Riparian	A
77	<i>Hyptis suaveolens</i>	Darp tulas	Shrub	NN, I	Riparian	A
78	<i>Ipomoea carnea fistulosa</i>	Besharam	Shrub	NN, I		A
79	<i>Jatropha curcas</i>	Mogali erand	Shrub	NN, I		A
80	<i>Lantana camara</i>	Tantani	Shrub	NN, I		A
81	<i>Leonotis nepetifolia</i>	Deepmal	Shrub	N		R
82	<i>Murraya koenigii</i>	Kadipatta	Shrub	N		R
83	<i>Phyllanthus reticulatus</i>	Nilumbi	Shrub	N	Riparian	A
84	<i>Plumbago zeylanica</i>	Chitrak	Shrub	N	Riparian	A
85	<i>Psoralea corylifolia</i>	Bavachi	Shrub	N		A
86	<i>Ricinus communis</i>	Erand	Shrub	NN, I		A
87	<i>Senna auriculata</i>	Tarwad	Shrub	N		A
88	<i>Senna tora</i>	Takala	Shrub	NN, I		A
89	<i>Senna uniflora</i>	Takala	Shrub	NN, I		A
90	<i>Sida acuta</i>	Jangali Methi	Shrub	N		A
91	<i>Solanum nigrum</i>	Laghu kavali	Shrub	N		M
92	<i>Solanum torvum</i>	Kurti	Shrub	N		A
93	<i>Urena lobata</i>	Vanbhendi	Shrub	N		A
94	<i>Vitex negundo</i>	Nirgudi	Shrub	N		M
95	<i>Xanthium strumarium</i>	Sankeshwar	Shrub	N		A
96	<i>Abutilon indicum</i>	Petari	Herb	N		R
97	<i>Achyranthes aspera</i>	Aaghada	Herb	N		A
98	<i>Alocasia macrorrhizos</i>	Kassalu	Herb	NN	Riparian	A
99	<i>Alternanthera ficoidea</i>	Kusal	Herb	NN, I		A
100	<i>Alternanthera sessilis</i>	Stalkless Joyweed	Herb	NN	Riparian	A
101	<i>Alysicarpus</i> sp.		Herb	N		R
102	<i>Amaranthus spinosus</i>	Kate Math	Herb	NN		A
103	<i>Asclepias curassavica</i>	Haladi Kunku	Herb	N	Riparian	M
104	<i>Bacopa monnieri</i>	Neer brahmi	Herb	N	Riparian	R
105	<i>Boerhavia erecta</i>	Punarnava	Herb	N		M
106	<i>Celosia argentea</i>	Kurdu	Herb	NN		M

Sr.No	Botanical name	Local name	Habit	Native (N)/Non-native (NN)/Invasive (I)	Habitat	Occurrence
107	<i>Colocasia esculenta</i>	Alu	Herb	N	Riparian	A
108	<i>Commelina benghalensis</i>	Kena	Herb	N		A
109	<i>Cyperus spp.</i>		Herb	N	Riparian	A
110	<i>Desmodium scorpiurus</i>		Herb	NN		M
111	<i>Dicliptera paniculata</i>	Kanjangha	Herb	N		A
112	<i>Heliotropium indicum</i>	Bhurundi	Herb	N		M
113	<i>Ludwigia adscendens</i>		Herb	N	Riparian	M
114	<i>Ludwigia octovalvis</i>	Panlavang	Herb	N	Riparian	A
115	<i>Nicotiana plumbaginifolia</i>	babbakhu	Herb	NN	Riparian	M
116	<i>Parthenium hysterophorus</i>	Gajar Gavat	Herb	NN		A
117	<i>Persicaria glabra</i>	Sheral	Herb	N	Riparian	A
118	<i>Portulaca oleracea</i>	Gholu	Herb	N	Riparian	A
119	<i>Rungia repens</i>		Herb	N		A
120	<i>Sida rhomboidea</i>	Jangali Methi	Herb	N		M
121	<i>Sonchus oleraceus</i>	Mhatara	Herb	N		A
122	<i>Synedrella nodiflora</i>	Synedrilla weed	Herb	NN, I		A
123	<i>Tridax procumbens</i>	Dagadi pala	Herb	N		A
124	<i>Vernonia cinerea</i>	Sahadevi	Herb	N		A
125	<i>Apluda mutica</i>	Moti gavat	Grass	N		A
126	<i>Aristida sp.</i>	Kusal	Grass	N		A
127	-	Bamboo	Grass	N		M
128	<i>Chloris gayana</i>		Grass	NN		A
129	<i>Cynodon dactylon</i>	Durva	Grass	N		A
130	<i>Dactyloctenium aegyptium</i>	Crow feet grass	Grass	N		M
131	<i>Dichanthium caricosum</i>		Grass	N		A
132	<i>Dinebra retroflexa</i>	Goradu	Grass	N		M
133	<i>Echinochloa colonum</i>	Borur	Grass	N		A
134	<i>Eleusine indica</i>	Ran nanchani	Grass	N		A
135	<i>Eragrostis tenella</i>	Love grass	Grass	N		A
136	<i>Heteropogon contortus</i>	Chubuk kata	Grass	N		M
137	<i>Melinis repens</i>	Ruby grass	Grass	N		R
138	<i>Oplismenus burmannii</i>	Venupatrika	Grass	N		M
139	<i>Panicum maximum</i>		Grass	NN		A
140	<i>Pennisetum pedicellatum</i>	Dinanath grass	Grass	NN		A

Sr.No	Botanical name	Local name	Habit	Native (N)/Non-native (NN)/Invasive (I)	Habitat	Occurrence
141	<i>Saccharum spontaneum</i>	Kamis	Grass	N	Riparian	A
142	<i>Setaria intermedia</i>	Chikata	Grass	N		M
143	<i>Setaria verticillata</i>		Grass	NN		M
144	<i>Sorghum halepense</i>	Boru	Grass	N		A
145	<i>Thelepogon elegans</i>	Tirpha	Grass	N		M
146	<i>Themeda</i> sp.	Kangaroo grass	Grass	N		M
147	<i>Urochloa setigera</i>		Grass	N	Riparian	A
148	<i>Aspidopterys cordata</i>	Bokad vel	Climber	N		R
149	<i>Caesalpinia bonduc</i>	Sagargota	Climber	N		R
150	<i>Canavalia</i> sp.	Abai	Climber	N		R
151	<i>Cardiospermum halicacabum</i>	Kapalphodi	Climber	N		M
152	<i>Clitoria</i> sp.	Gokarn	Climber	N		R
153	<i>Coccinia grandis</i>	Tondale	Climber	N		A
154	<i>Cocculus hirsutus</i>	Vasanvel	Climber	N		A
155	<i>Combretum ovalifolium</i>	Piluki	Climber	N	Riparian	A
156	<i>Cryptostegia grandiflora</i>	Vilayati vekhundi	Climber	NN		M
157	<i>Dioscorea bulbifera</i>	Kadu karanda	Climber	N		R
158	<i>Ipomoea cairica</i>	Garvel	Climber	NN		A
159	<i>Ipomoea hederifolia</i>	Lal pungali	Climber	NN, I		M
160	<i>Ipomoea parasitica</i>	Morning glory	Climber	NN		A
161	<i>Ipomoea triloba</i>	Bhovari	Climber	NN		A
162	<i>Luffa aegyptiaca</i>	Ghosavale	Climber	N		A
163	<i>Merremia hederacea</i>	Hemali	Climber	N	Riparian	A
164	<i>Mikania micrantha</i>	American rope	Climber	NN, I	Riparian	A
165	<i>Passiflora foetida</i>	Wel ghani	Climber	NN, I		A
166	<i>Pergularia daemia</i>	Utaran	Climber	N		A
167	<i>Tinospora cordifolia</i>	Gulvel	Climber	N		M
168	<i>Azolla filiculoides</i>	Water fern	Aquatic	N	Riparian	A
169	<i>Pontederia crassipes</i>	Jalparni, Water Hyacinth	Aquatic	NN, I	Riparian	M

Annexure 2: Floral species documented in the detailed floral assessment

List of floral species documented during detailed floral diversity assessment

S. No	Botanical name	Common name	Family	Habit	Native (N)/Non-native (NN)/Invasive (I)	Habitat
1	<i>Azadirachta indica</i>	Neem	Meliaceae	Tree	N	
2	<i>Balanites aegyptiaca</i>	Hinganbet	Zygophyllaceae	Tree	N	
3	<i>Cordia dichotoma</i>	Bhokar	Boraginaceae	Tree	N	Riparian
4	<i>Ficus hispida</i>	Dedh umbar	Moraceae	Tree	N	Riparian
5	<i>Ficus racemosa</i>	Umbar	Moraceae	Tree	N	Riparian
6	<i>Holoptelea integrifolia</i>	Wawal	Ulmaceae	Tree	N	Riparian
7	<i>Leucaena leucocephala</i>	Subabhul	Fabaceae	Tree	NN, I	
8	<i>Mitragyna parviflora</i>	Kalam	Rubiaceae	Tree	N	Riparian
9	<i>Phoenix sylvestris</i>	Shindi	Arecaceae	Tree	N	Riparian
10	<i>Pithecellobium dulce</i>	Vilayati chinch	Fabaceae	Tree	NN	
11	<i>Pongamia pinnata</i>	Karanj	Fabaceae	Tree	N	Riparian
12	<i>Prosopis juliflora</i>	Vedi Babhul	Fabaceae	Tree	NN, I	
13	<i>Salix tetrasperma</i>	Walunj	Salicaceae	Tree	N	Riparian
14	<i>Samanea saman</i>	Rain tree	Fabaceae	Tree	NN	
15	<i>Syzygium salicifolium</i>	Paan Jambhul	Myrtaceae	Tree	N	Riparian
16	<i>Tamarindus indica</i>	Chinch	Fabaceae	Tree	N	
17	<i>Terminalia arjuna</i>	Arjun	Combretaceae	Tree	N	Riparian
18	<i>Vachellia nilotica</i>	Babhul	Fabaceae	Tree	N	Riparian
19	<i>Ziziphus mauritiana</i>	Bor	Rhamnaceae	Tree	N	
20	<i>Achyranthes aspera</i>	Aaghada	Amaranthaceae	Shrub	N	
21	<i>Acmella uliginosa</i>	Acmela uglinosa	Fabaceae	Shrub	N	Riparian
22	<i>Ageratum houstonianum</i>	Osadi	Asteraceae	Shrub	NN, I	
23	<i>Amaranthus spinosus</i>	Kate math	Acanthaceae	Shrub	NN	
24	<i>Argemone mexicana</i>	Kate dhotra	Papaveraceae	Shrub	NN	
26	<i>Asclepias curassavica</i>	Haldi kunku	Asclepiaceae	Shrub	N	Riparian
27	<i>Canna sp.</i>	Kardal	Cannaceae	Shrub	N	
28	<i>Capparis divaricata</i>	Pachunda	Capparaceae	Shrub	N	
29	<i>Chromolaena odorata</i>	Ranmari	Asteraceae	Shrub	NN, I	
30	<i>Clerodendrum phlomidis</i>	Arani	Lamiaceae	Shrub	N	Riparian
31	<i>Colocasia esculenta</i>	Alu	Araceae	Shrub	N	Riparian
32	<i>Cyathocline purpurea</i>	Gangotra	Asteraceae	Shrub	N	Riparian
33	<i>Desmodium scorpiurus</i>	Desmodium	Fabaceae	Shrub	N	
34	<i>Dicliptera paniculata</i>	Kakjangha	Acanthaceae	Shrub	N	
35	<i>Heliotropium indicum</i>	Bhurundi	Boraginaceae	Shrub	N	

S. No	Botanical name	Common name	Family	Habit	Native (N)/Non-native (NN)/Invasive (I)	Habitat
36	<i>Hygrophila auriculata</i>	Talimkhana	Acanthaceae	Shrub	N	Riparian
37	<i>Lantana camara</i>	Tantani	Verbinaceae	Shrub	NN, I	
38	<i>Leucas longifolia</i>	Leucas	Lamiaceae	Shrub	N	
39	<i>Ludwigia octovalvis</i>	Pan lavang	Onagraceae	Shrub	N	Riparian
40	<i>Nicotiana plumbaginifolia</i>	Chitrak bambakhu	Solanaceae	Shrub	N	Riparian
41	<i>Persicaria glabra</i>	Sheral	Polygonaceae	Shrub	N	Riparian
42	<i>Phyllanthus reticulatus</i>	Nilumbi	Phyllanthaceae	Shrub	N	Riparian
43	<i>Plumbago zeylanica</i>	Chitrak	Plumbaginaceae	Shrub	N	Riparian
44	<i>Rumex dentatus</i>	Jangali palak	Polygonaceae	Shrub	N	Riparian
45	<i>Sida acuta</i>	Ran methi	Malvaceae	Shrub	N	
46	<i>Sida cordifolia</i>	Ran methi	Malvaceae	Shrub	N	
47	<i>Solanum nigrum</i>	Laghu kavali	Solanaceae	Shrub	N	
48	<i>Solanum virginianum</i>	Kate ringani	Solanaceae	Shrub	N	
49	<i>Sonchus oleraceus</i>	Mhatara	Asteraceae	Shrub	N	
50	<i>Sphaeranthus indicus</i>	Ghorakmundi	Asteraceae	Shrub	N	
51	<i>Urena lobata</i>	Van bhendi	Malvaceae	Shrub	N	
52	<i>Verbascum chinense</i>	Kutaki	Verbanaceae	Shrub	N	
53	<i>Vitex negundo</i>	Nirgudi	Lamiaceae	Shrub	N	
54	<i>Alternanthera ficoidea</i>	Kusal	Amaranthaceae	Herb	NN, I	
55	<i>Cyperus</i> sp.	Cyperus species 1	Cyperaceae	Herb	N	Riparian
56	<i>Cyperus</i> sp.	Cyperus species 2	Cyperaceae	Herb	N	Riparian
57	<i>Grangea maderaspatana</i>	Madras carpet	Asteraceae	Herb	N	Riparian
58	<i>Limnophila repens</i>	Sarpat turati	Plantaginaceae	Herb	N	Riparian
59	<i>Hygrophila serpyllum</i>	Purple flower	Acanthaceae	Herb	N	Riparian
60	<i>Parthenium hysterophorus</i>	Gajar gavat	Asteraceae	Herb	NN, I	
61	<i>Portulaca oleracea</i>	Gholu	Portulacaceae	Herb	N	Riparian
62	<i>Synedrella nodiflora</i>	Cynedrella weed	Asteraceae	Herb	NN, I	
63	<i>Dichanthium pertusum</i>	Marvel	Poaceae	Grass	N	
64	<i>Oplismenus burmannii</i>	Venupatrika	Poaceae	Grass	N	
65	<i>Setaria verticillata</i>	Ulat kata	Poaceae	Grass	NN	
66	<i>Sorghum halepense</i>	Boru	Poaceae	Grass	N	
67	<i>Cocculus hirsutus</i>	Vasan vel	Menispermaceae	Climber	N	
68	<i>Combretum ovalifolium</i>	Piluki	Combretaceae	Climber	N	Riparian
69	<i>Cryptolepis dubia</i>	Kavali	Apocynaceae	Climber	N	
70	<i>Passiflora foetida</i>	Vel ghani	Passifloraceae	Climber	NN, I	

Annexure 3: Checklist of regeneration in the 10 detailed-assessment stretches

Checklist of regeneration from 10 stretches selected for detailed floral diversity assessment

S. No	Botanical name	Common name	Native (N)/Non-native (NN)/Invasive (I)	Habitat	Occurrence
1	<i>Annona squamosa</i>	Sitafal	NN		M
2	<i>Azadirachta indica</i>	Neem	N		R
3	<i>Balanites aegyptiaca</i>	Hinganbet	N		M
4	<i>Combretum ovalifolium</i>	Piluki	N	Riparian	A
5	<i>Ficus hispida</i>	Dhed umbar	N	Riparian	R
6	<i>Ficus racemosa</i>	Umbar	N	Riparian	A
7	<i>Holoptelea integrifolia</i>	Wawal	N	Riparian	M
8	<i>Leucaena leucocephala</i>	Subabhul	NN, I		M
9	<i>Mangifera indica</i>	Mango	N	Riparian	R
10	<i>Murraya koenigii</i>	Kadipatta	N		R
11	<i>Phoenix sylvestris</i>	Shindi	N	Riparian	A
12	<i>Pithecellobium dulce</i>	Vilayati chinch	NN		A
13	<i>Pongamia pinnata</i>	Karanj	N	Riparian	A
14	<i>Prosopis juliflora</i>	Vedi babhul	NN, I		A
15	<i>Samanea saman</i>	Rain tree	NN		R
16	<i>Santalum album</i>	Chandan	N		R
17	<i>Syzygium salicifolium</i>	Pan jambhul	N	Riparian	M
18	<i>Ziziphus mauritiana</i>	Bor	N		R

Annexure 4: Checklist of bird species

Checklist of all bird species observed during detailed bird diversity assessment. WPA schedule = schedule under the Wild Life (Protection) Act, 1972, as amended in 2022; species in Schedule I are shown in bold.

Sr. No.	Common Name	Scientific Name	Family	Order	Aquatic/Terrestrial	WPA schedule
1	Alexandrine Parakeet	<i>Psittacula eupatria</i>	Psittaculidae	Psittaciformes	T	Schedule II
2	Ashy Drongo	<i>Dicrurus leucophaeus</i>	Dicruridae	Passeriformes	T	Schedule II
3	Ashy Prinia	<i>Prinia socialis</i>	Cisticolidae	Passeriformes	T	Schedule II
4	Asian Green Bee-eater	<i>Merops orientalis</i>	Meropidae	Coraciiformes	T	Schedule II
5	Asian Koel	<i>Eudynamys scolopaceus</i>	Cuculidae	Cuculiformes	T	Schedule II
6	Asian Tit	<i>Parus cinereus</i>	Paridae	Passeriformes	T	Schedule II
7	Asian Woolly-necked Stork	<i>Ciconia episcopus</i>	Ciconiidae	Ciconiiformes	A	Schedule II
8	Barn Swallow	<i>Hirundo rustica</i>	Hirundinidae	Passeriformes	T	Schedule II
9	Baya Weaver	<i>Ploceus philippinus</i>	Ploceidae	Passeriformes	T	Schedule II
10	Black Drongo	<i>Dicrurus macrocerus</i>	Dicruridae	Passeriformes	T	Schedule II
11	Black Kite	<i>Milvus migrans</i>	Accipitridae	Accipitriformes	T	Schedule II
12	Black Redstart	<i>Phoenicurus ochruros</i>	Muscicapidae	Passeriformes	T	Schedule II
13	Black-crowned Night Heron	<i>Nycticorax nycticorax</i>	Ardeidae	Pelecaniformes	A	Schedule II
14	Black-headed Cuckooshrike	<i>Lalage melanoptera</i>	Campephagidae	Passeriformes	T	Schedule II
15	Black-headed Ibis	<i>Threskiornis melanocephalus</i>	Threskiornithidae	Pelecaniformes	A	Schedule II
16	Black-winged Stilt	<i>Himantopus himantopus</i>	Recurvirostridae	Charadriiformes	A	Schedule II
17	Blyth's Reed Warbler	<i>Acrocephalus dumetorum</i>	Acrocephalidae	Passeriformes	T	Schedule II
18	Booted Warbler	<i>Iduna caligata</i>	Acrocephalidae	Passeriformes	T	Schedule II
19	Brahminy Starling	<i>Sturnia pagodarum</i>	Sturnidae	Passeriformes	T	Schedule II
20	Clamorous Reed Warbler	<i>Acrocephalus stentoreus</i>	Acrocephalidae	Passeriformes	A	Schedule II
21	Common Iora	<i>Aegithina tiphia</i>	Aegithinidae	Passeriformes	T	Schedule II
22	Common Kingfisher	<i>Alcedo atthis</i>	Alcedinidae	Coraciiformes	A	Schedule II
23	Common Myna	<i>Acridotheres tristis</i>	Sturnidae	Passeriformes	T	Schedule II
24	Common Sandpiper	<i>Actitis hypoleucos</i>	Scolopacidae	Charadriiformes	A	Schedule II
25	Common Tailorbird	<i>Orthotomus sutorius</i>	Cisticolidae	Passeriformes	T	Schedule II
26	Coppersmith Barbet	<i>Psilopogon haemacephalus</i>	Megalaimidae	Piciformes	T	Schedule II
27	cuckoo sp.	-	Cuculidae	Cuculiformes	T	Schedule II
28	Dusky Crag Martin	<i>Ptyonoprogne concolor</i>	Hirundinidae	Passeriformes	T	Schedule II
29	Eastern Cattle Egret	<i>Ardea coromanda</i>	Ardeidae	Pelecaniformes	A	Schedule II
30	Eastern Red-rumped Swallow	<i>Cecropis daurica</i>	Hirundinidae	Passeriformes	T	Schedule II

Sr. No.	Common Name	Scientific Name	Family	Order	Aquatic/Terrestrial	WPA schedule
31	Eurasian Collared-Dove	<i>Streptopelia decaocto</i>	Columbidae	Columbiformes	T	Schedule II
32	Eurasian Coot	<i>Fulica atra</i>	Rallidae	Gruiformes	A	Schedule II
33	Eurasian Hoopoe	<i>Upupa epops</i>	Upupidae	Bucerotiformes	T	Schedule II
34	Eurasian Spoonbill	<i>Platalea leucorodia</i>	Threskiornithidae	Pelecaniformes	A	Schedule I
35	Glossy Ibis	<i>Plegadis falcinellus</i>	Threskiornithidae	Pelecaniformes	A	Schedule II
36	Great Cormorant	<i>Phalacrocorax carbo</i>	Phalacrocoracidae	Suliformes	A	Schedule II
37	Great Egret	<i>Ardea alba</i>	Ardeidae	Pelecaniformes	A	Schedule II
38	Greater Coucal	<i>Centropus sinensis</i>	Cuculidae	Cuculiformes	T	Schedule II
39	Greater Spotted Eagle	<i>Clanga clanga</i>	Accipitridae	Accipitriformes	T	Schedule I
40	Green Sandpiper	<i>Tringa ochropus</i>	Scolopacidae	Charadriiformes	A	Schedule II
41	Greenish Warbler	<i>Phylloscopus trochiloides</i>	Phylloscopidae	Passeriformes	T	Schedule II
42	Grey Francolin	<i>Ortygornis pondicerianus</i>	Phasianidae	Galliformes	T	Schedule II
43	Grey Heron	<i>Ardea cinerea</i>	Ardeidae	Pelecaniformes	A	Schedule II
44	Grey Wagtail	<i>Motacilla cinerea</i>	Motacillidae	Passeriformes	A	Schedule II
45	Grey-headed Swampphen	<i>Porphyrio poliocephalus</i>	Rallidae	Gruiformes	A	Schedule II
46	House Crow	<i>Corvus splendens</i>	Corvidae	Passeriformes	T	Not scheduled
47	House Sparrow	<i>Passer domesticus</i>	Passeridae	Passeriformes	T	Schedule II
48	Indian Cormorant	<i>Phalacrocorax fuscicollis</i>	Phalacrocoracidae	Suliformes	A	Schedule II
49	Indian Golden Oriole	<i>Oriolus kundoo</i>	Oriolidae	Passeriformes	T	Schedule II
50	Indian Grey Hornbill	<i>Ocyrceros birostris</i>	Bucerotidae	Bucerotiformes	T	Schedule II
51	Indian Peafowl	<i>Pavo cristatus</i>	Phasianidae	Galliformes	T	Schedule I
52	Indian Pond Heron	<i>Ardeola grayii</i>	Ardeidae	Pelecaniformes	A	Schedule II
53	Indian Silverbill	<i>Euodice malabarica</i>	Estrildidae	Passeriformes	T	Schedule II
54	Indian Spot-billed Duck	<i>Anas poecilorhyncha</i>	Anatidae	Anseriformes	A	Schedule II
55	Indian White-eye	<i>Zosterops palpebrosus</i>	Zosteropidae	Passeriformes	T	Schedule II
56	Jungle Myna	<i>Acridotheres fuscus</i>	Sturnidae	Passeriformes	T	Schedule II
57	Large Grey Babbler	<i>Argya malcolmi</i>	Leiothrichidae	Passeriformes	T	Schedule II
58	Large-billed Crow	<i>Corvus macrorhynchos</i>	Corvidae	Passeriformes	T	Schedule II
59	Laughing Dove	<i>Spilopelia senegalensis</i>	Columbidae	Columbiformes	T	Schedule II
60	Lesser Whitethroat	<i>Curruca curruca</i>	Sylviidae	Passeriformes	T	Schedule II
61	Little Cormorant	<i>Microcarbo niger</i>	Phalacrocoracidae	Suliformes	A	Schedule II
62	Little Egret	<i>Egretta garzetta</i>	Ardeidae	Pelecaniformes	A	Schedule II
63	Little Grebe	<i>Tachybaptus ruficollis</i>	Podicipedidae	Podicipediformes	A	Schedule II
64	Little Ringed Plover	<i>Thinornis dubius</i>	Charadriidae	Charadriiformes	A	Schedule II
65	Long-tailed Shrike	<i>Lanius schach</i>	Laniidae	Passeriformes	T	Schedule II
66	Medium Egret	<i>Ardea intermedia</i>	Ardeidae	Pelecaniformes	A	Schedule II

Sr. No.	Common Name	Scientific Name	Family	Order	Aquatic/Terrestrial	WPA schedule
67	Oriental Honey Buzzard	<i>Pernis ptilorhynchus</i>	Accipitridae	Accipitriformes	T	Schedule II
68	Oriental Magpie Robin	<i>Copsychus saularis</i>	Muscicapidae	Passeriformes	T	Schedule II
69	Painted Stork	<i>Mycteria leucocephala</i>	Ciconiidae	Ciconiiformes	A	Schedule II
70	Pale-billed Flowerpecker	<i>Dicaeum erythrorhynchos</i>	Dicaeidae	Passeriformes	T	Schedule II
71	Pied Bushchat	<i>Saxicola caprata</i>	Muscicapidae	Passeriformes	T	Schedule II
72	Pied Kingfisher	<i>Ceryle rudis</i>	Alcedinidae	Coraciiformes	A	Schedule II
73	Pipit sp.	-	Motacillidae	Passeriformes	T	Schedule II
74	Plover sp.	-	Charadriidae	Charadriiformes	A	Schedule II
75	Purple Heron	<i>Ardea purpurea</i>	Ardeidae	Pelecaniformes	A	Schedule II
76	Purple Sunbird	<i>Cinnyris asiaticus</i>	Nectariniidae	Passeriformes	T	Schedule II
77	Purple-rumped Sunbird	<i>Leptocoma zeylonica</i>	Nectariniidae	Passeriformes	T	Schedule II
78	Red-breasted Flycatcher	<i>Ficedula parva</i>	Muscicapidae	Passeriformes	T	Schedule II
79	Red-naped Ibis	<i>Pseudibis papillosa</i>	Threskiornithidae	Pelecaniformes	T	Schedule II
80	Red-vented Bulbul	<i>Pycnonotus cafer</i>	Pycnonotidae	Passeriformes	T	Schedule II
81	Red-wattled Lapwing	<i>Vanellus indicus</i>	Charadriidae	Charadriiformes	A	Schedule II
82	Red-whiskered Bulbul	<i>Pycnonotus jocosus</i>	Pycnonotidae	Passeriformes	T	Schedule II
83	River Tern	<i>Sterna aurantia</i>	Laridae	Charadriiformes	A	Schedule I
84	Rock Pigeon	<i>Columba livia</i>	Columbidae	Columbiformes	T	Not scheduled
85	Rose-ringed Parakeet	<i>Psittacula krameri</i>	Psittaculidae	Psittaciformes	T	Schedule II
86	Rosy Starling	<i>Pastor roseus</i>	Sturnidae	Passeriformes	T	Schedule II
87	Ruddy Shelduck	<i>Tadorna ferruginea</i>	Anatidae	Anseriformes	A	Schedule II
88	Rufous-tailed Lark	<i>Ammomanes phoenicurus</i>	Alaudidae	Passeriformes	T	Schedule II
89	Shikra	<i>Tachyspiza badia</i>	Accipitridae	Accipitriformes	T	Schedule I
90	Siberian Stonechat	<i>Saxicola maurus</i>	Muscicapidae	Passeriformes	T	Schedule II
91	Small Minivet	<i>Pericrocotus cinnamomeus</i>	Campephagidae	Passeriformes	T	Schedule I
92	Greater Painted/Common Snipe	-	Scolopacidae	Charadriiformes	A	Schedule II
93	Spot-breasted Fantail	<i>Rhipidura albogularis</i>	Rhipiduridae	Passeriformes	T	Schedule II
94	Sykes's Warbler	<i>Iduna rama</i>	Acrocephalidae	Passeriformes	T	Schedule II
95	Taiga Flycatcher	<i>Ficedula albicilla</i>	Muscicapidae	Passeriformes	T	Schedule II
96	Tickell's Blue Flycatcher	<i>Cyornis tickelliae</i>	Muscicapidae	Passeriformes	T	Schedule II
97	Western Marsh Harrier	<i>Circus aeruginosus</i>	Accipitridae	Accipitriformes	A	Schedule I
98	Western Yellow Wagtail	<i>Motacilla flava</i>	Motacillidae	Passeriformes	A	Schedule II
99	White Wagtail	<i>Motacilla alba</i>	Motacillidae	Passeriformes	A	Schedule II
100	White-breasted Waterhen	<i>Amaurornis phoenicurus</i>	Rallidae	Gruiformes	A	Schedule II

Sr. No.	Common Name	Scientific Name	Family	Order	Aquatic/Terrestrial	WPA schedule
101	White-Browed Wagtail	<i>Motacilla maderaspatensis</i>	Motacillidae	Passeriformes	A	Schedule II
102	White-throated Kingfisher	<i>Halcyon smyrnensis</i>	Alcedinidae	Coraciiformes	A	Schedule II
103	Wire-tailed Swallow	<i>Hirundo smithii</i>	Hirundinidae	Passeriformes	A	Schedule II
104	Wood Sandpiper	<i>Tringa glareola</i>	Scolopacidae	Charadriiformes	A	Schedule II
105	Yellow-eyed Babbler	<i>Chrysomma sinense</i>	Paradoxornithidae	Passeriformes	T	Schedule II
106	Yellow-wattled Lapwing	<i>Vanellus malabaricus</i>	Charadriidae	Charadriiformes	T	Schedule II
107	Zitting Cisticola	<i>Cisticola juncidis</i>	Cisticolidae	Passeriformes	T	Schedule II

Annexure 5: Site-wise macroinvertebrate results

Descriptions, photographs and species checklists for the 11 macroinvertebrate sampling sites (Chapter 10). The cross-site summary is in Table 10.3.2.

Site 1

This site was located near Talawade village. The habitat was shallow with gravelly substrate, fine sediment. Decaying sediment was absent, water was relatively clean. There was a bund upstream, which was trapping the floating vegetation like water hyacinth (*Eichhornia* sp.) and water cabbage (*Pistia* sp.).



Figure 10.3.2 a: Location and photos of Site 1

This habitat showed a remarkable diversity of macroinvertebrates, with 12 species belonging to 6 different groups. The shallow habitat proved to be ideal for molluscs as 6 different species were present in the sample. There was a notable number of freshwater limpet - *Pettancylus tenuis*, which is a rarely encountered freshwater mollusc. We also observed few specimens of a freshwater sponge in this habitat, which is considered to be an ecological indicator, as this group is usually found in unpolluted habitats. We also encountered two other ecological indicator species: mayfly larvae and caddisfly larvae, which are members of dominant groups of aquatic insects and are usually found in habitats with flowing water and abundant dissolved oxygen.

These observations indicate that Site 1 is a suitable habitat for aquatic diversity as it supports multiple species of macroinvertebrates from a variety of taxa. The species collected also exhibit trophic level diversity as there are representatives of all consumer trophic levels, from detritivores and filterers to predators. These observations are supported by the low values of some crucial water parameters such as nitrates, phosphates, BOD and faecal coliforms, which suggest that this site is not heavily contaminated by agricultural runoff or organic pollutants.

Table 10.3.2 a: Macroinvertebrate diversity recorded from Site 1

Sr No	Common name	Scientific name	Classification	Relative abundance in the sample	Ecological role	Remarks
1	Freshwater sponge	<i>Corvospongilla</i> sp.	Spongillidae / Porifera	Low	Filterer	Ecological indicator
2	Pond snail	<i>Radix luteola</i>	Lymnaeidae / Gastropoda	Moderate	Grazer	
3	Freshwater limpet	<i>Pettancylus tenuis</i>	Planorbidae / Gastropoda	High	Scraper	
4	Freshwater snail	<i>Filopaludina bengalensis</i>	Viviparidae / Gastropoda	Low	Grazer	
5	Malaysian trumpet snail	<i>Melanooides tuberculata</i>	Thiaridae / Gastropoda	Moderate	Detritivore	
6	Freshwater clam	<i>Corbicula</i> sp.	Corbiculidae / Bivalvia	Moderate	Filterer	
7	Freshwater mussel	<i>Lamellidens</i> sp.	Unionidae / Bivalvia	Moderate	Filterer	
8	Non-biting midge larva	<i>Chironomus</i> sp.	Chironomidae / Diptera	Low	Detritivore	Ecological indicator
9	Small square-gilled mayfly larva	Caenidae sp.	Caenidae / Ephemeroptera	Moderate	Grazer	Ecological indicator
10	Free-living green caddisfly larva	Rhyacophilidae sp.	Rhyacophilidae / Trichoptera	Moderate	Predator	Ecological indicator
11	Water strider bug	<i>Aquarius adalaidis</i>	Gerridae / Hemiptera	High	Predator	
12	Pygmy boatman bug	<i>Micronecta</i> sp.	Micronectidae / Hemiptera	High	Herbivore	

Site 2

This site was located near Chikhali and Moi villages. The flow of water was gradual. The depth at the sampling location was considerably deep. There was sewage discharge, mixed with water from a nullah. There was black, decaying sediment, causing the eruption of methane bubbles. There was also agricultural runoff.



Figure 10.3.2 b: Location and photos of Site 2

This habitat showed a comparatively low diversity of aquatic macroinvertebrates (5 species belonging to 3 taxa), with a notably low abundance for all the species collected. Most of the species found here are pollution tolerant species of the Order Diptera, which can survive in hypoxic (low oxygen) conditions. The water parameter values for this site indicate organic pollution and mixing of river water with agricultural runoff (high nitrate values).

Table 10.3.2 b: Macroinvertebrate diversity recorded from Site 2

Sr No	Common name	Scientific name	Classification	Relative abundance in the sample	Ecological role	Remarks
1	True worm	Annelida sp.	Annelida	Low	Detritivore	
2	Non-biting midge larva	<i>Chironomus</i> sp.	Chironomidae / Diptera	Low	Detritivore	Ecological indicator
3	Mosquito larva	Culicidae sp.	Culicidae / Diptera	Low	Filterer	
4	Shorefly larva	Ephydriidae sp.	Ephydriidae / Diptera	Low	Detritivore	Ecological indicator
5	Pygmy boatman bug nymph	<i>Micronecta</i> sp.	Micronectidae / Hemiptera	Low	Herbivore	

Site 3

The site was located near Moshi village. There was black, decaying sediment. The flow of water was gradual, the water was green in colour and was malodorous. Clumps of floating vegetation could be seen near the banks (*Eichhornia*, *Pistia* and *Lemna*). There was solid waste contamination.

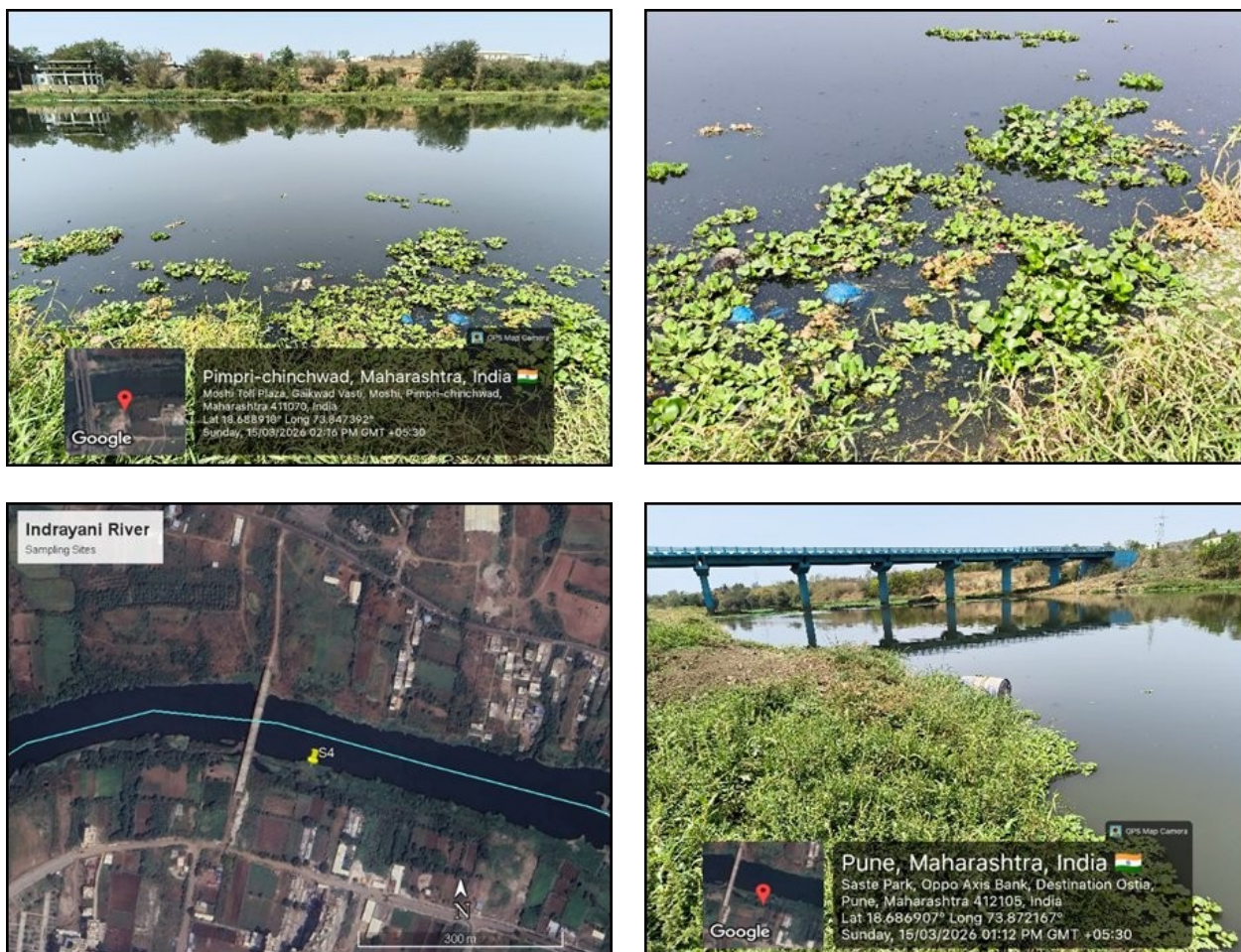


Figure 10.3.2 c: Location and photos of Site 3

Site 3 showed a remarkable diversity of macroinvertebrates, despite showing high levels of water pollution. We encountered 13 species belonging to 7 taxa, but this habitat was characterised by low abundances for most of the collected species. The most abundant species found here were the pollution tolerant mosquito larvae and non-biting midge larvae. This finding is consistent with the water quality at this location, as high levels of organic pollution and decaying sediment create hypoxic conditions, which are unsustainable for most aquatic species. We also collected a leech in this habitat, which is a common parasite on fish species.

Table 10.3.2 c: Macroinvertebrate diversity recorded from Site 3

Sr No	Common name	Scientific name	Classification	Relative abundance in the sample	Ecological role	Remarks
1	Leech	<i>Piscicola</i> sp.	Piscicolidae / Annelida	Low	Parasite	Ectoparasite on fishes
2	Pond snail	<i>Radix luteola</i>	Lymnaeidae / Gastropoda	Moderate	Grazer	
3	Malaysian trumpet snail	<i>Melanoides tuberculata</i>	Thiaridae / Gastropoda	Low	Detritivore	
4	Non-biting midge larva	<i>Chironomus</i> sp.	Chironomidae / Diptera	High	Detritivore	Ecological indicator
5	Mosquito larva / pupa	Culicidae sp.	Culicidae / Diptera	High	Filterer	
6	Shorefly pupa	Ephydriidae sp.	Ephydriidae / Diptera	Moderate	Detritivore	Ecological indicator
7	Sewer fly larva	Psychodidae sp.	Psychodidae / Diptera	Low	Detritivore	Ecological indicator

Sr No	Common name	Scientific name	Classification	Relative abundance in the sample	Ecological role	Remarks
8	Predacious diving beetle adult / larva	<i>Hydrovatus</i> sp.	Dytiscidae / Coleoptera	Low	Predator	
9	Water scavenger beetle larva	Hydrophilidae sp.	Hydrophilidae / Coleoptera	Moderate	Predator	
10	Bush dart damselfly nymph	Platycnemididae sp.	Platycnemididae / Odonata	Low	Predator	
11	Giant water bug nymph	<i>Diplonychus rusticus</i>	Belostomatidae / Hemiptera	Low	Predator	
12	Pondweed bug	<i>Mesovelia</i> sp.	Mesoveliidae / Hemiptera	Moderate	Omnivore	Semi-aquatic
13	Seed shrimp	<i>Chlamydotheca</i> sp.	Ostracoda / Crustacea	Low	Detritivore	

Site 4

This site was located near Moshi and Dudulgaon villages. The floating vegetation spread was arrested with a net, few loose clumps could be seen near the banks. The sediment was black and decaying, there was a sewage influx at the collection site.



Figure 10.3.2 d: Location and photos of Site 4

This habitat was also characterised by a comparatively low diversity of macroinvertebrates with only 6 species present, which belonged to four different taxa. There was a very high abundance of mosquito larvae and non-biting

midge larvae, followed by a moderate abundance of shorefly larvae. Two species of aquatic bugs and beetles were also encountered and were seen to be associated with the aquatic vegetation.

Table 10.3.2 d: Macroinvertebrate diversity recorded from Site 4

Sr No	Common name	Scientific name	Classification	Relative abundance in the sample	Ecological role	Remarks
1	Pond snail	<i>Radix luteola</i>	Lymnaeidae / Gastropoda	Moderate	Grazer	
2	Non-biting midge larva	<i>Chironomus</i> sp.	Chironomidae / Diptera	High	Detritivore	Ecological indicator
3	Mosquito larva	Culicidae sp.	Culicidae / Diptera	High	Filterer	
4	Shorefly larva	Ephydriidae sp.	Ephydriidae / Diptera	Moderate	Detritivore	Ecological indicator
5	Water scavenger beetle	<i>Berosus indicus</i>	Hydrophilidae / Coleoptera	Moderate	Scavenger	
6	Pygmy boatman bug	<i>Micronecta</i> sp.	Micronectidae / Hemiptera	Moderate	Herbivore	

Site 5

This site was located in Alandi town. The habitat was shallow, the flow of water was moderate. There was an influx of sewage, making the water black in colour and malodorous. Decaying fine black sediment and methane bubbles were observed. *Eichhornia* and *Pistia* clumps were present.



Figure 10.3.2 e: Location and photos of Site 5

This site was present in a heavily urbanised stretch of the river and was characterised by the lowest diversity of aquatic macroinvertebrates. We encountered only three species here, all belonging to Order Diptera. Two of these species (*Chironomus* sp. and Ephydriidae sp.) are considered to be indicators of pollution as these larvae are capable of living in low-oxygen conditions and are often encountered in heavily polluted habitats. This site showed a high abundance of mosquito larvae as well, which is a significant observation, considering the consequences for this urban location.

Table 10.3.2 e: Macroinvertebrate diversity recorded from Site 5

Sr No	Common name	Scientific name	Classification	Relative abundance in the sample	Ecological role	Remarks
1	Non-biting midge larva	<i>Chironomus</i> sp.	Chironomidae / Diptera	High	Detritivore	Ecological indicator
2	Mosquito larva	Culicidae sp.	Culicidae / Diptera	High	Filterer	
3	Shorefly larva	Ephydriidae sp.	Ephydriidae / Diptera	Moderate	Detritivore	Ecological indicator

Site 6

This site was downstream of a small bund and was located near Charholi village. The flow of water was gradual, the water was green and soapy, and the sediment was sticky, probably due to detergent pollution. Clumps of *Eichhornia*, *Pistia* and *Lemna* were seen near the banks.



Figure 10.3.2 f: Location and photos of Site 6

This habitat showed a moderate diversity of macroinvertebrates, with 8 species belonging to 6 taxa. Most of the species were present in low to moderate abundances, with a dominance of non-biting midge larvae. The water scavenger beetle larvae, pond snails and pondweed bugs were seen to be associated with the clumps of floating vegetation. But this habitat showed a moderate ecological diversity, as the species represent most trophic levels and there are multiple species of predators, but all of them are generalist species with a wide prey base, which might be the reason they are commonly encountered in a variety of aquatic habitats.

Table 10.3.2 f: Macroinvertebrate diversity recorded from Site 6

Sr No	Common name	Scientific name	Classification	Relative abundance in the sample	Ecological role	Remarks
1	Leech	<i>Piscicola</i> sp.	Piscicolidae / Annelida	Low	Parasite	Ectoparasite on fishes
2	Pond snail	<i>Radix luteola</i>	Lymnaeidae / Gastropoda	Moderate	Grazer	
3	Non-biting midge larva	<i>Chironomus</i> sp.	Chironomidae / Diptera	High	Detritivore	Ecological indicator
4	Shorefly larva	Ephydriidae sp.	Ephydriidae / Diptera	Moderate	Detritivore	Ecological indicator
5	Water scavenger beetle larva 1	Hydrophilidae sp. 1	Hydrophilidae / Coleoptera	Moderate	Predator	
6	Water scavenger beetle larva 2	Hydrophilidae sp. 2	Hydrophilidae / Coleoptera	Low	Predator	
7	Small square-gilled mayfly larva	Caenidae sp.	Caenidae / Ephemeroptera	Low	Grazer	Ecological indicator
8	Pondweed bug	<i>Mesovelgia</i> sp.	Mesoveliidae / Hemiptera	Moderate	Omnivore	Semi-aquatic

Site 7

This site, located near Nargudi and Dhanore villages, was downstream of a bund, and was completely covered in floating vegetation (both *Eichhornia* and *Pistia*). The flow of water through the bund was leading to an accumulation of foam near the bund. The sediment was black and decaying.



Figure 10.3.2 g: Location and photos of Site 7

This habitat was completely covered by floating vegetation (*Eichhornia* and *Pistia*) and showed moderate macroinvertebrate diversity. A total of 12 species from 6 invertebrate taxa were recorded from this site. Among these, the abundance of non-biting midge larvae, shore fly pupae and hover fly larvae indicates the deteriorated ecological state of the waterbody. The high number of mosquito larvae and pupae is due to the excessive growth of invasive *Eichhornia* floating vegetation which stagnates the water and create suitable breeding grounds for mosquitoes. There is moderate diversity and low number of predators like beetle larvae, damsel fly nymph and bug nymphs, which indicates disturbed food web and ecological disturbance.

The moderate diversity, with dominance of pollution tolerant taxa, observed at this site correlates with the elevated levels of nitrates, orthophosphates, BOD and COD. It evidently shows that this site is heavily polluted with organic load which is affecting its biodiversity.

Table 10.3.2 g: Macroinvertebrate diversity recorded from Site 7

Sr No	Common name	Scientific name	Classification	Relative abundance in the sample	Ecological role	Remarks
1	True worm	Annelida sp.	Annelida	Moderate	Detritivore	
2	Freshwater snail	<i>Filopaludina bengalensis</i>	Viviparidae / Gastropoda	Low	Grazer	
3	Non-biting midge larva	<i>Chironomus</i> sp.	Chironomidae / Diptera	High	Detritivore	Ecological indicator
4	Mosquito larva/pupa	Culicidae sp.	Culicidae / Diptera	High	Filterer	
5	Shore fly pupa	Ephydriidae sp.	Ephydriidae / Diptera	Moderate	Detritivore	Ecological indicator

Sr No	Common name	Scientific name	Classification	Relative abundance in the sample	Ecological role	Remarks
6	Hover fly larva	Syrphidae sp.	Syrphidae / Diptera	Low	Detritivore	Ecological indicator
7	Predacious diving beetle larva 1	Dytiscidae sp. 1	Dytiscidae / Coleoptera	Low	Predator	
8	Predacious diving beetle larva 2	Dytiscidae sp. 2	Dytiscidae / Coleoptera	Low	Predator	
9	Water scavenger beetle larva	Hydrophilidae sp.	Hydrophilidae / Coleoptera	Low	Predator	
10	Water scavenger beetle	<i>Enochrus</i> sp.	Hydrophilidae / Coleoptera	Low	Scavenger	
11	Bush dart damselfly nymph	Platycnemididae sp.	Platycnemididae / Odonata	Moderate	Predator	
12	Backswimmer bug nymph	<i>Anisops</i> sp.	Notonectidae / Hemiptera	Low	Predator	

Site 8

This site, located near Wadgaon Shinde, was downstream of a bund. It was completely covered with *Eichhornia* (dominant) and *Pistia* downstream of the bund. The water was blackish, mildly malodorous, and there was some amount of foam present. The sediment had silt and black, decaying organic matter.



Figure 10.3.2 h: Location and photos of Site 8

This habitat was completely covered by floating vegetation (*Eichhornia* and *Pistia*) and showed low macroinvertebrate diversity. A total of 7 species from 3 invertebrate taxa were recorded from this site. Among these, the presence of non-biting midge larvae in considerable number, indicates the degraded ecological state of the waterbody. The high number of mosquito larvae and pupae was due to the excessive growth of floating vegetation. Three species of freshwater snails were found in low number. Two bug species were reported, of which the herbivore Pygmy boatman bug was dominantly present.

The lack of other macroinvertebrate biodiversity is due to the ecological disturbance to the habitat caused by the organic pollution, which is evident from the high values recorded for Nitrates and BOD.

Table 10.3.2 h: Macroinvertebrate diversity recorded from Site 8

Sr No	Common name	Scientific name	Classification	Relative abundance in the sample	Ecological role	Remarks
1	Bladder snail	<i>Physella acuta</i>	Physidae / Gastropoda	Low	Grazer	
2	Trumpet snail	<i>Melanoides</i> sp.	Thiaridae / Gastropoda	Low	Detritivore	
3	Freshwater snail	<i>Filopaludina bengalensis</i>	Viviparidae / Gastropoda	Low	Grazer	
4	Non-biting midge larva	<i>Chironomus</i> sp.	Chironomidae / Diptera	Moderate	Detritivore	Ecological indicator
5	Mosquito larva / pupa	Culicidae sp.	Culicidae / Diptera	High	Filterer	
6	Pygmy boatman bug	<i>Micronecta quadristrigata</i>	Micronectidae / Hemiptera	High	Herbivore	
7	Backswimmer bug nymph	<i>Anisops</i> sp.	Notonectidae / Hemiptera	Low	Predator	

Site 9

This site was located near Bhawadi village. The habitat was shallow (0.5 m in depth) with rocky substrate, silt, and almost no sediment. Some floating vegetation (*Pistia* and *Eichhornia*) was seen in small clumps.



Figure 10.3.2 i: Location and photos of Site 9

This site, surrounded by the agricultural fields, and with a limited growth of floating vegetation showed moderate macroinvertebrate diversity, with 10 species recorded from 6 taxa. The true worms and pygmy boatman bugs were in abundance suggesting the nutrient cycling and primary productivity. The other species recorded were low in number.

The lack of other macroinvertebrate taxa is due to the ecological disturbance to the habitat caused by the organic pollution, which is evident from the high values recorded for Nitrates and BOD.

Table 10.3.2 i: Macroinvertebrate diversity recorded from Site 9

Sr No	Common name	Scientific name	Classification	Relative abundance in the sample	Ecological role	Remarks
1	True worm	Annelida sp.	Annelida	High	Detritivore	
2	Leech	<i>Piscicola</i> sp.	Piscicolidae / Annelida	Low	Parasite	Ectoparasite on fishes
3	Freshwater limpet	<i>Pettancylus tenuis</i>	Planorbidae / Gastropoda	Low	Scraper	
4	Freshwater mussel	<i>Lamellidens</i> sp.	Unionidae / Bivalvia	Low	Filterer	
5	Non-biting midge larva	<i>Chironomus</i> sp.	Chironomidae / Diptera	Low	Detritivore	Ecological indicator
6	Predacious diving beetle	<i>Peschetius</i> sp.	Dytiscidae / Coleoptera	Low	Predator	
7	Water scavenger beetle larva	Hydrophilidae sp.	Hydrophilidae / Coleoptera	Low	Predator	

Sr No	Common name	Scientific name	Classification	Relative abundance in the sample	Ecological role	Remarks
8	Water scavenger beetle 1	<i>Berosus pulchellus</i>	Hydrophilidae / Coleoptera	Low	Scavenger	
9	Water scavenger beetle 2	<i>Enochrus</i> sp.	Hydrophilidae / Coleoptera	Low	Scavenger	
10	Pygmy boatman bug / nymph	<i>Micronecta quadristrigata</i>	Micronectidae / Hemiptera	High	Herbivore	

Site 10

This site was located near Markal and Tulapur villages. It was completely covered with floating vegetation, *Pistia* and *Eichhornia*, with considerable depth. The flow of water was very slow. The sediment was black in colour.



Figure 10.3.2 j: Location and photos of Site 10

Despite being completely covered by *Pistia* and *Eichhornia*, this site showed high diversity of invertebrates, with 20 species from 8 invertebrate taxa. Among these, pond snails, sewer fly larvae and pupae and fruit fly larvae and pupae were abundantly present. The occurrence and number of larvae of non-biting midges, shore flies, sewer flies and hover flies indicate an organically polluted water body. Moderate diversity of beetles and low diversity for insect groups like mayflies, bugs and moths (caterpillars) was recorded.

The BOD and COD values at this site exceed the desired limits, indicating the polluted state of the river. Nitrate and orthophosphate levels are moderate, likely due to the uptake of these macronutrients by excessive floating vegetation.

Table 10.3.2 j: Macroinvertebrate diversity recorded from Site 10

Sr No	Common name	Scientific name	Classification	Relative abundance in the sample	Ecological role	Remarks
1	True worm	Annelida sp.	Annelida	Low	Detritivore	
2	Leech	<i>Piscicola</i> sp.	Piscicolidae / Annelida	Moderate	Parasite	Ectoparasite on fishes
3	Pond Snail	<i>Lymnaea</i> sp.	Lymnaeidae / Gastropoda	High	Grazer	
4	Freshwater limpet	<i>Pettancylus tenuis</i>	Planorbidae / Gastropoda	Moderate	Grazer	
5	Non-biting midge larva	<i>Chironomus</i> sp.	Chironomidae / Diptera	Moderate	Detritivore	Ecological indicator
6	Shore fly larva / pupa	Ephydriidae sp.	Ephydriidae / Diptera	Low	Detritivore	Ecological indicator
7	Sewer fly larva / pupa	Psychodidae sp.	Psychodidae / Diptera	High	Detritivore	Ecological indicator
8	Hover fly larva	Syrphidae sp.	Syrphidae / Diptera	Low	Detritivore	Ecological indicator

Sr No	Common name	Scientific name	Classification	Relative abundance in the sample	Ecological role	Remarks
9	Fruitfly larva / pupa 1	Drosophilidae sp.	Drosophilidae / Diptera	High	Decomposer	
10	Fruitfly larva / pupa 2	Tephritidae sp.	Tephritidae / Diptera	Low	Decomposer	
11	Water scavenger beetle 1	<i>Enochrus</i> sp.	Hydrophilidae / Coleoptera	Low	Scavenger	
12	Water scavenger beetle 2	<i>Sternolophus</i> sp.	Hydrophilidae / Coleoptera	Low	Scavenger	
13	Water scavenger beetle larva 1	Hydrophilidae sp.	Hydrophilidae / Coleoptera	Low	Predator	
14	Water scavenger beetle larva 2	Hydrophilidae sp.	Hydrophilidae / Coleoptera	Low	Predator	
15	Rove beetle	Staphylinidae sp.	Staphylinidae / Coleoptera	Low	Predator	Semi-aquatic
16	Small minnow mayfly larva	Baetidae sp.	Baetidae / Ephemeroptera	Low	Grazer	Ecological indicator
17	Bush dart damselfly nymph	Platycnemididae sp.	Platycnemididae / Odonata	Low	Predator	
18	Pygmy backswimmer bug	<i>Paraplea frontalis</i>	Pleidae / Hemiptera	Low	Predator	
19	Moth caterpillar 1	Lepidoptera sp. 1	Lepidoptera / Insecta	Low	Herbivore	
20	Moth caterpillar / Pupa 2	Lepidoptera sp. 2	Lepidoptera / Insecta	Low	Herbivore	

Site 11

This site was located near Tulapur village. It had steep banks with no emergent vegetation. The flow of water was very slow, almost still water in shallow parts of the habitat. The water was turbid. Floating vegetation was present: *Pistia* and *Lemna*.

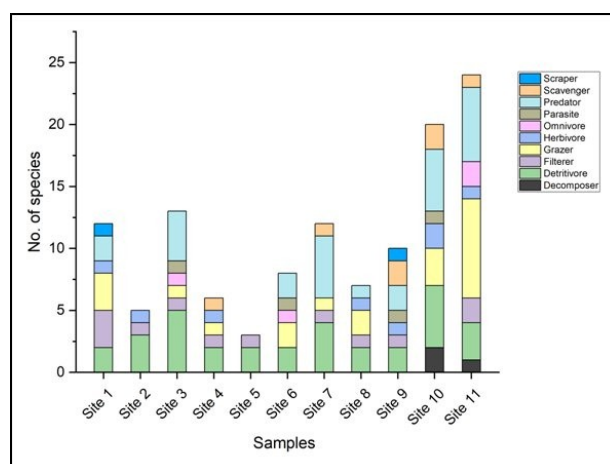
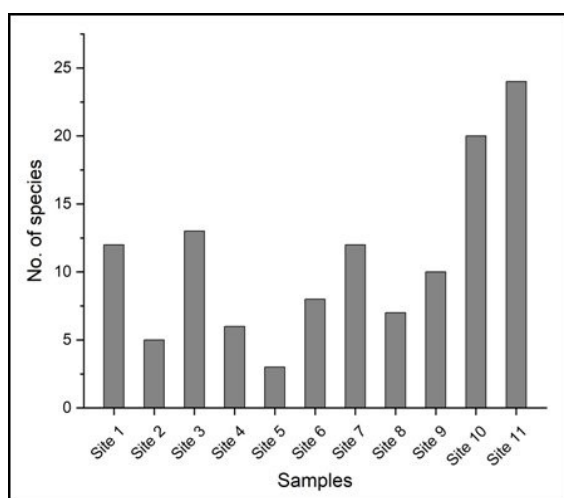


Figure 10.3.2 k: Location and photos of Site 11

This was located just before the Indrayani and Bhima river confluence. The highest diversity of macroinvertebrates was recorded from this site. A total of 24 species from 10 taxa were recorded from this site. Among these, groups like Gastropoda and Hemiptera were the most species-rich, whereas Coleoptera and Ephemeroptera were moderately diverse. The abundance of snails from this site denotes the high primary productivity. Presence and abundance of species from multiple insect orders occupying diverse ecological roles indicate a balanced ecosystem. Occurrence and good number of mayflies from two families indicate good ecological conditions and a healthy aquatic ecosystem.

BOD and COD values for this site are higher than the desired values which is likely due to the organic pollution this site receives from the upstream areas.

Table 10.3.2 k: Macroinvertebrate diversity recorded from Site 11

Sr No	Common name	Scientific name	Classification	Relative abundance in the sample	Ecological role	Remarks
1	Moss animals	Phylactolaemata sp.	Phylactolaemata / Bryozoa	Low	Filterer	Statoblasts found
2	Pond snail	<i>Radix</i> sp.	Lymnaeidae / Gastropoda	Low	Grazer	
3	Bladder snail	<i>Physella acuta</i>	Physidae / Gastropoda	High	Grazer	
4	Trumpet snail 1	<i>Melanooides</i> sp. 1	Thiaridae / Gastropoda	Moderate	Detritivore	

Sr No	Common name	Scientific name	Classification	Relative abundance in the sample	Ecological role	Remarks
5	Trumpet snail 2	<i>Melanoides</i> sp. 2	Thiaridae / Gastropoda	Low	Detritivore	
6	Freshwater snail 1	<i>Idiopoma</i> sp.	Viviparidae / Gastropoda	Moderate	Grazer	
7	Freshwater snail 2	<i>Filopaludina bengalensis</i>	Viviparidae / Gastropoda	Low	Grazer	
8	Freshwater mussel	<i>Lamellidens</i> sp.	Unionidae / Bivalvia	Moderate	Filterer	
9	Non-biting midge larva	<i>Chironomus</i> sp.	Chironomidae / Diptera	Moderate	Detritivore	Ecological indicator
10	Housefly larva	Muscidae sp.	Muscidae / Diptera	Low	Decomposer	
11	Predacious diving beetle	<i>Peschetius</i> sp.	Dytiscidae / Coleoptera	Low	Predator	
12	Water scavenger beetle larva	Hydrophilidae sp.	Hydrophilidae / Coleoptera	Low	Predator	
13	Small minnow mayfly larva	Baetidae sp.	Baetidae / Ephemeroptera	High	Grazer	Ecological indicator
14	Small square-gilled mayfly larva	Caenidae sp.	Caenidae / Ephemeroptera	Low	Grazer	Ecological indicator
15	Glories damselfly nymph	Calopterygidae sp.	Calopterygidae / Odonata	Moderate	Predator	
16	Giant water bug	<i>Diplonychus rusticus</i>	Belostomatidae / Hemiptera	Low	Predator	
17	Water strider bug	<i>Limnometra fluviorum</i>	Gerridae / Hemiptera	Moderate	Predator	
18	Pondweed bug nymph	<i>Mesovelia</i> sp.	Mesoveliidae / Hemiptera	Low	Omnivore	
19	Pygmy boatman bug 1	<i>Micronecta quadristrigata</i>	Micronectidae / Hemiptera	Low	Grazer	
20	Pygmy boatman bug 2	<i>Micronecta ludibunda</i>	Micronectidae / Hemiptera	Low	Grazer	
21	Pygmy backswimmer bug	<i>Paraplea frontalis</i>	Pleidae / Hemiptera	High	Predator	
22	Moth caterpillar	Lepidoptera sp.	Lepidoptera / Insecta	Low	Herbivore	
23	Freshwater prawn	<i>Macrobrachium</i> sp.	Palaemonidae / Decapoda	High	Omnivore	
24	Crab	Brachyura sp.	Brachyura / Decapoda	Low	Scavenger	Moult found

Annexure 6: Checklists of butterflies and odonates

Butterflies were recorded on six survey days between 29 January and 17 February 2026, and odonates at six sites (A1–A6) (Chapter 8). WPA schedule = schedule under the Wild Life (Protection) Act, 1972, as amended in 2022.

Table A6.1: Butterflies

Sr. No.	Common name	Scientific name	Family	Surveys recorded (of 6)	WPA schedule
1	Indian Jezebel	<i>Delias eucharis</i>	Pieridae	2	Not scheduled
2	Common Grass Yellow	<i>Eurema hecabe</i>	Pieridae	4	Not scheduled
3	Indian Wanderer	<i>Pareronia hippia</i>	Pieridae	1	Not scheduled
4	Plain Tiger	<i>Danaus chrysippus</i>	Nymphalidae	3	Not scheduled
5	Striped Tiger	<i>Danaus genutia</i>	Nymphalidae	3	Not scheduled
6	Grey Pansy	<i>Junonia atlites</i>	Nymphalidae	2	Not scheduled
7	Lemon Pansy	<i>Junonia lemonias</i>	Nymphalidae	6	Not scheduled
8	Blue Pansy	<i>Junonia orithya</i>	Nymphalidae	1	Not scheduled
9	Blue Tiger	<i>Tirumala limniace</i>	Nymphalidae	1	Not scheduled
10	Common Three-Ring	<i>Ypthima asterope</i>	Nymphalidae	1	Not scheduled
11	Common Five-Ring	<i>Ypthima baldus</i>	Nymphalidae	1	Not scheduled
12	Common Four-Ring	<i>Ypthima huebneri</i>	Nymphalidae	1	Not scheduled
13	African Babul Blue	<i>Azanus jesous</i>	Lycaenidae	2	Not scheduled
14	Common Cerulean	<i>Jamides celeno</i>	Lycaenidae	1	Not scheduled
15	Zebra Blue	<i>Leptotes plinius</i>	Lycaenidae	4	Not scheduled
16	Tailless Lineblue	<i>Prosotas dubiosa</i>	Lycaenidae	6	Schedule II
17	Common Line Blue	<i>Prosotas nora</i>	Lycaenidae	1	Not scheduled
18	Blue Pierrots	<i>Tarucus</i> sp.	Lycaenidae	1	Not scheduled
19	Dark Grass Blue	<i>Zizeeria karsandra</i>	Lycaenidae	3	Not scheduled
20	Lesser Grass Blue	<i>Zizina otis</i>	Lycaenidae	1	Not scheduled
21	Tiny Grass Blue	<i>Zizula hylax</i>	Lycaenidae	3	Not scheduled
22	Common Banded Awl	<i>Hasora chromus</i>	Hesperiidae	1	Not scheduled

Table A6.2: Odonates

Sr. No.	Common name	Scientific name	Family	Sites recorded (of 6)	WPA schedule
1	Ditch Jewel	<i>Brachythemis contaminata</i>	Libellulidae	2	Not scheduled
2	Granite Ghost	<i>Bradinopyga geminata</i>	Libellulidae	1	Not scheduled
3	Ruddy Marsh Skimmer	<i>Crocothemis servilia</i>	Libellulidae	1	Not scheduled
4	Wandering Glider	<i>Pantala flavescens</i>	Libellulidae	1	Not scheduled
5	Pygmy Dartlet	<i>Agriocnemis pygmaea</i>	Coenagrionidae	3	Not scheduled
6	Common Bluetail	<i>Ischnura senegalensis</i>	Coenagrionidae	3	Not scheduled
7	Saffron-faced Blue Dart	<i>Pseudagrion rubriceps</i>	Coenagrionidae	3	Not scheduled
8	Yellow Featherlegs	<i>Copera marginipes</i>	Platycnemididae	3	Not scheduled

Annexure 7: Habitats recorded at each location in the rapid assessment

Habitats are taken from the rapid-survey notes for each location (November 2025). W5, E16, E17, E24 and E35–E38 could not be surveyed. Old, mature trees are as recorded by the flora team.

Stretch	Location	River bank habitats	River bed habitats and water inflows	Farmland up to the bank
W1	Talawade	Narrow strip of riparian trees	–	Yes
W2	Talawade	Narrow strip of riparian trees	Mudflats at meander	Yes
W3	Nighoje	Narrow strip of riparian trees	–	Yes
W4	Shinde Vasti	Riparian woodland	Stream	Yes
W6	Moi	Riparian woodland; old, mature trees	Stream	
W7	Pimpri (Kashi Guruji temple)	Mixed or degraded vegetation; plantation	Stream confluence	Yes
W8	Jadhav Wadi	Mixed or degraded vegetation	Sandbars, stream	Yes
W9	Chikhali	Narrow strip of riparian trees	Sandbars, stream	
W10	Kinara Nexus	Mixed or degraded vegetation; wetland	Sandbars	
W11	Kurali, Moshi	Narrow strip of riparian trees	–	
W12	Moshi, Chikhali	Narrow strip of riparian trees	–	Yes
W13	Chimboli, Moshi	Riparian woodland	–	Yes
W14	Moshi	Narrow strip of riparian trees	–	Yes
W15	Dudulgaon	Narrow strip of riparian trees; old, mature trees	Mudflats at meander	
W16	Kelgaon	Narrow strip of riparian trees; plantation	–	Yes
W17	Kelgaon	Narrow strip of riparian trees; grassy floodplain	–	Yes
W18	Siddhabet, Alandi	Riparian woodland; old, mature trees; wetland	–	
W19	Alandi	Mixed or degraded vegetation; plantation	–	
W20	Devachi Alandi	Mixed or degraded vegetation; floodplain	–	
W21	Charholi	Mixed or degraded vegetation; floodplain	–	Yes
W22	Charholi	Riparian woodland; old, mature trees; floodplain	Sandbars, rocky outcrops, stream	
W23	Charholi	Riparian woodland; old, mature trees; floodplain	Sandbars, rocky outcrops, island	
W24	Charholi	Riparian woodland; old, mature trees; floodplain	Sandbars, stream, meander	
W25	Charholi	Mixed or degraded vegetation; floodplain	Sandbars, mudflats, rocky outcrops, island, stream	
W26	Charholi (Hiramata temple)	Narrow strip of riparian trees	Mudflats, stream	

Stretch	Location	River bank habitats	River bed habitats and water inflows	Farmland up to the bank
E1	Tulapur (Indrayani-Bhima confluence)	Narrow strip of riparian trees; old, mature trees	River confluence	Yes
E2	Tulapur	Riparian woodland	Stream	
E3	Tulapur	Narrow strip of riparian trees	-	Yes
E4	Tulapur	Narrow strip of riparian trees	Stream	Yes
E5	Tulapur	Narrow strip of riparian trees; old, mature trees	-	Yes
E6	Markal	Riparian woodland; old, mature trees	-	Yes
E7	Markal	Mixed or degraded vegetation	-	Yes
E8	Markal	Mixed or degraded vegetation	-	Yes
E9	Markal	Mixed or degraded vegetation	-	
E10	Markal	Mixed or degraded vegetation	-	Yes
E11	Markal	Mixed or degraded vegetation; old, mature trees	Mudflats	
E12	Markal	Mixed or degraded vegetation	Stream	
E13	Tulapur	Riparian woodland	-	Yes
E14	Markal	Riparian woodland; old, mature trees	-	Yes
E15	Markal	Riparian woodland	-	Yes
E18	Markal	Riparian woodland; old, mature trees; wetland	Stream	
E19	Markal	Riparian woodland; old, mature trees	-	
E20	Markal	Mixed or degraded vegetation; old, mature trees	Sandbars	
E21	Markal	Riparian woodland; old, mature trees	-	
E22	Markal	Mixed or degraded vegetation	-	
E23	Markal	Mixed or degraded vegetation	-	Yes
E25	Bhawadi	Mixed or degraded vegetation	Mudflats, rocky outcrops	
E26	Bhawadi	Riparian woodland	Rocky outcrops	Yes
E27	Bhawadi	Riparian woodland; old, mature trees	-	
E28	Bhawadi	Riparian woodland; old, mature trees; floodplain	Mudflats at meander	Yes
E29	Bhawadi	Riparian woodland	Spring	
E30	Shinde Vasti	Riparian woodland; old, mature trees; floodplain	Sandbars, mudflats	
E31	Shinde Vasti	Mixed or degraded vegetation	-	
E32	Golegaon	Riparian woodland; floodplain	Sandbars	
E33	Golegaon	Mixed or degraded vegetation; plantation	-	
E34	Vadgaon Shinde	Mixed or degraded vegetation	Sandbars, island	

Stretch	Location	River bank habitats	River bed habitats and water inflows	Farmland up to the bank
E39	Nirgudi, Solu	Mixed or degraded vegetation	-	
E40	Solu	Riparian woodland; old, mature trees	Sandbars, rocky outcrops, 4 streams, 9 springs	
E41	Solu	Riparian woodland; old, mature trees	Sandbars	