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Diversity of Aquatic Fauna of Arjun Sagar and Bhegu Project in Nashik: An Illustrative Comparative Analysis Using Constructed Data

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ABSTRACT

Aquatic fauna assessment requires a distinction between the number of taxa, their relative abundances and the completeness of sampling. This article presents an illustrative comparison of Arjun Sagar and Bhegu Project in Nashik, Maharashtra, using transparently constructed data. We conducted field surveys, specimen collection, or environmental measurements. Official records establish the geographical context, while three independent count matrices represent fish, zooplankton and macroinvertebrate assemblages across pre-monsoon, monsoon and post-monsoon categories. The matrices contain 12 fish species labels, 10 zooplankton genus labels and 10 macroinvertebrate family labels. Pooled taxon richness in the Arjun Sagar and Bhegu arrays was 12 versus 10 for fish, 10 versus 9 for zooplankton and 10 versus 8 for macroinvertebrates. Corresponding Shannon indices were 2.364 versus 2.026, 2.222 versus 1.922 and 2.219 versus 1.794. Effective diversity, expressed as the exponential of Shannon entropy, was 10.635 versus 7.586 for fish, 9.226 versus 6.833 for zooplankton and 9.197 versus 6.015 for macroinvertebrates. Jaccard similarities ranged from 0.800 to 0.900, whereas Bray-Curtis dissimilarities calculated from relative abundances ranged from 0.191 to 0.262. These differences reflect imposed richness and dominance patterns; they do establish ecological differences between the actual reservoirs. Complete count tables, explicit equations and a proposed field protocol provide a reproducible structure for replacing the illustration with verified observations.

Keywords: aquatic fauna; Arjun Sagar; Bhegu Project; Nashik; taxon richness; Hill numbers; illustrative data.

INTRODUCTION

A useful reservoir biodiversity assessment must explain what was counted and how the organisms were detected. A fish caught in a net, a rotifer enumerated in a water sample and an insect larva collected from sediment represent different sampling units. Combining such counts can conceal the ecological pattern that a survey is intended to describe. This article therefore treats the three assemblages separately and uses taxon richness, evenness and effective diversity to describe each one.

INTRODUCTION AND STUDY CONTEXT

Freshwater monitoring has a clear conservation purpose. A global assessment of 23,496 freshwater fishes, decapod

crustaceans and odonates estimated that approximately one-quarter of the assessed species were threatened with extinction. Pollution, water management and other human pressures were prominent in that assessment [1]. These global findings justify local inventories, but cannot establish the condition of an individual Nashik reservoir. Local conclusions require identified specimens, documented sampling effort and repeated observations. The two water bodies selected here are identifiable in official records. Zilla Parishad Nashik places Arjun Sagar near Jaydar and Suple in Kalwan [2]. A national dam-register annexure lists "Arjunsagar (Punand), Suple" on the Punad River [3]. India-WRIS lists Punad Dam in Nashik under the Tapi basin, and Bhegu Dam in Kalvan, Nashik, under the basin group of west-flowing rivers from Tapi to Tadri [4]. The text uses the spelling Kalwan throughout. These records support the site identities; they do not supply a faunal inventory.

Table 1. Official geographical context of the two named projects [2–4].

Attribute	Arjun Sagar	Bhegu Project
Register name	Arjunsagar (Punand), Suple; Punad Dam	Bhegu Dam
Administrative setting	Kalwan, Nashik, Maharashtra	Kalwan, Nashik, Maharashtra
River named in records	Punad / Punand	Bhegu
India-WRIS basin group	Tapi	West-flowing rivers from Tapi to Tadri
Purpose listed by India-WRIS	Irrigation	Irrigation

Local evidence and the analytical objective

Kapadnis and colleagues described plankton sampling at four Arjunsagar stations during September–December 2020 and reported major zooplankton groups [5]. The paper provides local background, but no numerical zooplankton abundance matrix suitable for this comparison. A separate Maharashtra study documented fish diversity in Ujani Reservoir using observations from April 2021 to March 2023 [6]. Its inventory concerns Ujani and cannot be transferred to Arjun Sagar or Bhegu. The present constructed counts are not extracted from either publication. The objective is to transparently compare aquatic assemblages using explicit counts while separating analytical results from field evidence. Specifically, the article examines how richness and dominance affect diversity, how presence-based similarity differs from abundance-based dissimilarity, and how seasonal pooling changes interpretation. These questions are addressed descriptively. A higher calculated index does not designate a cleaner, healthier, or more conservation-important reservoir. Here, the term aquatic fauna is restricted to fishes, metazoan zooplankton, and aquatic macroinvertebrates. We exclude phytoplankton because they are not fauna. This analysis excludes amphibians, reptiles, aquatic birds, and other animal groups. Consequently, the listed taxonomic units do not represent a complete reservoir biodiversity inventory.

MATERIALS AND METHODS

Data provenance and construction

All counts in Tables 3-5 are invented integers selected for a worked comparative example. The construction deliberately gives the Bhegu arrays fewer represented labels and greater concentration in a few dominant labels. It is a stochastic simulation fitted to environmental measurements. We specified seasonal changes directly to avoid imposing the same temporal pattern on every assemblage. The design includes two site labels, three seasonal categories, and three separately analysed assemblages, yielding 18 site-season-assemblage composites. Each assemblage has six count vectors. A vector is one composite, a set of independent station replicates. The seasonal categories have

survey year. For demonstration, we assume equal effort within an assemblage; it was measured. Counts have field density, catch-per-unit-effort or biomass interpretation.

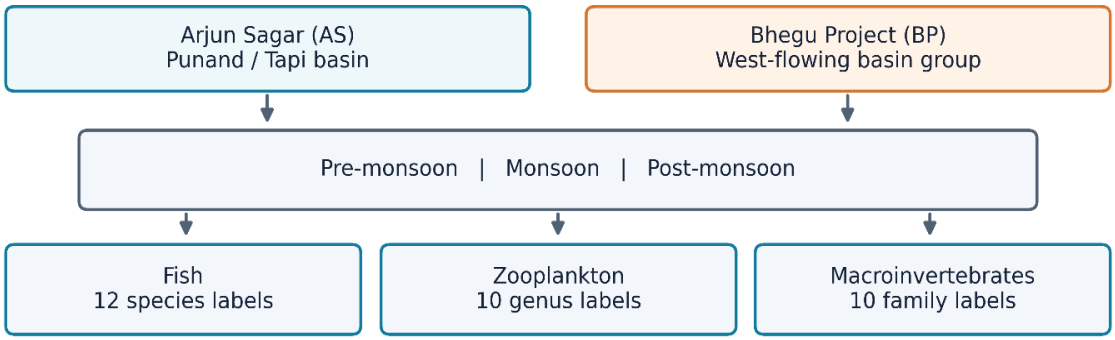


Figure 1. Structure of the illustrative comparison. River-basin labels follow official records [3,4].

Proposed collection framework for a real survey

A replacement field study would establish georeferenced inlet, littoral and open-water or dam-proximal stations after reconnaissance. Sampling visits would be repeated within each season, retaining station and visit identifiers. We would maintain separate effort records for each assemblage. The proposed framework in Table 2 follows the general principle of distinct biological and habitat protocols used in structured lake monitoring [7]; it is not a report of procedures already performed.

Table 2. Proposed field measurements needed to replace the illustrative counts.

Assemblage	Collection and effort record	Identification record
Fish	Standardised gear type, mesh, net area and deployment duration; keep gear-specific catches separate	Photographs, diagnostic characters and expert-verified specimen identity
Zooplankton	Known filtered water volume, mesh aperture, preserved volume and counted aliquot fraction	Microscopy images and genus or species identification with a stated key
Macroinvertebrates	Defined sampled area or sweep time, substrate class and mesh aperture	Sorted specimens, life stage and a consistent identification rank

Statistical Analysis

For one assemblage and one site, let n_i denote the count assigned to taxon i, N the sum of counts, and p_i its relative abundance. S is the number of labels with positive counts. Calculations use natural logarithms and the convention that a zero-count term contributes zero. No index combines the three assemblages. Fish richness refers to species labels, zooplankton richness to genus labels and macroinvertebrate richness to family labels.

$$N = \sum_{i=1}^{S} n_i , \quad p_i = \frac{n_i}{N}$$

$$H' = -\sum_{i=1}^{S} p_i \ln(p_i) , \quad J' = \frac{H'}{\ln S}$$

$$\lambda = \sum_{i=1}^{S} {p_i}^2 , \quad Simpson\ diversity = 1 - \lambda$$

$$D^0 = S , \quad D^1 = exp(H') , \quad D^2 = \frac{1}{\lambda}$$

The last line reports Hill diversity at orders zero, one and two [8,9]. For compact notation, the order is displayed as a superscript; effective diversity has units of equally common taxa. Pielou evenness J′ measures entropy relative to ln S [10]. The Simpson expression used here is the plug-in form $1 - \Sigma p_i^2$, not the estimator based on $n_i(n_i - 1)$. Dominance is the largest p_i. These definitions avoid the ambiguity of reporting only "Simpson index".

A reproducible calculation from the fish table The pooled Arjun Sagar fish vector is (91, 56, 69, 40, 32, 51, 17, 15, 64, 72, 26, 34). It gives N = 567, S = 12, Σn_i^2 = 33,029 and $\Sigma n_i \ln n_i$ = 2254.523719. Therefore, H′ = ln (567) − 2254.523719/567 = 2.364127; λ = 33029/567² = 0.102738; 1 − λ = 0.897262; J′ = 0.951395; and exp(H′) = 10.634751. All other results are calculated by the same operations on Tables 3–5.

Between-site comparison and limits of inference

Jaccard similarity is a/(a + b + c), where a is the number of shared labels and b and c are labels represented only in the first and second arrays. Bray–Curtis dissimilarity [11] is calculated after converting each site vector to proportions. Because each vector sums to one, the expression becomes one-half of the summed absolute differences between corresponding proportions.

$$BC_{rel} = \frac{\sum |p_{i,AS} - p_{i,BP}|}{2}$$

Pooled indices are computed after adding seasonal counts taxon by taxon, so seasons contribute according to their count totals. They are not arithmetic means of seasonal indices. Rounding occurs only in displayed results. No p-values, confidence intervals, ANOVA or environmental correlations are estimated: the counts are constructed and each seasonal cell lacks independent replication. A genuine field comparison would also assess sample completeness; equal effort or equal N alone does not guarantee comparable coverage [12,13].

RESULTS

Fish composition in the illustrative matrices

Table 3. Constructed fish counts across the three seasonal categories. All entries are illustrative counts, field records.

Taxon label	AS Pre	AS Mon	AS Post	AS Total	BP Pre	BP Mon	BP Post	BP Total
Labeo rohita	22	31	38	91	34	38	41	113
Cyprinus carpio	15	18	23	56	17	24	27	68
Oreochromis mossambicus	19	24	26	69	29	42	35	106
Channa striata	10	13	17	40	6	10	12	28
Channa punctata	8	11	13	32	5	7	8	20
Mystus vittatus	13	18	20	51	9	13	15	37
Wallago attu	4	7	6	17	1	2	3	6
Ompok bimaculatus	3	5	7	15	0	0	0	0
Puntius sophore	16	21	27	64	8	13	17	38
Rasbora daniconius	18	24	30	72	5	12	16	33
Labeo calbasu	6	9	11	26	0	0	0	0
Glossogobius giuris	9	11	14	34	3	5	6	14
Total counts	**143**	**192**	**232**	**567**	**117**	**166**	**180**	**463**

AS = Arjun Sagar; BP = Bhegu Project; Pre = pre-monsoon; Mon = monsoon; Post = post-monsoon. A zero denotes an unrepresented label in this constructed matrix.

The fish matrix contains 567 counts assigned to 12 species labels for Arjun Sagar and 463 counts assigned to 10 labels for Bhegu. *Labeo rohita* is the largest component in both pooled arrays, with 91 and 113 counts, corresponding to 16.05% and 24.41%. *Oreochromis mossambicus* accounts for a further 12.17% and 22.89%, respectively. Together, these two labels comprise 28.22% of the Arjun Sagar array and 47.30% of the Bhegu array. The latter distribution is therefore more concentrated even before considering a diversity index. Arjun Sagar has H′ = 2.364, J′ = 0.951 and 10.635 effective taxa; Bhegu has H′ = 2.026, J′ = 0.880 and 7.586 effective taxa. Their effective-diversity ratio is 1.402. Inverse Simpson values of 9.734 and 6.315 retain the same ordering. These comparisons describe the assigned compositions, not ecological advantages at the actual sites. *Ompok bimaculatus* and *Labeo calbasu* are unrepresented in the Bhegu matrix. Their assigned zeros do not demonstrate field absence. The ten represented Bhegu labels overlap with Arjun Sagar, giving a Jaccard similarity of 10/12 = 0.833. Relative-abundance Bray–Curtis dissimilarity is 0.239. Label overlap and proportional composition therefore provide distinct descriptions.

Seasonal count and diversity patterns

Illustrative fish counts increase from 143 to 192 to 232 at Arjun Sagar and from 117 to 166 to 180 at Bhegu. Richness remains constant within each site. Arjun Sagar H′ is 2.352, 2.369 and 2.364, with a small maximum in the monsoon category. Bhegu H′ increases from 1.922 to 2.015 to 2.086. Thus, a larger total count does not mechanically imply a larger entropy: the taxon proportions determine the index.

RESULTS CONTINUED

Zooplankton composition and evenness

Table 4. Constructed zooplankton counts using genus-level labels. All entries are illustrative counts from field records.

Taxon label	AS Pre	AS Mon	AS Post	AS Total	BP Pre	BP Mon	BP Post	BP Total
Brachionus	74	82	79	235	120	145	112	377
Keratella	39	45	48	132	43	50	57	150
Filinia	21	28	31	80	17	23	29	69
Asplanchna	18	23	26	67	8	13	17	38
Polyarthra	27	35	39	101	21	28	31	80
Daphnia	25	18	37	80	0	0	0	0
Moina	54	63	58	175	66	82	76	224
Ceriodaphnia	31	27	43	101	14	20	29	63
Mesocyclops	47	55	62	164	58	73	67	198
Diaptomus	29	24	35	88	8	12	16	36
Total counts	**365**	**400**	**458**	**1223**	**355**	**446**	**434**	**1235**

AS = Arjun Sagar; BP = Bhegu Project; Pre = pre-monsoon; Mon = monsoon; Post = post-monsoon. A zero denotes an unrepresented label in this constructed matrix.

Zooplankton totals are closely matched: 1,223 counts in the Arjun Sagar matrix and 1,235 in the Bhegu matrix. Nevertheless, the first array includes ten represented genera, while the second includes nine. *Brachionus* contributes 235 counts at Arjun Sagar and 377 at Bhegu, or 19.22% and 30.53%. The modest difference in total counts therefore accompanies a substantial difference in the allocation of counts among genera. These totals are enumeration values in the illustration, not individuals per litre. Shannon

entropy is 2.222 for Arjun Sagar and 1.922 for Bhegu. Effective diversity is 9.226 versus 6.833 genera, and Pielou evenness is 0.965 versus 0.875. The Arjun Sagar effective-diversity value is 1.350 times the Bhegu value. This ratio compares equivalent numbers of equally common genera and is more interpretable than a percentage change in the raw entropy index. The plug-in Simpson diversities are 0.883 and 0.822, respectively. Jaccard similarity is 0.900, the highest of the three assemblages; relative-abundance Bray–Curtis dissimilarity is 0.191. High genus overlap is compatible with uneven counts, demonstrating the limits of a checklist alone. The dominance of an illustrative genus cannot establish actual water quality.

Seasonal interpretation and identification scale

Arjun Sagar has 365, 400 and 458 counts across the seasonal categories, with effective diversity of 9.104, 8.921 and 9.475. Bhegu has 355, 446 and 434 counts, while effective diversity increases from 6.311 to 6.583 to 7.451. At Bhegu, the largest total and highest diversity fall into different categories. The divergence follows from the assigned relative abundances. Genus-level identification is retained consistently; it cannot establish species richness. A field study would retain microscopy images and identification notes for uncertain material. Earlier Arjunsagar work supplies local context [5], but does not validate these counts. Unrepresented or omitted genera cannot be interpreted as absences from the actual reservoir.

RESULTS CONTINUED

Aquatic macroinvertebrate composition

Table 5. Constructed macroinvertebrate counts using family-level labels. All entries are illustrative counts from field records.

Taxon label	AS Pre	AS Mon	AS Post	AS Total	BP Pre	BP Mon	BP Post	BP Total
Chironomidae	42	58	46	146	78	93	71	242
Naididae	22	29	25	76	40	49	43	132
Baetidae	21	17	29	67	0	0	0	0
Caenidae	18	15	26	59	8	6	13	27
Libellulidae	15	19	23	57	9	12	16	37
Coenagrionidae	12	16	21	49	7	10	14	31
Corixidae	19	28	25	72	15	22	20	57
Notonectidae	11	18	22	51	11	17	18	46
Thiaridae	24	31	28	83	30	36	33	99
Unionidae	9	7	12	28	0	0	0	0
Total counts	**193**	**238**	**257**	**688**	**198**	**245**	**228**	**671**

AS = Arjun Sagar; BP = Bhegu Project; Pre = pre-monsoon; Mon = monsoon; Post = post-monsoon.

Arjun Sagar has 688 counts across ten families; Bhegu has 671 across eight. Chironomidae dominates at 21.22% and 36.07%, respectively. Pooled H′ is 2.219 and 1.794, and effective diversity is 9.197 and 6.015 families. Their ratio of 1.529 is the largest within-assemblage contrast, reflecting the imposed richness and dominance patterns.

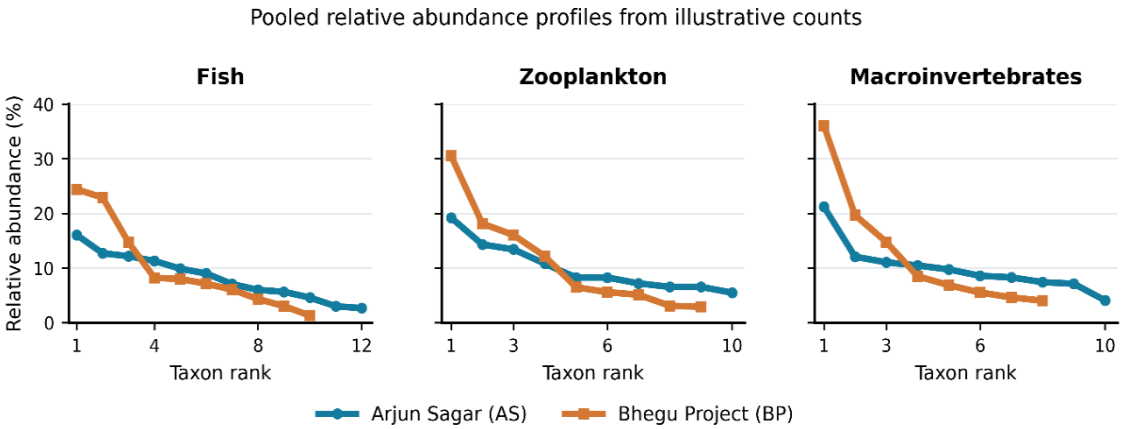


Figure 2. Relative-abundance profiles from illustrative counts. Taxa are ranked independently within each site and assemblage; matching ranks need not identify the same taxon. Steeper profiles indicate greater assigned dominance.

Jaccard similarity is 0.800 and relative-abundance Bray-Curtis dissimilarity is 0.262. All represented Bhegu families also occur in the Arjun Sagar matrix, giving nested representation. Figure 2 retains the distinct identification ranks. Bhegu counts peak in the monsoon category (198, 245, 228), while effective diversity peaks post-monsoon (5.587, 5.709, 6.637). Richness remains eight. These values cannot diagnose the actual environmental condition of the reservoirs.

COMPARATIVE DIVERSITY SUMMARY

Table 6. Pooled descriptive indices calculated from the illustrative count matrices.

Assemblage	Site	N	S	H′	1 − λ	J′	D^1	D^2
Fish	AS	567	12	2.364	0.897	0.951	10.635	9.734
Fish	BP	463	10	2.026	0.842	0.880	7.586	6.315
Zooplankton	AS	1223	10	2.222	0.883	0.965	9.226	8.518
Zooplankton	BP	1235	9	1.922	0.822	0.875	6.833	5.610
Macroinvertebrates	AS	688	10	2.219	0.881	0.964	9.197	8.427
Macroinvertebrates	BP	671	8	1.794	0.791	0.863	6.015	4.779

S uses species labels for fish, genus labels for zooplankton, and family labels for macroinvertebrates. $D^1 = \exp(H')$; $D^2 = 1/\lambda$. Counts and richness must not be summed into a whole-fauna abundance or species total.

Table 7. Pooled between-site comparisons within each illustrative assemblage.

Assemblage	Shared	AS only	BP only	Jaccard similarity	Bray–Curtis dissimilarity
Fish	10	2	0	0.833	0.239
Zooplankton	9	1	0	0.900	0.191
Macroinvertebrates	8	2	0	0.800	0.262

Bray–Curtis uses normalized relative abundances. Jaccard uses represented labels, so it is unaffected by within-label count differences.

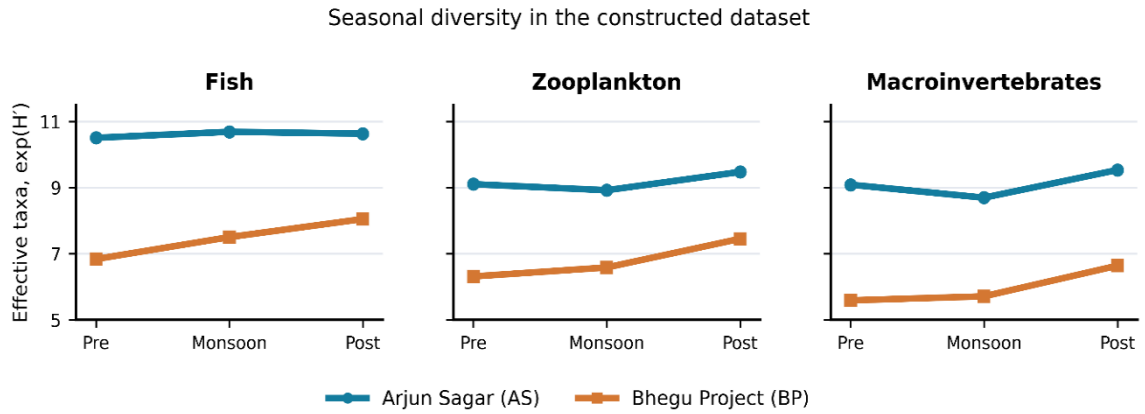


Figure 3. Seasonal effective diversity calculated as exp(H′). Pre and Post denote pre-monsoon and post-monsoon. Compare AS and BP within each panel.

The pooled Arjun Sagar arrays have higher richness, evenness and effective diversity within every assemblage. Agreement among indices is expected because the matrices were designed to show those contrasts. In every site–assemblage combination, richness does change across the three seasonal categories; seasonal differences in effective diversity therefore arise entirely from changing proportions. A comparison of D^1 gives interpretable within-group ratios of 1.402 for fish, 1.350 for zooplankton and 1.529 for macroinvertebrates. The ratios refer to equally common taxonomic units at the stated identification rank. Absolute D^1 values should be used to rank one biological assemblage against another when their identification ranks and sampling processes differ.

DISCUSSION

What the constructed comparison demonstrates

The strongest analytical result is the separation of abundance, richness and evenness. Similar totals can produce different effective diversities, as the zooplankton arrays show. Conversely, increasing counts can accompany stable or declining entropy if the added counts are concentrated in already dominant labels. Effective numbers express these contrasts more directly than small numerical differences between entropy values [8,9]. They remain summaries of the supplied matrix and cannot establish whether the matrix adequately represents a reservoir. The overlap results also require careful wording. In every assemblage, the labels represented at Bhegu are a subset of those represented at Arjun Sagar. The Jaccard contrast therefore reflects labels omitted from one constructed set, while Bray–Curtis captures additional differences in the shares of common labels. Calling this evidence of species turnover would overstate the result. The analysis supports a description of nested label representation and unequal dominance within the illustration.

Ecological explanations that require field evidence

In a real survey, habitat structure, connectivity, stocking history and hydrological change would be reasonable candidate explanations to investigate. The sites fall within different basin classifications [4], so shared administrative location alone would not justify treating them as ecologically interchangeable. A reservoir effect could not be separated cleanly from catchment or basin effects using only one reservoir in each category. A broader design would include additional independently sampled water bodies or restrict inference to the named sites. The presence of a taxon, including a potentially tolerant or introduced form, is not sufficient to diagnose a disturbance. A defensible interpretation would link verified identifications to repeated biological samples, water chemistry, habitat observations and relevant management records. Catch records would

also need gear information, because fish inventories depend on the methods used to detect species; original comparative work has shown the value of complementary gears and eDNA [14]. No specific gear performance is assumed for Nashik in the present analysis.

Sampling completeness and temporal structure

The equal-effort assumption simplifies the worked example, but does not establish equal detectability or completeness. A field dataset should retain unpooled samples so researchers can apply rarefaction or coverage-based comparisons appropriately [12, 13]. There is no defensible empirical standard error for a single site–season composite. Treating the three seasons as interchangeable replicates would also ignore their ordered environmental context. Record repeated stations and visits before pooling, and any later model should match that sampling structure. For a practical follow-up, a reconnaissance survey should confirm site identity, accessibility and station coordinates, then document gear, filtered volume or sampled area separately for each assemblage. Researchers could measure temperature, dissolved oxygen, pH, conductivity, transparency, and habitat condition concurrently. Retain identification uncertainty, replicate counts, and quality-control checks with the raw records.

CONCLUSION

The constructed matrices demonstrate separate comparisons of fish, zooplankton and macroinvertebrates for two named Nashik projects. The imposed Bhegu arrays have lower effective diversity and greater dominance, while retaining substantial label overlap with Arjun Sagar. These calculations verify species occurrence ranks in the actual reservoirs. Documented observations must replace the constructed counts before we can draw an empirical biodiversity conclusion.

Declaration by Authors

Data Availability: This article uses constructed data only.

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Conflict of Interest: No conflicts of interest declared.

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