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Trophic Ecomorphology and Character Homoplasy in Benthic Cyprinids across Peninsular River Gradients of the Deccan Plateau: A Critical Synthesis

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Abstract
Background: Benthic cyprinids inhabiting peninsular Indian rivers occupy hydrodynamically contrasting riffles, runs, pools and regulated reaches. Their subterminal mouths, lip folds, barbels, body profiles and fin configurations are often interpreted as ecological adaptations or taxonomic signals, although similar character states may have evolved independently. Objective: To evaluate the relationships among river gradients, trophic ecomorphology, osteological character states and molecular phylogeny, with explicit attention to homoplasy and the geographic limits of available evidence. Approach: We critically integrate published studies of Indian and South Asian fish assemblages, taxonomic revisions, comparative anatomy and functional ecomorphology, using a literature cutoff of 2023. Findings: Western Ghats field studies establish spatially differentiated fish assemblages and feeding partitioning; labeonine phylogenies document repeated evolution of oromandibular traits; the historical Puntius complex and the Western Ghats Lepidopygopsis lineage demonstrate how external resemblance may conceal phylogenetic heterogeneity. Direct replicated biomechanical comparisons across Deccan drainages remain uncommon. Synthesis: Morphological similarity should be evaluated using explicit character definitions, diet data, hydrodynamic measurements, developmental controls and character-state reconstruction on independently inferred phylogenies. Conclusion: A coordinated evidence framework can distinguish diagnostic morphology, ecological plasticity, convergence and true synapomorphy without overstating data from local river inventories. This manuscript is a critical synthesis and systematic-review framework; it does not claim completed PRISMA screening or pooled effect estimates.

Keywords: Functional Ecomorphology; Character Homoplasy; Trophic Partitioning; Benthic Feeding; Cyprinidae; Garra; Labeonini; Deccan Plateau; Western Ghats; Peninsular India; Cypriniformes; River Gradients; Oral Disc; Comparative Osteology.

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Introduction
The transition from river-channel position to trophic performance is a multi-step process: water velocity and substrate affect station-holding costs, encounter rates with food, manoeuvrability and the mechanical demands of acquisition. Fish phenotype mediates these effects through body shape, fin placement, oral orientation, buccal kinematics and processing structures. Classic ecomorphology therefore asks whether a character predicts measurable ecological performance, not simply whether bottom-associated fishes look alike (Gatz, 1979; Winemiller, 1991; Wainwright, 1996).

Peninsular India is a particularly valuable, though unevenly sampled, setting. Western Ghats headwaters and plateau-associated rivers contain steep gradients between torrential upper reaches and low-gradient, sediment-rich or regulated waters. The plateau includes catchments connected to west-flowing rivers and east-flowing systems such as the Krishna and Godavari; however, these drainage systems should not be assumed to share species composition or evolutionary histories. Inventories of the Indrayani and Hiranyakeshi rivers document freshwater assemblages but do not directly estimate feeding biomechanics or homoplasy (Dahanukar et al., 2012; Kumkar et al., 2017).

The taxonomic language also demands precision. Historical uses of “cyprinids” commonly refer to a broader Cyprinidae than is recognized in several molecularly informed classifications. Some superficially comparable benthic cypriniforms, such as Psilorhynchus, are not members of Cyprinidae sensu stricto. We therefore distinguish core cyprinid evidence from comparative cypriniform examples and retain historical species names when reporting older studies (Stout et al., 2016; Tan and Armbruster, 2018; Betancur-R. et al., 2017).

The principal proposition of this review is that a feeding trait can be ecologically useful and taxonomically diagnostic while still failing to be a shared derived evolutionary state. The phylogeny of Labeonini, for example, reveals repeated transitions in lip architecture and non-monophyly of several traditionally defined genera, directly challenging evolutionary conclusions based solely on similar scraping or suction-related structures (Yang and Mayden, 2010; Yang et al., 2012). This article is a critical synthesis of

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published field, anatomical and phylogenetic evidence—not a pooled meta-analysis or a completed PRISMA systematic review. Its purpose is to evaluate the strength and geographic scope of existing inferences and to propose an evidentiary framework for future, independently screened studies.

Review Question, Scope and Methodological Status

Primary question: what evidence supports relationships between benthic trophic morphology and hydrological habitat along peninsular Indian river gradients, and when do similar characters represent homoplasy rather than shared ancestry? Secondary questions concern scale dependence, trophic partitioning, ontogenetic change, diagnostic character reliability and conservation consequences.

Eligible evidence types include (i) field diet and habitat studies from Western Ghats and peninsular rivers; (ii) comparative osteological and molecular work on Indian/South Asian cyprinids; and (iii) established comparative ecomorphological methods used as mechanistic context. Studies of unrelated fish families or overseas faunas are explicitly treated as methodological analogues rather than direct estimates for Deccan species. Records must have been published by 2023. No study published after that date contributes to the manuscript.

A completed systematic review would require reproducible database exports, predefined eligibility decisions, duplicate removal, independent screening, documented risk-of-bias appraisal, and a PRISMA record-flow diagram. Those procedures were not undertaken as a complete systematic screen for this manuscript. Accordingly, this paper is presented as a critical synthesis with a prospective evidentiary framework; no fabricated selection counts, pooled effects, or PRISMA outcomes are claimed (Page et al., 2021).

Evidence stratum	What it tests	What it cannot establish
River fish inventory	Documents local occurrence and basin composition.	Does not establish species-level diet, feeding performance or homoplasy.
Diet / microhabitat field study	Measures dietary resource use and microhabitat occupancy.	Does not establish the evolutionary origin of the measured characters.
Comparative anatomy	Documents repeatable, explicitly homologized anatomical states.	Does not establish independent origins without an explicit phylogenetic tree.
Molecular phylogeny	Infers relationships among the taxa actually sampled.	Does not establish the functional advantage of oral characters.
Integrated phylogenetic ecomorphology	Tests associations among ecology, trait states and ancestry.	Does not establish causality without biomechanical or experimental evidence.

Table 1. Inferential hierarchy for the present evidence synthesis.

River gradients and the geography of feeding opportunity

3.1. Longitudinal and lateral heterogeneity

Hydrological variation is not a single upstream–downstream axis. Within a reach, near-bed velocity, shear stress, coarse-substrate shelter, boundary-layer structure and seasonal discharge can diverge substantially from mean channel conditions. Benthic fishes may exploit hydraulically protected crevices even when the measured free-stream velocity is high. Habitat observations should record the velocity actually experienced at the position occupied by fish, rather than substituting a station-average discharge for individual exposure. Morphological interpretations based on channel labels such as “torrent” or “pool” are therefore hypotheses until near-fish flow conditions and foraging behaviour are documented (Gatz, 1979; Wainwright, 1996; Langerhans et al., 2003).

3.2. Seasonal disturbance and river regulation

Monsoon pulses reshape substrate, turbidity and access to benthic food resources, while dry-season fragmentation can redistribute organisms into isolated residual reaches. Impoundment and diversions alter habitat mosaics and potentially the selective environment for fish mobility and foraging. A cross-sectional study across different basins cannot cleanly separate effects of current from drainage ancestry, climatic season or local anthropogenic modification. Inventories of Indrayani and Hiranyakeshi and the Western Ghats

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regional biodiversity assessment show why the spatial sampling design must explicitly distinguish catchment, site and seasonal replication (Dahanukar et al., 2012; Kumkar et al., 2017; Daniel et al., 2011).

3.3. Deccan Plateau versus Western Ghats

The Western Ghats is the major orographic boundary and source region for numerous peninsular drainage networks, but "Western Ghats" and "Deccan Plateau" are not interchangeable geographic units. Case evidence from Periyar in the southern Ghats or Mizoram and Manipur should not be presented as direct observations from plateau reaches. Here they provide either adjacent peninsular evolutionary context or outgroup-like taxonomic contrasts (Dahanukar et al., 2013; Knight, 2013; Dishma and Vishwanath, 2013). This geographic tagging is essential to avoid manufactured claims of extensive Deccan-wide replication.

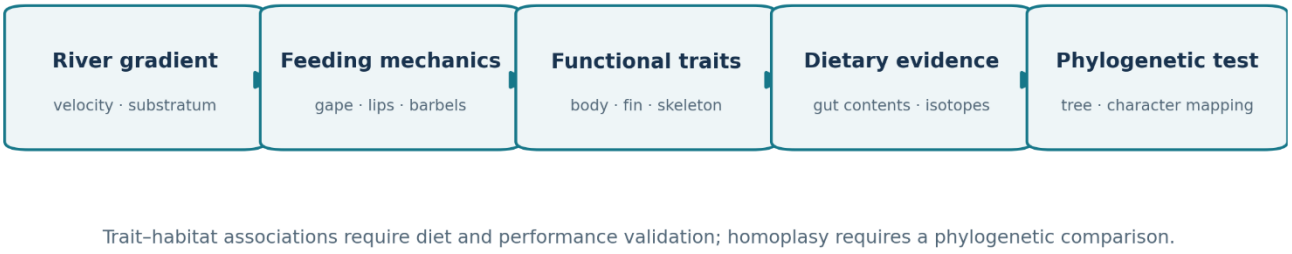


Figure 1. Conceptual evidence chain illustrating the hierarchical path from environmental river gradients to phylogenetic testing. Environmental observations, feeding measurements, comparative character assessment and phylogenetic hypotheses represent distinct evidentiary stages; arrows indicate the proposed analytical sequence rather than estimated causal coefficients.

Trophic ecomorphology: Characters, funCTIONS AND ASSUMPTIONS

4.1. Oral orientation and food acquisition

A terminal, subterminal or inferior mouth can be informative about the direction of food acquisition, but an orientation category alone does not determine diet. Surface grazers and bottom-associated omnivores can share inferior oral positions while differing in scraping force, suction kinematics, detritus processing or capture behaviour. Labeonines are particularly variable in rostral folds, papillae, upper and lower lip sheaths and associated structures. These may differentiate taxa in identification keys without defining a clade (Yang and Mayden, 2010; Yang et al., 2012).

Mechanical interpretation should consider mouth opening geometry, kinematic excursion, muscle lever arms, substrate interaction and prey attachment. The functional-morphology framework of Wainwright (1996) establishes that associations between gross form and diet become substantially stronger when linked to mechanistic measures. Direct bite-force and scraping-performance data remain a critical missing layer for many peninsular cyprinids.

4.2. Barbels and nonvisual benthic foraging

Rostral and maxillary barbels contribute to a taxonomic diagnosis in many barbs but are not universal measures of tactile feeding capability. Presence, number and proportional length must be distinguished from innervation, sensory density and demonstrated feeding behaviour. Historical revisions of Puntius sensu lato show that barbel conditions may help separate named groups when combined with lateral-line scales, dorsal-ray morphology and colour, yet the same states can have complex evolutionary histories (Pethiyagoda et al., 2012; Pethiyagoda, 2013).

4.3. Body profiles and position-holding

A dorsoventrally compressed body can reduce the height at which a fish is exposed to faster water and may allow use of substrate-adjacent hydraulic refuges. However, shape also covaries with size, ontogeny and ancestry, and selection by predation or habitat complexity may produce similar forms. Across non-Indian fish systems, flow-associated shape divergence has been documented using geometric morphometrics, reinforcing the need to control phylogenetic and population relationships before assigning an adaptive mechanism (Langerhans et al., 2003).

4.4. Fin architecture and manoeuvrability

Pectoral fin position, leading-edge geometry and paired-fin surface area may contribute to posture control near the bed. Yet fin shape can be strongly correlated with body size and taxonomic identity. A robust comparison should use landmark-based geometry, size

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correction and direct behavioural video rather than infer drag or thrust from illustrations alone. These considerations extend foundational ecomorphological arguments in Gatz (1979) and Winemiller (1991).

4.5. Pharyngeal structures and resource processing

Cyprinid pharyngeal teeth and arches are relevant to food processing, potentially providing information distinct from oral acquisition. Tooth formula, cusp shape, wear and associated skeletal articulations should be scored systematically, because a shared gross feeding description may conceal contrasting processing mechanisms. Fine-resolution skeletal data from cypriniform comparative work support the feasibility of character-based inference, provided homology definitions are explicit (Mabee et al., 2011; Conway, 2011).

Character complex	Suggested measure	Potential trophic inference	Major source of confounding
Mouth position and gape	Orientation angle, gape width/SL, kinematics	Direction and geometry of food capture	Size, ancestry, specimen deformation
Lips / rostral fold / disc	Papillae, keratinised sheath, disc architecture	Substrate contact, scraping, adherence	Repeated evolutionary origins
Barbels	Presence, number, proportional length	Tactile search opportunity	Multiple losses, sensory function untested
Pectoral fin	Area, angle, aspect ratio	Station holding and manoeuvring	Habitat, size, ontogeny
Body depth / compression	Landmark shape, depth/SL	Hydraulic exposure and locomotion	Development, flow plasticity
Pharyngeal teeth	Formula, row counts, wear, crown form	Food processing and crushing	Diet-induced wear and common ancestry
Gut and isotopic diet	Prey volume/number, isotopic niche	Actual resource acquisition	Season, digestion, baseline variability

Table 2 footnote. SL = standard length; the slash (/) separates alternative anatomical terms or possible measures. Measurements are proposed variables, not observed effect estimates.

Table 2. Candidate trophic-ecomorphological measurements. These are study-design recommendations, not measured values from the Deccan.

Food partitioning in Western Ghats Stream Assemblages

The study by Johnson and Arunachalam (2012) is an especially relevant direct ecological reference: it explicitly investigated feeding habits and food partitioning in a Western Ghats stream fish community. Such assemblage work demonstrates why diet records are needed alongside morphological descriptions. It cannot, however, by itself establish that a similar oral structure evolved independently in different cyprinid lineages, nor does its single study system justify broad transfer across the Krishna–Godavari plateau.

A strong comparative design would collect fish across riffles, runs and pools at multiple seasons and compare diets through standardized gut-content categories and stable-isotope analyses where appropriate. Diet overlap and isotopic niche width answer different questions: overlap measures co-use of observed resources at the sampling time, while isotope values integrate assimilated foods over tissue-specific timescales. Neither directly proves feeding performance. Sampling should retain individual body length, reproductive stage and local microhabitat to avoid confusing ontogenetic niche change with between-species adaptation (Johnson and Arunachalam, 2012; Winemiller, 1991).

The older regional identification literature remains useful for determining the taxon represented by a specimen. However, species names in Hamilton (1822), Day (1878), Menon (1999), Talwar and Jhingran (1991) and Jayaram (2010) belong to different historical taxonomic frameworks and must be reconciled before trait databases are merged. Collapsing synonyms can artificially increase apparent trait variation within a species.

character Homoplasy: from Apparent Adaptation to Explicit Phylogenetic Inference

6.1. Definitions and the need for polarity

Homoplasy includes similarity arising independently or through evolutionary reversal rather than through inheritance of a state from the relevant common ancestor. A synapomorphy is a shared derived homologous state supporting a specified clade; a

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symplesiomorphy is shared ancestry at a deeper level. Diagnostic value and phylogenetic value are thus not interchangeable. A lip character may be practical for identification while displaying repeated gains or losses across the molecular tree (Yang et al., 2012; Conway, 2011).

6.2. Labeonine mouth architecture

Yang and Mayden (2010) cautioned that similarities of lips and suctorial structures can arise through convergence or parallelism. A larger multilocus analysis by Yang et al. (2012) included 34 genera and 142 putative species with four nuclear and five mitochondrial genes, and reported non-monophyly of traditionally delimited Labeo, Garra, Bangana, Cirrhinus and Crossocheilus. That conclusion directly supports testing the evolutionary history of oral characters rather than assuming every similar adhesive or scraping configuration represents a unique shared origin.

Importantly, species from across Asia and Africa contribute to the broader labeonine framework. The statistical demonstration of homoplasy is therefore primarily derived from wide comparative phylogenies rather than from a Deccan-only experiment. Within plateau waters, a study must establish species identities, sample congeners and relevant outgroups, and optimize character states before assigning a specific number of gains or losses.

6.3. Lepidopygopsis and false biogeographic affinity

The Western Ghats endemic Lepidopygopsis typus was historically treated as closely allied to Himalayan schizothoracines because of external similarities, including an anal-fin scale sheath. Dahanukar et al. (2013) used nuclear and mitochondrial data to reject that assumed relationship and placed the species closer to a lineage containing Asian–African barbins. The study explicitly proposed that the scale-sheath similarity could reflect a symplesiomorphy or homoplasy. This case is strong evidence for an interpretive error in phenotype-based historical affinity; it does not demonstrate a specific modern river-flow adaptation without independent performance tests.

6.4. Puntius complex and the limits of generic labels

Pethiyagoda et al. (2012) analysed 31 South Asian species historically assigned to Puntius, integrating morphology, osteology and mitochondrial evidence, and recognized multiple lineages. This reveals how an historically broad genus can conceal heterogeneous trait combinations and phylogenetic histories. Later regional revisions of Pethia and closely related forms clarified the importance of scale counts, fin spines, pigmentation and type-linked naming (Knight, 2013; Katwate et al., 2015; Lalramliana et al., 2014; Shangningam and Vishwanath, 2018). These are taxonomic and comparative examples, not evidence that all such species are benthic feeders.

6.5. Waikhomia and multi-character diagnosis

Katwate et al. (2020) introduced Waikhomia for the Maharaja barbs using an integrative combination including 30 vertebrae, absence of a post-epiphysial fontanelle, infraorbital and caudal skeletal features, lateral-line characters and coloration. The case illustrates why joint character patterns often diagnose taxonomic entities more defensibly than isolated traits subject to convergence. It is not a demonstration of measured suction performance in those fishes.

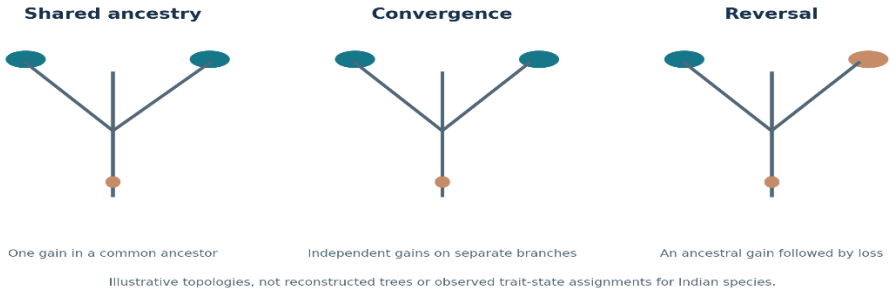


Figure 2. Evolutionary pathways capable of producing similar trophic characters in benthic cyprinids. The schematic distinguishes inheritance of an ancestral state, independent convergence and evolutionary reversal; it does not represent an empirical phylogeny of the named Indian genera.

Osteology and Developmental Constraints

Morphological comparisons require homology-based character definitions rather than visually convenient labels. Cypriniform hyoid and branchial structures can be partitioned into discrete states with articulated anatomical descriptions: Mabee et al. (2011) analysed 62 characters across 53 taxa. Conway (2011) demonstrated the importance of extensive osteological sampling in Psilorhynchus, a river-associated cypriniform comparison group outside Cyprinidae sensu stricto. Both studies show the analytical value of skeletal data, not a universal set of synapomorphies valid for all Indian benthic cyprinids.

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Ontogeny can complicate coding. Ossification sequence, skeletal miniaturization and retention of juvenile features affect character expression. Studies of Paedocypris and Danionella document how morphological novelty and reduced skeletal traits can coexist, cautioning against interpreting all absences as independent adaptive losses (Rüber et al., 2007; Britz and Conway, 2009; Britz et al., 2009). This developmental literature is used here as a methodological analogue, not as Deccan River occurrence evidence.

Priority skeletal systems include the premaxillary complex, kinethmoid, dentary, suspensorium, hyoid and gill arches, pharyngeal teeth, pectoral girdle and caudal skeletal supports. Quantified trait states should be archived with photographed vouchers, cleared-and-stained preparations and explicit orientation. Character definitions should be reproducible independently of the preferred tree, with missing data and damaged structures coded separately.

Geographic and Taxonomic Evidence Matrix

Study / geographical context	Evidence actually provided	Responsible interpretation
Johnson & Arunachalam 2012 — Western Ghats stream	Community feeding habits and food partitioning	Direct regional dietary evidence; no phylogenetic proof of homoplasy
Dahanukar et al. 2012 — Indrayani River	Local species inventory	Distribution context; no measured feeding mechanism
Kumkar et al. 2017 — Hiranyakeshi	Regional fish fauna record	Basin inventory, not comparative trophic performance
Dahanukar et al. 2013 — Periyar	Multilocus position of Lepidopygopsis	Misleading morphological affinity; not a flow experiment
Katwate et al. 2020 — northern Western Ghats	Waikhomia integrative diagnosis	Anatomical taxonomic evidence; function remains to test
Yang et al. 2012 — pan-labeonine	Wide multilocus phylogeny	Direct basis for testing repeated oral character evolution
Pethiyagoda et al. 2012 — South Asian Puntius s.l.	Generic and morphological revision	Historically broad names can pool unrelated trait patterns

Table 3 footnote. s.l. = sensu lato (in the broad historical sense); "pan-labeonine" denotes sampling across the Labeonini rather than the Deccan Plateau alone. Geographic contexts and inferential boundaries are intentionally kept separate.

Table 3. Evidence mapping with strict geographic and inferential boundaries.

Comparative regional taxonomic literature supplies guardrails for ecological data synthesis. Silas (1958) and Vishwanath and Laisram (2004) document historical concepts and diagnostic practice; studies of Puntius in Myanmar (Kullander, 2008; Kullander and Fang, 2005) demonstrate that similar names cover taxonomically and geographically differentiated assemblages. Larger catalogues for Southeast Asian and European fishes have comparative methodological value for standardized names and character definition but provide no direct Deccan trophic measurements (Kottelat, 2013; Kottelat and Freyhof, 2007). Those records belong in a contextual reference stratum, not in a pooled analysis of Indian feeding performance.

The broad history of cypriniform systematics adds a second interpretive safeguard: relationships inferred from mitochondrial and nuclear datasets may differ from classifications assembled through gross morphology or limited sampling (Yang et al., 2010; Stout et al., 2016; Britz and Conway, 2011). Taxonomic descriptions of small Indian Pethia species (Katwate et al., 2018) are similarly useful for verifying identifications and assessing coexistence, but do not independently establish microhabitat-specific selection. Direct comparison of diet is consequently restricted to studies that measured diet, not inferred from the cited taxonomic record.

Analytical Design For a Future Quantitative Synthesis

A rigorous paired design would sample replicate taxa within each drainage and habitat, measuring site-level velocity near the fish, substratum texture, turbidity, depth, canopy cover and seasonal flow. Representative individuals should be sampled across size ranges, with external shape digitized using repeatable landmarks and oral structures described by explicit states. Diet should be observed concurrently and compared across size-matched individuals; where ethical and feasible, high-speed feeding videography can test performance. A non-invasive diet approach may supplement destructive gut sampling.

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Phylogenetic inference must be independent of the character under test. Mitochondrial COI can assist species matching, but nuclear loci and robust outgroups are necessary for many deeper or introgression-sensitive questions. Indian freshwater fish barcode studies provide identification utility and evidence of limitations, while broader FISH-BOL research demonstrates the role of curated sequence-voucher reference sets (Chakraborty and Ghosh, 2014, 2015; Ward et al., 2005, 2009; Hebert et al., 2003).

Once trees and coded states are available, the consistency index (CI) and retention index (RI) can summarize apparent homoplasy on a specified tree, while likelihood-based ancestral-state methods can compare evolutionary models. CI or RI values should never be estimated for the Deccan fauna without a complete trait matrix and phylogeny. Likewise, phylogenetic generalized least squares or mixed models can test morphology–environment relationships after accounting for shared ancestry, body size and site replication. Different trees and character encodings should be included in sensitivity analyses.

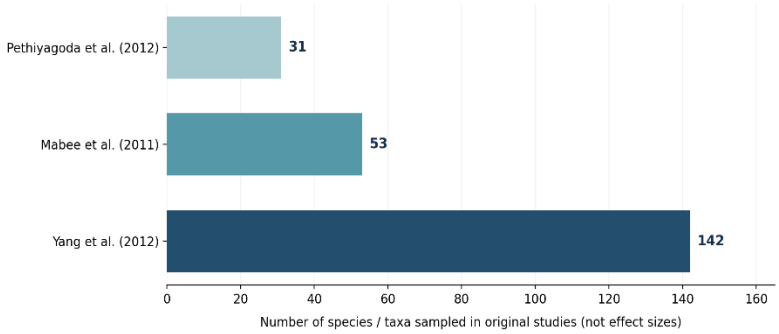


Figure 3. Sampling breadth reported in three published comparative cypriniform studies. Pethiyagoda et al. (2012) examined 31 South Asian species formerly assigned to Puntius; Mabee et al. (2011) surveyed skeletal characters in 53 cypriniform species; and Yang et al. (2012) sampled 142 putative Labeonini species. The horizontal axis represents numbers of species or taxa sampled in the respective original studies, not study-level effect sizes, measures of trophic differentiation, or results of a pooled meta-analysis. The studies represent different taxonomic sampling universes.

Proposed Evidentiary Framework For Future Systematic Assessment

Search bibliographic databases from inception through 2023 using platform-adapted terms combining “cyprinid” OR “Cypriniformes” OR “Garra” OR “Labeo” OR “barb” with “benthic”, “rheophilic”, “feeding”, “trophic”, “ecomorphology”, “lip”, “oral disc”, “osteology”, “homoplasy”, “Western Ghats”, “Deccan”, “Krishna”, “Godavari”, “Bhima”, “Indrayani” and “peninsular India”. Record each database, interface, date, syntax, retrieved count and filters. Bibliographic chaining should be documented separately from database retrievals. Regional journals and historical monographs merit explicit inclusion because excluding them would systematically bias the record toward well-indexed molecular studies.

Pre-specify three outcome groups: A, species and habitat occurrence; B, diet and measured morphology; C, explicit homoplasy tests using a phylogenetic hypothesis. Assess B studies for season, individual size, site replication, trait measurement reliability and diet verification; assess C studies for outgroup choice, loci, character independence, tree uncertainty and missing taxa. Present PRISMA flow only after the actual record set is screened. A future synthesis could pool standardized correlations only within compatible outcome classes, not across taxonomic diagnoses and diet tables (Page et al., 2021).

Reporting domain	Minimum criterion	Consequence when missing
Drainage position	Coordinates, basin, elevation, site type	False regional generalization
Flow data	Near-fish velocity, season, substrate	Weak hydraulic attribution
Morphological traits	Landmarks, size adjustment, repeatability	Allometry mistaken for ecological separation
Diet	Individual data, season, identification level	Mismatch of trait and food evidence
Osteology	Voucher, preparation, character definitions	Homology cannot be independently checked
Phylogeny	Nuclear/mitochondrial evidence, outgroups, tree uncertainty	Convergence cannot be reconstructed reliably
Taxonomic names	Original authority, current	Synonymy inflates ecological

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	combination, voucher	comparisons
Review methods	Search log, exclusion log, risk-of-bias protocol	Systematic-review label unsupported

Table 4 footnote. All criteria are methodological recommendations. "Nuclear/mitochondrial evidence" denotes nuclear and/or mitochondrial molecular data; no shorthand in this table indicates a pooled effect size.

Table 4. Reporting and bias-control checklist for a Deccan Plateau trophic-ecomorphology programme.

implications For Freshwater Biodiversity Conservation

The conservation consequence of mistaken morphology-based taxonomy is not merely nominal. A basin-restricted lineage can be classified as a geographically widespread taxon, obscuring its vulnerability to fragmentation or changed flow. Conversely, a distinctive ecomorph may occur independently in several drainages and should not automatically be counted as a shared evolutionarily significant unit. Historical inventories and the 2011 Western Ghats biodiversity assessment emphasize the need for reliable locality records and defensible taxonomic identity before extrapolation to threat status (Daniel et al., 2011; Menon, 1999; Jayaram, 2010).

Hydropower, water abstraction, sedimentation and channel simplification are plausible mechanisms modifying available microhabitats. Yet the present reference base does not provide defensible comparative effect sizes linking those stressors to jaw evolution in all Deccan benthic cyprinids. Management should therefore conserve heterogeneous river habitats and support voucher-linked surveillance without claiming that a single preferred oral morphology predicts conservation resilience.

Evidence Limitations and Future Priorities

The main weakness of the literature is asymmetry: taxonomic descriptions are numerous, but synchronized measurements of near-bed flow, diet, feeding performance and phylogenetic character transitions are far rarer. The regional feeding study by Johnson and Arunachalam (2012) supplies an important ecological component, whereas the Labeonini phylogenies provide strong broad-scale evolutionary evidence. Neither alone supplies the full integrated causal chain for the Deccan Plateau.

Three future tests merit priority. First, compare co-occurring bottom-feeding species across replicated velocity classes while controlling for body length, ancestry and season. Second, quantify the performance of differing mouth-disc and lip architectures on natural substrata rather than equating visible anatomy with suction force. Third, reconstruct the evolution of each independently coded trait on genome-supported trees and evaluate how conclusions change with outgroup selection, ancestral-state uncertainty and local sampling. These hypotheses do not assume that every similar structure is convergent.

Conclusions

Benthic cyprinids of peninsular India offer a compelling framework for evaluating how trophic morphology, river hydraulics and ancestry interact. Existing evidence supports the importance of habitat and diet heterogeneity, documents extensive taxonomic revision, and provides broad phylogenetic demonstrations that similar lip and oral characters can arise repeatedly. However, the evidence does not yet justify Deccan-wide numerical estimates of convergence, universal feeding guild assignments based on mouth shape, or a pooled effect of flow on anatomical character evolution. Progress requires a coordinated, explicitly hierarchical programme joining local hydrodynamics, directly measured diet and performance, reproducible osteology, curated vouchers, and independently supported phylogenies. In this framework, similarity is a hypothesis for testing rather than a substitute for evolutionary proof.

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