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Community Composition of Freshwater Fishes from Aquatic Streams and Rivers in the Western Ghats of South India

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Abstract: This study's goal was to evaluate the variety and distribution of freshwater fishes in three distinct rivers and hill streams in South India's Western Ghats. A total of 1234 fish, comprising six orders, eight families, fifteen genera, and 18 species, were present. Of the 18 species, 13 were identified as native, while four were introduced and one endemic. The most alarming finding is *Oreochromis niloticus*, which may be a pest in this region. The four most abundant exotic species comprised 39.79% of the overall count: *Oreochromis niloticus* (18.56%), *Gambusia affinis* (9.24%), *Barbodes binotatus* (7.21%), and *Garra rufa* (4.78%). The diversity index calculated by Shannon Weiner for the 15 sampling locations is within the permitted range of 0.81 to 1.54 (H′=1.538). However, due to the prevalence of multiple introduced species, the population structure of endemic freshwater fish species in distinct streams and rivers may be disrupted. The insights acquired from this study may be used to support a variety of fish conservation strategies in this area.

Keywords: *Ichthyofauna; Abundance: Endemic; Exotic; Western Ghats*

1. Introduction

Streams and rivers are regarded as crucial for inland water fisheries and hydrological supplies (Lynch *et al*., 2017). These waters are regarded as a source of food in numerous underdeveloped regions of the world (Caraco, 2009). They provide a major contribution to the Indian economy (Sandilyan *et al*., 2018). However, there has been a sharp reduction in biodiversity in many of these aquatic resources as a result of pollution, overexploitation, invasive species, and rapid land-use changes (Havel *et al*., 2015, Cantonati *et al*., 2020, Adla *et al*., 2022, Biswas and Sarkar, 2022).These even present biosecurity issues including disease outbreaks and the spread of contagious diseases (Krishna Kumar and Vennila, 2022).Since aquaculture is one of India's most important sectors, these resources must be safeguarded protected, and properly managed (Swaminathan and Bhavani, 2013).One of the initiatives performed to assist these activities is to examine the present fish inventories as environmental indicators and descriptors of fishery stability, as well as the ecological integrity of aquatic habitats (Beggel *et al*., 2021; Sarkar *et al*., 2021; Pinna *et al*., 2023; Nasri *et al*., 2024).

Impacts of climate change, invasive alien species, and habitat degradation at different geographical and temporal scales in a particular aquatic environment (Malmqvist and Rundle, 2002, Friberg, 2014, Bellard *et al*., 2018, Corrales *et al*., 2020).Several research onthe assessment of biodiversity inland freshwater resources to the integrity of the aquatic environment have been carried out in Western Ghats, India (Sugunan, 1994, Kumar, 2000, Ponniah and Gopalakrishnan, 2000; Dahanukar *et al*., 2004, Daniels, 2006; Lakra *et al*., 2010; Sarkar *et al*., 2010; Shanhnawaz *et al*., 2010; Lakra *et al*., 2011, Sarkar *et al*., 2012, Raman *et al*., 2013, Raja *et al*., 2014,Singh, 2014, Manikandan and Muralidharan, 2015, Raja *et al*., 2015, Raghavan, 2019, Roy *et al*., 2021a). Information on the current state of freshwater fish assemblages in the streams and rivers of the Western Ghats, South India, is shown in this study. This research is necessary because it will help predict how future conservation and development efforts affect the ecosystem.

1. Methodology

2.1 Study area

The present study was carried out in the Kurangani Hills, Kodaikanal Hills, and Palani Hills along the Western Ghats of India. Kurangani hills are located at an altitude of 122 m to 1981 m. The hills have more than six small streams, all of them flowing into the Kottagudi River (Balaguru *et al*., 2018). The Kodaikanal Hills station lies in the northwest portion of the range. It's one of the most beautiful hill towns and eco-tourist spotsin South India.It is encircled by the states of Kerala in the west, the Indira Gandhi Wildlife Sanctuary in the east, Pollachi in the north, Dindigul in the northeast, and Theni in the south. This area's altitude ranges from 300 to 2654 m, and its yearly rainfall is 165 cm on average (Prabha *et al*., 2019). Palani Hills are a mountain range from 1800 to 2500 m reaching the western part and 1000 to 1500 m reaching the eastern part in Dindigul district of Tamil Nadu, Western Ghats (Jeevith *et al*., 2022) Figure 1.

2.2 Fish sampling

A total of 15 sites comprising streams and rivers (Figure 1) were surveyed for fish sampling between November 2021 and July 2022 in which two sites, eight sites, and five sites were from Kurangani, Kodaikanal, and Palani hills respectively. The fish samples were collected standard methods (Talwar andJhingram, 1991, Tekriwaland Rao, 1999, Jayaram, 2009). Collected fishes were preserved in 200 ml sterile plastic containers with 5% formalin and transported to the laboratory for future analysis.Fishes were identified up to the species level following standard protocols (Daniels, 2002, Jayaram, 2010, Katwate *et al*., 2012, Raja *et al*., 2014, Arunachalam *et al*., 2017, Das, 2018, Kannan and Johnson, 2020, Thampy *et al*., 2021).

2.3 Data analyses

The number of species in a fish community served as an estimate for species richness (Lakra *et al*., 2010). The following formula was used to determine each species' relative abundance:

$$\text{Abundance} = (ai/A) \times 100$$

Where: ai is the number of individuals caught in the i^{th} species, and A is the total number of species collected in one sampling area during a sampling period (Yagos*et al*., 2022). Fish species diversity for the study sites was evaluated using Simpson's Diversity Index, 'Shannon-Wiener' Index (H′). Statistical software PAST version 4.03b and Microsoft Excel carried out fish abundance measures.

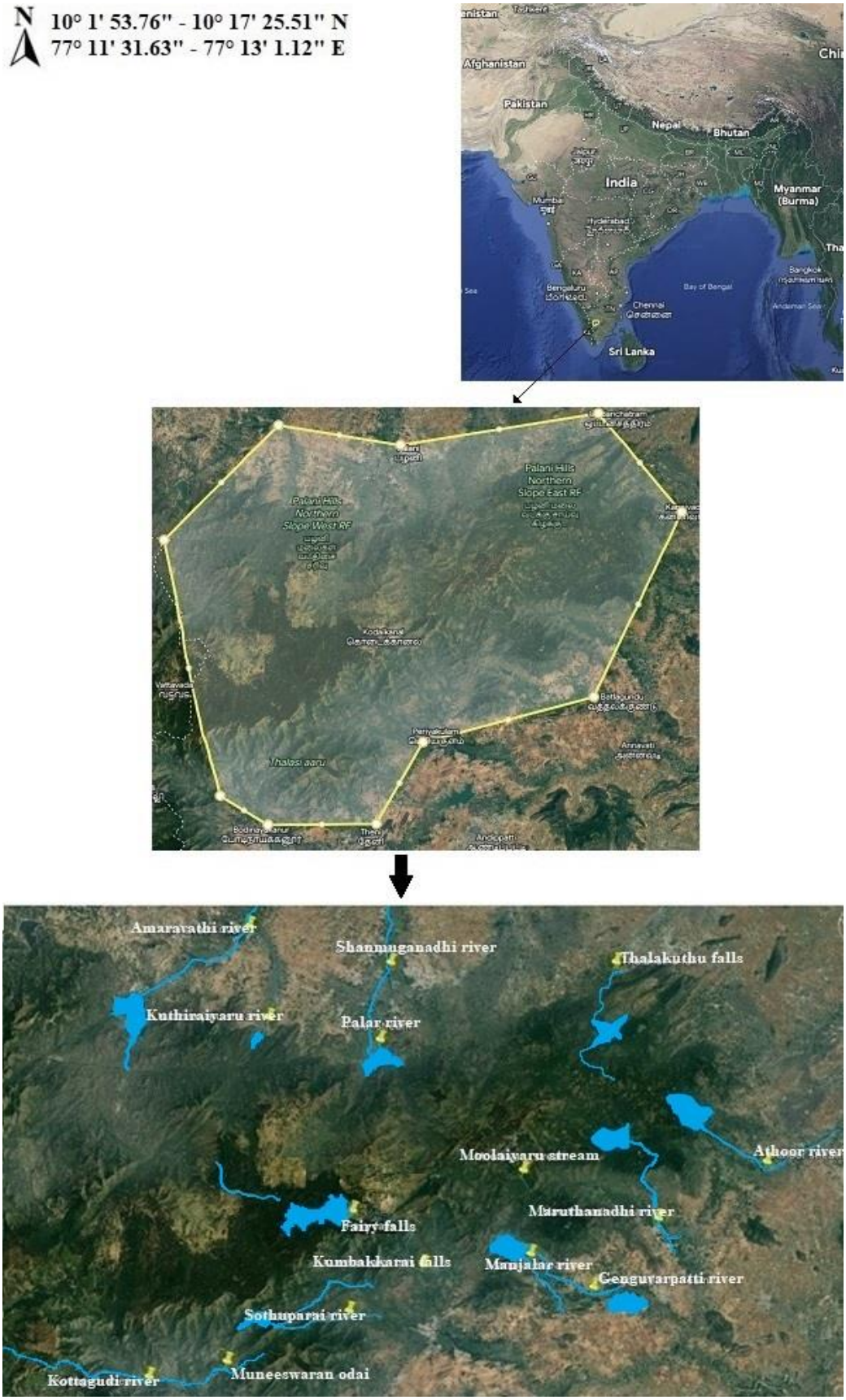

Figure 1. Map showing the streams and rivers in the Western Ghats where samples were taken.

2. Results and Discussion

During the field sampling, 1234 individual samples were collected from streams and rivers of three distinct hill regions, Western Ghats. A total of 18 fish species are six orders, eight families, and 15 genera (Table 1 & Figure 2a,b). SNR site of Palani Hill had the highest number of collected specimens (n=348), followed by AMR (n=167), KYR (n=143), PLR (n=89), and TKF (n=35). Furthermore, the MJR site of Kodai Hill had the highest number of collected specimens (n=138), GPR (n=65), KKF (n=40) ATR (n=39), MYR (n=33), FFY (n=20), SPR and MNR each (n=13). Only two sites were surveyed of Kurangani Hill, the highest number of collected specimens in the KGR site (n=88) and MNO (n=3) Table 2.

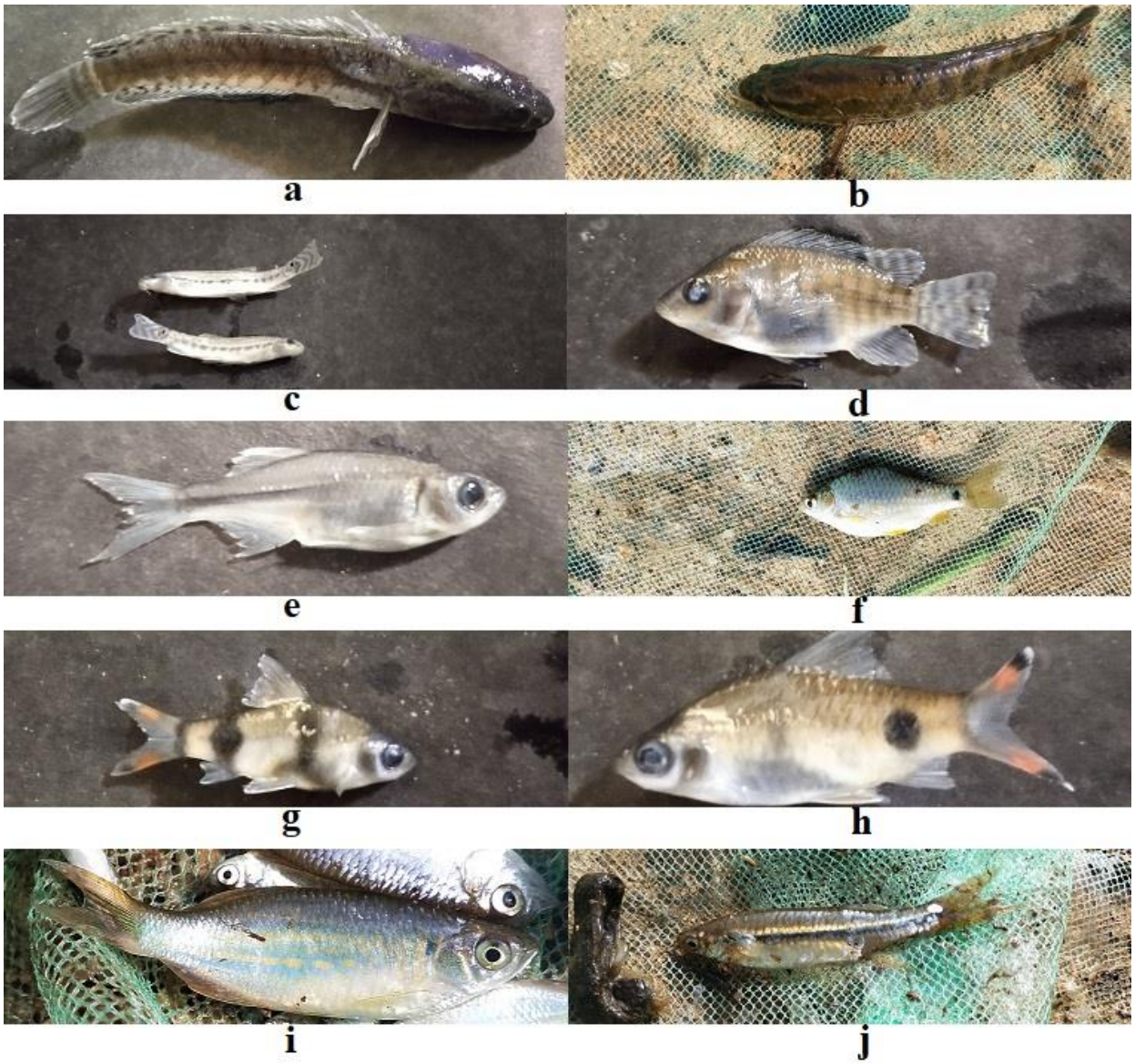

Figure 2a. Collected fish species are streams and rivers of Western Ghats (a) *Channa striata*, (b) *Channa punctata*, (c) *Lepidocephalichthys thermalis*, (d) *Oreochromis niloticus*, (e) *Amblypharyngodon mola*, (f) *Barbodes binotatus*, (g) *Dawkinsia filamentosa*, (h) *Dawkinsia tambraparniei*, (i) *Devario aequipinnatus* and (j) *Esomus danrica*

Table 1. Distributionof fishes in streams and rivers of three distinct hills, Western Ghats.

Order	Family	Species	Common name	IUCN Status	Fish status	Importance of species
Anabantiformes	Channidae	*Channa striata*	Snakehead murrel	LC (stable)	Native	Food
		Channa punctata	Spotted snakehead	LC (stable)	Native	Food
Cichliformes	Cichlidae	*Oreochromis niloticus*	Nile tilapia	LC (unknown)	Exotic/Introduced	Food
Cypriniformes	Cobitidae	*Lepidocephalichthys thermalis*	Spiny loaches	LC (stable)	Native	Ornamental
	Cyprinidae	*Amblypharyngodon mola*	Mola carplet	LC (stable)	Native	Food
		Barbodes binotatus	Spotted barb	LC (decreasing)	Exotic/Introduced	Ornamental
		Dawkinsia filamentosa	Filament barb	LC (unknown)	Native	Ornamental
		Dawkinsia tambraparniei	Tambraparni dookinsia	EN (decreasing)	Native	Ornamental
		Devario aequipinnatus	Giant danio	LC (unknown)	Native	Ornamental
		Esomus danrica	Indian flying barb	LC (stable)	Native	Food and ornamental
		Garra mullya	Suckerfish	LC (stable)	Native	Ornamental
		Garra rufa	Red Garra	LC (decreasing)	Exotic/Introduced	Ornamental
		Neolissochilus capudelphinus	Mahseer	NE (unknown)	Native	Food
		Rasbora dandia	Black-line rasbora	LC (stable)	Native	Food and ornamental
	Nemacheilidae	*Schistura denisoni*	Stone loaches	LC (stable)	Endemic	Food and ornamental
Cyprinodontiformes	Poecilliidae	*Gambusia affinis*	Mosquito fish	LC (stable)	Exotic/Introduced	Biological control
Perciformes	Ambassidae	*Chanda nama*	Elongate Glassfish	LC (decreasing)	Native	Food and ornamental
Synbranchiformes	Mastacembeliae	*Mastacembelus armatus*	Zig-zag eel	LC (stable)	Native	Food and ornamental

Abbreviation: LC – Least concern, NE – Not evaluate, and EN – Endemic

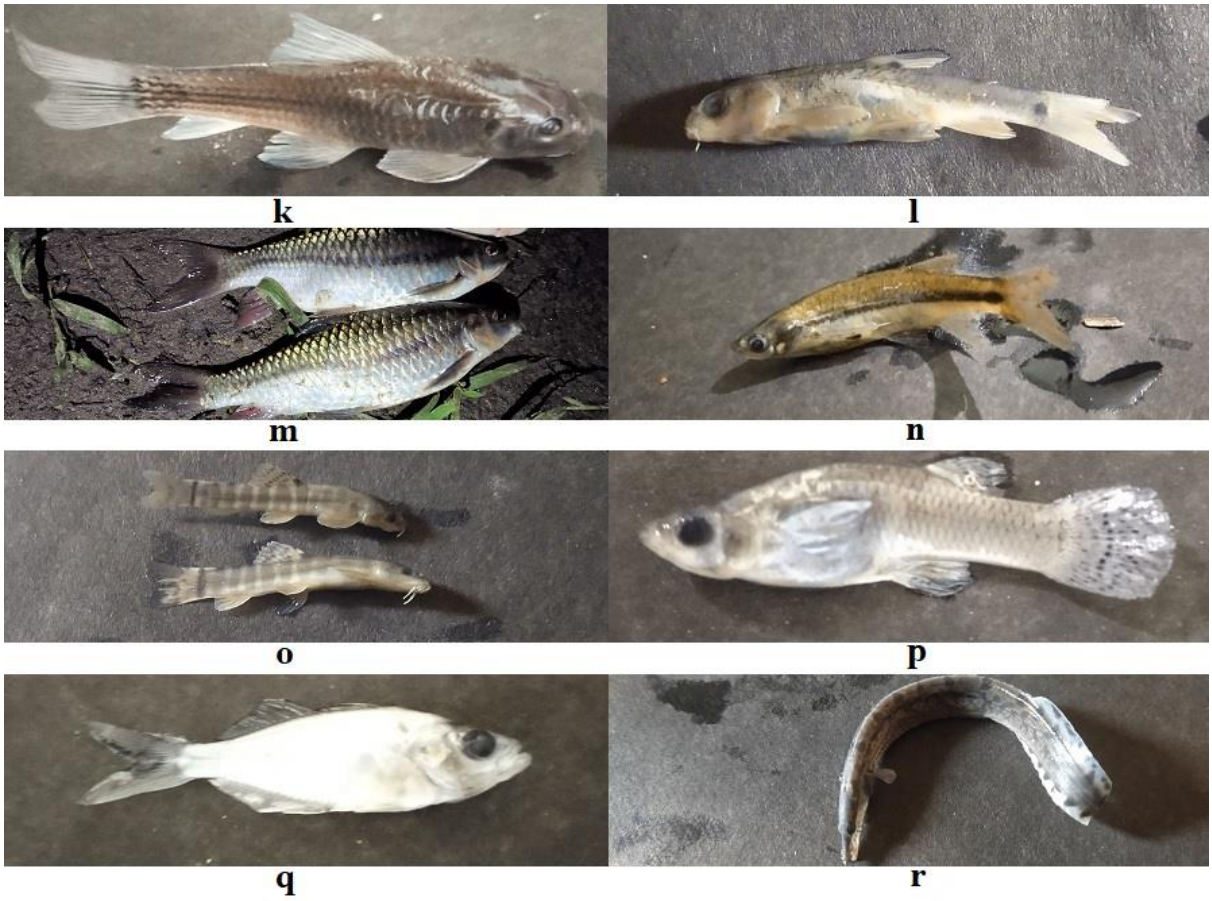

Figure 2b. Continue…. (k) *Garramullya*, (l) *Garrarufa*, (m) *Neolissochilus capudelphinus*, (n) *Rasbora dandia*, (o) *Schisturadenisoni*, (p) *Gambusia affinis*, (q) *Chanda nama*and (r) *Mastacembelusarmatus*

Identify 18 fish species belonging to six orders, eight families, and 15 genera. The family that dominated was Cyprinidae, with eight genera (*Amblypharyngodon*, *Barbodes*, *Dawkinsia*, *Devario*, *Esomus*, *Garra*, *Neolissochilus,* and *Rasbora*) and ten taxa (Table 1). Out of the 18 recorded species 13 were native (*Amblypharyngodon mola*, *Chanda nama*, *Channa punctata*, *Channa striata*, *Dawkinsia filamentosa*, *Dawkinsia tambraparniei*, *Devario aequipinnatus*, *Esomus danrica*, *Garramullya*, *Lepidocephalichthys thermalis*, *Mastacembelus armatus*, *Neolissochilus capudelphinus,* and *Rasbora dandia*); four species were exotic (*Barbodes binotatus*, *Gambusia affinis*, *Garrarufa,* and *Oreochromis niloticus*); and one species were endemic (*Schisturadenisoni*). A total of 15 streams and rivers were sampled, but Nile tilapia (*O. niloticus*) was collected in nine sites. In addition, Mosquito fish (*G. affinis*) were in four sites followed by Red garra (*G. rufa*) in two sites and Spotted barb (*B. binotatus*) in one site. Among the four exotic species, *O.niloticus* recorded the highest total catch and *G. rufa* recorded the lowest total catch. Nevertheless, the 39.71% result for these four invasive species shows that the species group is more prevalent than the native (Figure 3). A descriptive detail of four exotic species was given in Table 3.

Regarding economic values, only six species were identified with high economic values. These were *A. mola*, *C. nama*, *C. punctata*, *C. striata*, *M. armatus*, *N. capudelphinus*. The other native and endemic species had less to no economic value. Introduced species such as *O. niloticus* appeared because of their livelihood potential and economic benefits. The others are recreational fishes with no economic value, such as *B. binotatus*, *G. affinis,* and *G. rufa*, which escaped to the river system and multiplied.

Table 2. The distribution of fish species was 15 sampling sites.

Species/sites	KGR	MNO	GPR	MYR	FYF	SPR	KKF	MJR	MNR	ATR	TKF	SNR	AVR	KYR	PLR	Abundance
Channa striata	–	–	+	–	–	+	–	–	+	–	–	+	–	–	–	20
Channa punctata	+	–	–	–	–	–	–	+	–	–	–	–	–	–	–	26
Oreochromis niloticus	+	–	+	–	–	–	+	+	–	+	+	+	+	+	–	229
Lepidocephalichthysthermalis	–	–	+	+	–	–	+	+	–	–	–	+	–	–	–	31
Amblypharyngodon mola	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–	39
Barbodes binotatus	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	88
Dawkinsiafilamentosa	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	3
Dawkinsiatambraparniei	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	5
Devario aequipinnatus	+	–	+	+	–	+	+	–	–	–	–	–	+	–	+	302
Esomusdanrica	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	21
Garramullya	+	–	+	–	–	–	+	–	–	–	–	–	–	–	–	8
Garrarufa	–	–	+	–	–	–	+	–	–	–	–	–	–	–	–	59
Neolissochilus capudelphinus	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	3
Rasbora dandia	+	–	+	–	–	+	–	+	+	–	+	+	–	+	+	254
Schisturadenisoni	–	–	–	+	–	–	–	–	–	–	–		–	–	–	7
Gambusia affinis	–	–	–	–	+	–	–	–	–	–	–	+	–	+	+	114
Chanda nama	–	–	–	–	–	–	–	–	+			+	–	+	+	22
Mastacembelusarmatus	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	3
Total number of species from each site	88	3	65	33	20	13	40	138	13	39	35	348	167	143	89	**1234**

Site abbreviation – Kottagudi River (KGR), Muneeswaran Odai (MNO), Genguvarpatti River (GPR), Moolaiyar River (MYR), Fairy Falls (FYF), Sothuparai River (SPR), Kumbakkarai Falls (KKF), Manjalar River (MJR), Athoor River (ATR), Talakkuthu Falls (TKF), Shanmuganathi River (SNR), Amaravathi River (AVR), Kudhriyar River (KYR) and Palar River (PLR).

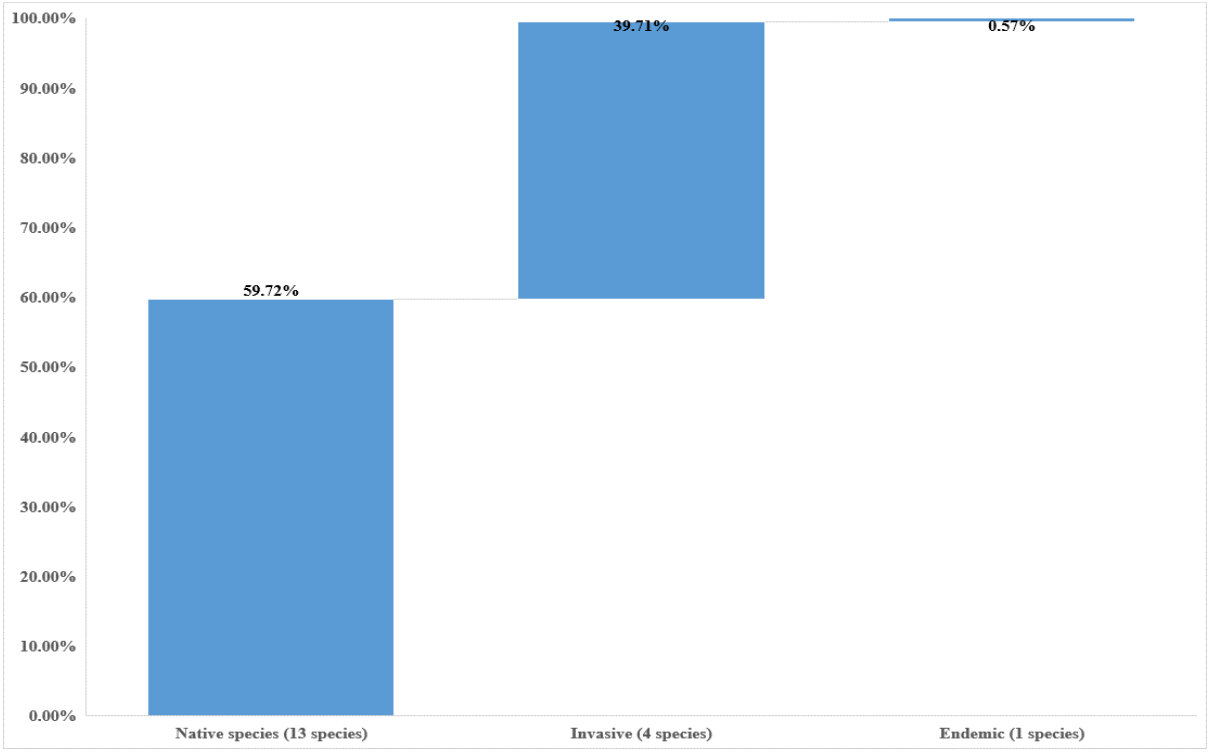

Figure 3. A waterfall bar chart is used to compare values across native, invasive, and endemic species levels

Table 2 and Figure 4 show the community structure of freshwater fish species recorded from the streams and rivers of three hills of the Western Ghats. Out of 15 sites, three sites have the highest number of endemic species, PLR (five taxa out of seven species) followed by GPR (five taxa out of six species), MJR (four taxa out of six species), and KGR (four taxa out of four species) and lowest number of endemic species was found in SNR (four taxa out of seven species). The distribution of some species is specific. This might be due to the physicochemical parameters of each site. For instance, endemic species of *N. capudelphinus* were found in the MNO site, but not in the other sites, while *D. aequipinnatus* and *R. dandia* were commonly found in sites GPR, KGR and SPR, but absent in site MNO. In addition, exotic species *O. niloticus* could only be at nine sites ATK, GPR, KGR, KKF, KYR, MJR, MNR, SNR, and PLR, but absent of MNO site. On the other hand, some species were distributed in all study sites, meaning they have a wide range of habitat adaptations.

The endemic species widely distributed in some study sites are part of the Cyprinidae family, namely *D. aequipinnatus*, *L. thermalis*, *N. capudelphinus,* and *R. dandia*. A similar result was attained by earlier researchers (Raghavan *et al*., 2008, Shanawaz*et al*., 2010). The other endemic species of *S. denisoni* are concentrated few sites only at GPR, PLR, and SNR. From an ecological point of view, the manifestation of these fish populations is usually reliant on the environmental status and habitat attributes of their ecosystem, including vegetation (Vieira *et al*., 2015), elevation (Kumar *et al*., 2017), water temperature (Atkore *et al*., 2017), pH (Bera *et al*., 2014), water velocity (Mondal and Bhat, 2020), and substrate type. Since they rely on certain ecological characteristics, these native fish species are significant bioindicators of the health of streams and rivers (Roy *et al*., 2021b). This might be the cause of the higher number of native species. An introduced species, such as the cichlids, established a feral population in nine sites, while others like *B. binotatus*, *G. affinis,* and *G. rufa* are found in different sites FYF, GPR, KKF, KYR, MJR, PLR, and SNR. It was identified by (Froese and Pauly, 2023) as an introduced species.

Table 3. A descriptive detail of four exotic species in Western Ghats, South India.

Exotic fish	Impact	References
B. binotatus	• It resides in Majalar's large- to medium-sized rivers, tranquil lakes, slow-moving canals, and brooks. • Competition for food and physical resources between the native species and the invasive species affects habitat structure and species diversity. • This fish might displace more delicate and serene local species.	**Present study**
G. affinis	• In 1928, mosquito fish were introduced from Italy to India to control mosquito larvae. • On the other hand, another research claims that *Gambusia* is ineffective as a larvicide. • *Gambusia* sp.has endured in India for nearly a century in a variety of climes and seasons. • *Gambusia* sp. competes with native fish because they are more tolerant to contamination than the latter. • The population of other fish species tends to decline when the number of *Gambusia* increases, presumably as a result of competition for scarce resources. Because of its prolific reproduction and rapacious habitat, *Gambusia* has earned the nickname "fish destroyer". • Only the introduced *G. affinis* species was found at the low- to high-ranged FYF, KYR, PLR, and SNR locations. This demonstrates an exceptional ability to adapt to a wide range of ecological situations. *Gambusia* sp. threatens the biodiversity of local fish, and the impacted nations are working to eliminate them from the ecosystem.	Lloyd, 1986 Singh and Gupta, 2016 Myers, 1965 **Present study**
G. rufa	• It indicates that this species has been discovered in rivers and sporadic mountain streams. • The fact that the native fish groups and the exotic *G. rufa* shared a significant mean prey overlap suggests that there is intense competition between native and foreign species in the ecosystem. • *G. rufa* was discovered in several streams and rivers in the three-hill area. *G. rufa* need a balanced diet because they are omnivores. It might lead to future risks to native species.	Okur and Yalcin-Ozdilek, 2008 Sreekanth *et al*., 2022 Jayasree *et al*., 2016 **Present study**
O. niloticus	• *O. niloticus* an exotic fish was introduced to India in 1987 for aquaculture purposes. • The Nile tilapia provided more than 7.17% of the world's inland fish production. • Tilapia is the second most produced commercially alien fish in the world, behind carp.	Singh and Lakra, 2011 Singh and Lakra 2006 Ridha, 2006

	• The Nile tilapia is a widely grown species because it can survive in a variety of environmental conditions. • The percentage and contribution of Nile tilapia have significantly expanded over the past three decades to support worldwide aquaculture and fisheries production. • Most frequently, tilapia eat the eggs of other species, which leads local species to become extinct. On the other hand, native species suffered from low growth rates and age structure as a result of the introduction of species like tilapias. • A total of 15 streams and rivers were sampled, but Nile tilapia (*O. niloticus*) was collected in nine sites. Tilapia has a lot of potential detrimental effects on local species' biodiversity. By competing with other species for food and shelter, they upset the biological balance and harm the local environment. Additionally, the intense tilapia production causes eutrophication of the water.	Tsadik and Bart, 2007 De Silva *et al*., 2004 Dwivedi *et al*., 2017; Johnson *et al*., 2020 **Present study**

Table 4. The diversity index and several taxa were recorded from 15 study sites in the Western Ghats.

Biological indices	**KGR**	**MNO**	**GPR**	**MYR**	**FYF**	**SPR**	**KKF**	**MJR**	**MNR**	**ATR**	**TKF**	**SNR**	**AVR**	**KYR**	**PLR**	**Overall**
Taxa S	4	1	6	3	1	3	3	6	3	1	1	6	1	4	7	**18**
Individuals	88	3	65	33	20	13	40	138	13	39	35	348	167	143	89	**1234**
Simpson 1-D	0.6258	0	0.711	0.4959	0	0.6509	0.4638	0.5551	0.6627	0	0	0.5805	0	0.5507	0.719	**0.719**
Shannon H	1.1623	0	1.498	0.855	0	1.0732	0.8146	1.153	1.0931	0	0	1.132	0	0.9611	1.538	**1.538**

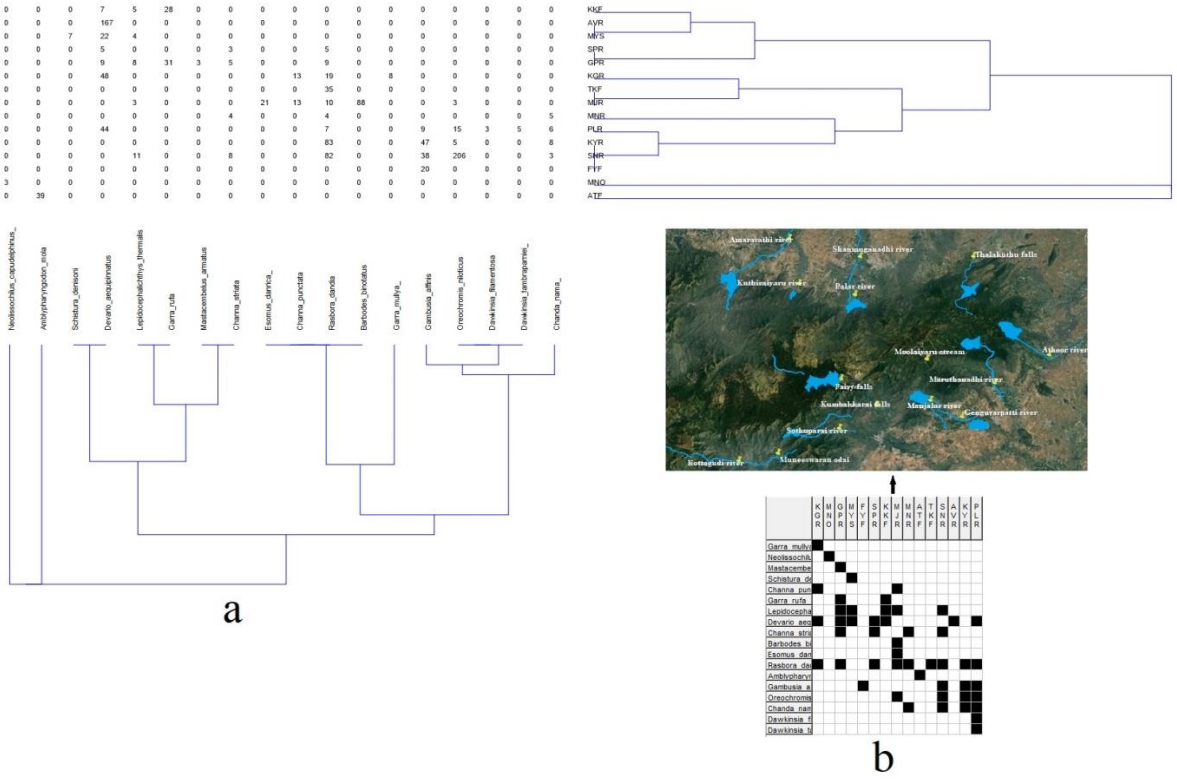

Figure 4. Freshwater species community structure over 15 sites, with a - cluster analysis and b - seriation.

The introduced species found in this study have the potential to lower fish diversity by outcompeting native species because they are habitat generalists and extremely prolific (Singh and Lakra, 2011, Dwivedi *et al*., 2016, Jayasree *et al*., 2016). Only one of the introduced *G. affinis* species was found at the low- to high-ranged FYF, KYR, PLR, and SNR locations. This demonstrates an exceptional ability to adapt to a wide range of ecological situations. Burnett *et al*., 2006,their outstanding capacity for adaptation to a wide range of ecological conditions and their effectiveness as resource users might be credited with their success in invasion and establishment. Introduced species frequently appear as a result of intentional introduction by fishermen and inadvertent emigration from surrounding ponds (Singh and Lakra, 2006). It is well established that the escapement of introduced cultured fish species and their potential to be invasive are aquaculture's most detrimental effects on biodiversity loss (De Silva *et al*., 2005). Predation has the adverse impact of reducing the population of desired non-commercial and smaller commercial fish species. In agriculture runoff and anthropogenic influence sites of KGR, MNR, MYR, and SPR, the only native species of *C. nama*, *C. punctata*, *C. striata*, *D. aequipinnatus*, *L. thermalis*, *R. dandia*, and *S. denisoni* were collected, indicating rich diversity but less abundance of species. According to Hoque *et al*. (2022), delicate native fish are endangered by household waste and agricultural effluents. Climate change and anthropogenic activity could damage the riverine system, eventually decreasing diversity and eradicating groups that are susceptible like native fish species (Ficke *et al*., 2007, Singh, 2014).

3.1 Diversity indices

Species richness and the number of individual and biological indices are summarized in Table 4. Among the 15 sampling sites, PLR had the highest species richness with 7 taxa, followed by GPR, MJR, and SNR (each site six taxa), KYR and KGR (each site four taxa), MNR, MYR, KKF, and SPR (each site three species) and ATR, AVR, FYF, MNO and TKF (each site one species).Simpson and

Shannon values were highest in PLR (0.719 and 1.538) and lowest in KKF (0.4638 and 0.8146).Although foreign species were found in PLR-rich groups, the diversity indices suggested that certain species' numbers would be diminishing. On the other hand, *D. aequipinnatus*, the only native species at the AVR site, had a dominant population over other species. This outcome prediction clearly showed invasive threats to the native fish population (Figure 3).

Conclusion

The Western Ghats' three separate hill ranges' freshwater fish populations were examined, and it was shown that the diversity indices ranged from 0.6653 to 1.498. Although the PLR site had the greatest number of endemic species, the GPR site had the highest diversity index value. At the PLR site, invasive species, agricultural runoff, and anthropogenic impact are the causes of less endemic fish populations. An introduced species of *O. niloticus*was most abundant and dominant in nine sites. On the other hand, the AVR site's greater abundance of the *D. aequipinnatus* solitary native fish population provides proof that endemic fish populations were more numerous in undisturbed areas. On the Shannon-Weiner diversity index, a value of 1.538 is rated as moderate to good. Even though the streams and rivers in the watershed often have high levels of diversity, introduced species have the potential to disturb native populations of freshwater species.

Authors' contributions

SV- experimental design, conduct of experiments, writing of manuscript, and interpretation of data

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