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Comparison of trophic structure of fish assemblages in two tropical streams in Sri Lanka: a seasonal dry zone stream and a perennial wet zone stream

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ABSTRACT

Most tropical rivers especially in the Asian region, are severely impacted by various human perturbations, and the diverse habitats in streams support rich invertebrate and vertebrate communities. It is hypothesized that the fish assemblages and their dietary structure in two tropical streams differ because they flow through different terrains and are exposed to different climatic conditions. In the wet zone stream, which is geomorphological more complex, fish faunal diversity showed significant longitudinal variations, and sustains endemic fish species. In the diets of fish, taxonomic composition was different along the longitudinal gradients, but dietary taxa richness in the two streams was virtually similar having 32 dietary taxa in wet zone stream and 36 taxa in dry zone stream. In the wet zone stream, we observed a lower proportion of specialist feeding species than those in the dry zone stream. Trophic indices of individual species in fish assemblages ranging from herbivory to carnivory also indicate structuring of fish communities along the longitudinal gradients of the two streams based on dietary structure. The main differences between the fish assemblages in the wet zone compared to the dry zone were the higher number of endemic species and the lower percentage of specialist feeders with higher trophic indices. The outcome of this study hopefully contributes to plan future biodiversity conservation management schemes under various river basin development strategies.

KEYWORDS

dietary breadth, endemism, freshwater fish, macroinvertebrates, trophic index

1 | INTRODUCTION

Rich biodiversity is a characteristic feature of tropical rivers and streams, but geomorphologically their habitat characteristics are governed by simple physical characteristics, i.e., flow and gradient (Callow & Petts, 1992; Welcomme, 2000). Form and function of a river/stream system from headwaters to lower reaches present a wide range of habitats having well oxygenated, nutrient poor lower order streams in upper reaches and usually nutrient rich and often less oxygenated slow flowing lower reaches (Welcomme, 1985). As these diverse habitats in streams support invertebrate and vertebrate communities, the presence of species through food webs in stream ecosystems can vary with space and time (Rosi-Marshall & Bruce, 2002). Welcomme, Amarasinghe, Vijverberg, Leichtfried & Füreder (2017a) have also shown that different discharge regimes due to landscape properties in the catchment of two Sri Lankan streams, affected trophic interactions of fish assemblages.

Habitat occupation by stream fish is known to be governed by combination of physical factors such as flow velocity, depth and substrate type (Arunachalam, Nair, Vijverberg & Kortmulder, 1997) that produce a mosaic of microhabitats favouring diverse assemblage structure (Gorman & Karr, 1978). Dietary structure of stream fish assemblages in relation to habitat heterogeneity is therefore important to be investigated. Also, habitat heterogeneity coupled with longitudinal gradient in streams of different climatic zones with contrasting terrains is an important piece of knowledge to understand

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incorporation of habitat conservation in biodiversity conservation strategies are important in tropical stream habitats. McManamay, Griffiths, DeRolph & Pracheil (2018) stated that habitat alteration in freshwater ecosystems due to anthropogenic stressors have a strong link to freshwater biodiversity decline and extinction risk. Bossuyt, Meegaskumbura, Beenaerts, Gower, Pethiyagoda, et al. (2004) suggested that future conservation programs for the Indian subcontinent including Sri Lanka should take into account patterns of local endemism at the finest scale at which they may occur. Hence, as a 'rule-of-thumb', the degree of endemism can be treated as the basis for defining conservation strategies for the riparian habitats.

Two tropical streams, a seasonal stream in the dry zone and a permanent stream in the wet zone of Sri Lanka were studied. We test the hypothesis that the fish assemblages and their dietary structure in these streams differ because they flow through different terrains and are exposed to different climatic conditions. The outcome of this study hopefully contributes to plan future biodiversity conservation management schemes under various river basin development strategies.

2 | MATERIALS AND METHODS

2.1 | Study sites

Studies were conducted in two streams in Sri Lanka (Fig. 1a). Eswathu Oya (hereafter EO-WZ) is a perennial low order stream that runs through the wet zone of the country (Fig. 1b). Yan Oya (hereafter YO-DZ) is a seasonal stream, flows 122 km along the low land dry-zone and drains to the Indian Ocean (Fig. 1c). Five stretches, each 25 meters were selected both from EO-WZ and YO-DZ for comparing fish assemblages and

their trophic structure. Those stretches were our ten sampling sites. The distance between the first and the fifth site for EO-WZ and YO-DZ was 11km and 20km respectively.

Geographic locations, altitudes, morphometric properties (bank width, channel width, average depth and maximum depth) and flow characteristics (average flow velocity, average discharge and maximum velocity) of the selected 10 sites are given in Table 1.

Eswathu Oya (EO-WZ)

Eswathu Oya is subjected to torrential rains during south-west monsoon hence flashy floods occur seasonally. It is a tributary of Kelani River and cascades through a hilly area. In general, catchment land-use includes human settlements, rubber plantations, home gardens, natural forest reserves, and livestock and farming activities. Welange et al. (2017b) have describe the physical features of the five sites as follows; riffle–pool combination was more frequent within the first four sites where bedrocks were imminent as outcrops, e5 site flows through a flat area, vegetation cover over e1-e3 was 100% and about 10% in e4-e5 (Plate 1). Some physico-chemical parameters such as clarity of water, temperature (25 to 28°C), pH (5.5 to 6.1), conductivity (24 and 41 μScm^{-1}) and flow velocity (0-0.15 cms^{-1}) of the five sites were also given by Welange et al. (2017b).

Yan Oya (YO-DZ)

Welange et al. (2017b) have described the five sites as follows; catchment comprises with scrub forest, grasslands, paddy fields, slash-and-burn cultivation and human settlements. This stream flows through a flat landscape hence riffle-pool combination was rare (Plate 2). The vegetation cover over y1 site was about 50% and in other four sites, it was about 80%, average depth of sampling sites increased from 17 to 36 cm from y1 to

y5 and all four fractions of POM were found throughout y1 to y5. Some physico-chemical parameters such as temperature (26.5 to 28°C), pH (6-7), conductivity (323 to 507 $\mu\text{S cm}^{-1}$) and flow velocity (0.1 to 0.5 cm s^{-1}) were also given for the five sites (Weliange et al. 2017b).

2.2 | Sampling of fish

Fish sampling in EO-WZ was performed from 23rd to 28th February 2006 and in YO-DZ from 4th to 8th March 2006. Sampling was done using Backpack EFKO electro-fishing equipment with Honda aggregate. During each sampling session, three fishing runs were done in each 25m stretch (e1-e5 and y1-y5) at an interval of 30-40 minutes to recover the un-caught fish from the electrical shock and allow to be active again. Each fishing run was about 20 minutes as described by Weliange et al. (2017a). All the sampled fish were identified to the species level *in situ*, and maximum of ten individuals from each species were preserved in 10% formalin for stomach content analysis.

In the laboratory sampled fish from each site were treated separately, dissected, and stomach contents were collected. Fish with empty stomachs were disregarded. Diet items were observed using a stereo microscope and identified to the lowest possible taxonomic level (Dudgeon, 1999; Fernando & Weerawardhane, 2002). Bio-volumes of each diet item were determined using the Points Method described by Hynes (1950). This method included assuming the relative abundance of each diet items compare to Baetidae larva (Order Ephemeroptera) as a standard, from the simple visual inspections of stomach contents. Diet items (animals and plants) were pooled into broader categories based on the trophic level and the taxonomic affiliation of each diet item (Table 2).

2.3 | Fish faunal similarity in the two streams

To compare the species richness between EO-WZ and YO-DZ faunal similarity was compared by coefficient of biogeographic resemblance (CBR) (Duellman, 1990),

$$CBR = 2C/(N_1+N_2) \quad (1)$$

where C is the number of species common to both streams, N_1 and N_2 are species richness in EO-WZ and YO-DZ stream. This index measures the similarity in species composition between two streams. The CBR ranges from 0 (no species in common) to 1.0 (share the same relative numbers and kinds of species).

2.4 | Fish faunal diversity

As fish sampling was performed with three electro-fishing runs having about 20 minutes in each fishing run, number of fish caught in each site of the stream was treated as relative abundance of individual fish species. Based on the relative abundance of species present in the samples, Shannon-Weiner diversity index (H') in each site of the two streams was determined and H' values between sites of each stream and between the two streams were compared using t-test (Hutcheson, 1970; Magurran, 1988). Determination of H' and pair-wise comparison of H' by t-test were done using PAST (version 3.17) statistical software (Hammer, Harper & Ryan, 2001).

2.4 | Dietary taxa richness

Dietary taxa richness is the total number of faunal and floral taxa found in the stomach of fish. It is the number that can vary according to the taxonomic resolution of the prey categories. Dietary taxa richness of the total fish assemblage of EO-WZ and YO-DZ were used to cluster fish species belongs to similar trophic guilds by Bray-Curtis similarity analysis (Bray and Curtis, 1957), which illustrates the fish species with similar diet items in the guts. proportions of diet items consumed by each fish species were double square

root transformed to reduce heteroscedasticity before perform the cluster analysis. The trophic guilds given as a dendrogram by the Bray-Curtis analysis are named base on the diet item that contributed most. This similarity analysis was performed by Minitab (version 16) statistical software.

2.5 | Dietary breadth

The relative level of diet specialization of a given fish species was quantified by estimating Levin's standardized index of dietary breadth (B_s) as follows:

$$B_s = [(\sum_j P_{ij}^2)^{-1} - 1] (n-1)^{-1} \quad (2)$$

where P_{ij} is the proportion of prey j in the diet of predator i and n is the number of prey categories (Hurlbert, 1978). B_s ranges from 0, when only one diet item type is consumed (diet specialist) to 1 when all resources are used equally (generalists).

2.6 | Trophic index

For calculating the trophic index (T_i) of fish, diet items were classified into trophic classes (T); plant based diet items like algae, detritus, diatom, phytoplankton are classified as $T = 0.0$, herbivorous insects and fish that consume plant food are classified as $T = 1.0$, animals that consume plant and herbivorous animals equally are classified as $T = 1.5$, animals that consume only herbivorous prey are classified as $T = 2$, and so on (Table 2).

The following method employed by Adams, Kimmel & Plosky (1983) and Winemiller (1990) was used to calculate trophic index of each fish species per site;

$$T_i = 1.0 + \sum_{j=1}^n T_j (p_{ij}) \quad (3)$$

where T_j is the trophic class of prey j and p_{ij} is the fraction of the consumed diet (proportion by volume) of fish i consisting of prey j . It is understood that T_i represents trophic continuum in the ecological pyramids rather than the discrete trophic levels of consumers (Adams et al., 1983).

In the trophic guilds resulted from Bray-Curtis similarity analysis, B_s and T_i were compared along the longitudinal gradient of each stream to investigate whether there was a trophic divergence in constituent species of each trophic guild along the spatial dimensions.

3 | RESULTS

3.1 | Species richness and endemism

In total, 38 fish species belonging to 16 families were found in the ten sites of the two streams (Tables 3 and 4). Fish species richness was 22 and 27 in EO-WZ and YO-DZ respectively. Among them, there were 16 species of Cyprinidae, 4 species of Cichlidae, 3 species of Channidae, 2 species each from Clariidae and Balitoridae. One species from each of the following families were also recorded; Anabantidae, Anguillidae, Aplocheilidae, Bagridae, Cobitidae, Eleotridae, Gobiidae, Heteropneustidae, Mastacembelidae, Osphronemidae and Siluridae.

EO-WZ had 10 endemics and twelve indigenous fish species. YO-DZ had 2 endemics, one translocated indigenous species (*Etiopis suratensis*), 3 exotic species (*Clarias batrachus*, *Oreochromis niloticus*, *Oreochromis mossambicus*) and 21 indigenous species. *C. batrachus* has been accidentally introduced to freshwaters in Sri Lanka through aquarium fish industry (Silva & Kurukulasuriya, 2010).

Also given in Tables 3 and 4 are Shannon-Weiner indices (H') of fish species in each sampling site of the two streams and those of pooled data for each stream separately. Pair-wise comparison of H' between sites in each stream (Table 5) indicated the following trends. In EO-WZ, H' of three sites in upper reaches of the stream (e1, e2 and e3) did not show significant differences between each other. Similarly, there was no significant difference of H' between two sites in the lower reaches (e4 and e5). However, in EO-WZ, H' of sites in the upper reaches were found to be significantly different from those of the sites in the lower reaches. In contrast, in EO-DZ, practically H' of all sites were significantly different from each other. The diversity indices of fish species in the two streams were not significantly different showing that both streams has more or less similar species heterogeneity.

3.2 | Fish faunal similarity in the two streams

Faunal similarity between the two streams was 0.44, indicating that both streams share about 44% of the species. Among the 12 species shared, 8 were cyprinids (*Dawkinsia singhala*, *Devario malabaricus*, *Garra ceylonensis*, *Pethia ticto*, *Puntius bimaculatus*, *Puntius vittatus*, *Rasbora daniconius* and *S. sarana*) and other 4 species were *Channa gachua*, *Heteropneutes fossilis*, *Mastacembelus armatus* and *Mystus vittatus*.

In both stream, species occurrence varied longitudinally. In EO-WZ, of the 22 species recorded, three sites in the upper reaches (e1 to e3) had 6-7 species while in sites e4 and e5, there were 12 and 13 species respectively (Table 2A). In contrast, in YO-DZ, number of fish species along the longitudinal gradient did not exhibit such a trend. In the two sites in upper reaches (y1 and y2) there were 12 and 10 species respectively, while in sites y3, y4 and y5, species richness was 22, 18 and 9 respectively. Of the 10 endemic

fish species recorded in the present study, except *D. singhala* and *G. ceylonensis*, which occurred in both streams, all other 8 species were recorded from EO-WZ. All three exotic species were recorded only from YO-DZ.

3.4 | Dietary taxa richness

There were 32 food items in the diets of fish species sampled from EO-WZ and 35 food items in fish species sampled from YO-DZ (Table 2). In EO-WZ, 20 taxa of benthic macro invertebrates dominated the diets of fish species, which included larval stages of ephemeropteran mayflies, trichopteran caddisflies, dipterans, coleopterans, brachyuran crabs and caridean shrimps (Supplementary Table S1). Rest of the food items were algae, detritus, terrestrial insects, fish and amphibians. Some animal based diet items such as tadpoles, fish scales, *S. notostigma*, *B. signata*, coleopteran larva, ephemeropteran larvae, Hydropsychidae larvae, Psephenidae larvae and Simuliidae larvae were also found in EO-WZ. Also, *Spirogyra* (SPR) was found only in e5 site. In YO-DZ the most dominant food items in the diets (Supplementary Table S2) consisted of 23 taxa of benthic macro invertebrates (larval stages of ephemeropterans, trichopteran, plecopterans, dipterans, coleopterans and caridean adults). Other major groups of food found in the fish diets were algae, detritus, terrestrial insects, *R. caverii*, *R. daniconius*, amphibians and zooplankton. Some of those diet items such as larvae of Baetidae, Caenidae, Coenagrionidae, Ephemera, Polymitarcyidae and Perlidae, as well as adult amphibian, molluscs and fish (*L. thermalis*, *Rasbora* species) were found only in the fish diets in YO-DZ.

3.5 | Trophic groups

The dendrograms based on Bray Curtis similarity analysis of dietary composition of fish species in the EO-WZ (Fig. 2a) and YO-DZ (Fig. 3a) have shown that in both streams, fish species were characterized by distinctive dietary habits having a few species with dietary similarities. In EO-WZ, the largest trophic guild was formed by *A. dayi*, *B. signata*, *C. orientalis* and *R. daniconius* all of which occupied upper reaches of the stream. They mainly fed on terrestrial insects (Fig. 2). In YO-DZ, there were two larger trophic guilds (Fig. 3). One trophic guild was formed by fish species, *D. malabaricus*, *E. maculatus*, *G. giuris*, *M. vittatus* and *O. bimaculatus* which mainly fed on caddis fly larvae of the family Helicopsychidae. The other trophic guild was formed by *D. singhala*, *E. danricus*, *P. bimaculatus*, *P. chola* and *L. thermalis*, and they fed mainly on fine detritus.

3.5 | Dietary breadth and trophic index

To estimate dietary breadth and trophic class could not be determined for fish species without gut/stomach contents in the samples. From the available data of T_i and B_s , it can be seen that many fish species in both streams had T_i values ≥ 2 (Figs. 2b and 3b). In YO-DZ, *M. armatus*, *R. daniconius* and *R. caverii* had higher (about 3) trophic indices. Some fish species such as *R. daniconius* and *M. armatus* had lower T_i in EO-WZ than in YO-DZ. In fact, *R. daniconius* in site 5 (e5) of EO-WZ fed exclusively on *Spirogyra*.

Generally dietary breadths of fish species with higher T_i (e.g., *M. armatus*, *Rasbora* spp.) were narrower in both streams except some species such as *M. vittatus*, *C. orientalis*, *O. bimaculatus* (Figs. 2c and 3c). However, diets of many of these species consisted of benthic macroinvertebrates (Figs. 2 and 3).

4 | DISCUSSION

The fish faunal similarity between the two streams was low (CBR = 0.44) indicating that number of species common to both streams was few. In fact only 11 species (six cyprinid species and four top carnivores) were common to both streams, only two endemics *D. singhala* and *G. ceylonensis* were found in both streams. The wet zone stream (EO-WZ) is geologically more complex than the dry zone stream (YO-DZ) (Weliange et al., 2017a). The low fish faunal similarity between the two streams can therefore be attributed to their difference in geomorphological complexity. Furthermore, fish faunal diversity in EO-WZ longitudinally varied significantly, in contrast to YO-DZ. This also indicates that the fish faunal diversity along the longitudinal gradient in the wet zone stream is more heterogeneous possibly due to more complex geomorphology of the stream. However, overall fish faunal diversity between the two streams was not significantly different indicating more or less species heterogeneity in the two streams. Occurrence of fish species specific to each stream having low CBR would have brought about similar fish faunal diversity indices in the two streams.

The perennial streams in the wet zone of Sri Lanka are reported to be geomorphologically more complex and sustain more endemic fish species (Senanayake & Moyle, 1982). According to Senanayake & Moyle (1982), distribution of freshwater fish species in Sri Lanka is related to topography of the island. In the southwestern region of the country, rivers and streams drain over the second peneplain of the island where the highest number of endemic fish species are found. The lowest peneplain of the island consists of the streams of the dry zone and the lowest number of endemic fish species occurs in this region. It is known that the biology and ecology of riverine species, which

complete their entire life cycle in riverine habitats, are closely linked with the annual hydrological regimes and flood patterns (Poff, Allan, Bain, Karr, Prestegard, Richter, Sparks & Stromberg 1997; Welcomme & Halls, 2001). The higher endemism in the wet zone stream than in the dry zone stream must therefore be due to the more complex and more stable environment in the wet zone. Wickramanayake & Moyle (1989) have suggested that fish assemblages in the wet zone streams of Sri Lanka are co-evolved systems with competition serving as an important structuring force that reinforces species segregation.

Contrary to our expectations, the higher habitat diversity in the wet zone stream did not lead to a higher species richness, to a higher percentage of specialist feeders and to a higher number of taxa in the diet. The main differences between the fish assemblages in the wet zone as compared with the dry zone were the higher number of endemic species, the lower percentage of specialist feeders and occurrence of fish species that were feeding higher in the food chain.

Although taxonomic composition was different, dietary taxa richness in the two streams was more or less similar having 32 and 35 dietary taxa in wet zone stream and dry zone stream respectively. It was evident that there was a longitudinal variation of dietary structure of fish species in both streams, which was essentially reflected both by the variation in food availability and the variation of occurrence of fish species. Dietary breadths of fish species in both streams were also more or less similar. However, proportion of specialist feeders in the dry zone stream was much greater than in the wet zone stream. It was evident that in the wet zone stream the dominant trophic class was 2

whereas in the dry zone stream it was 1, which probably reflects differences in food availability in the two streams.

In conformity with general ecological principles (Osborne, 2000), fish assemblages in the two streams are structured for food resource partitioning along trophic and spatial gradients, especially among trophic specialists. Among trophic generalists, such a divergence is not evident due to lack of food limitation in lower trophic levels.

In conclusion, the higher habitat diversity in the wet zone stream did not lead to higher species richness, to a higher proportion of specialist feeders and to a higher number of taxa in the diets of the fish assemblage. The main differences between the fish assemblages in the wet zone as compared with the dry zone were the higher number of endemic species, the lower percentage of specialist feeders and fish were feeding higher in the food chain. The observed changes in food availability along the gradients of the two streams are important biological characteristics that should be taken into account for planning biodiversity conservation measures for stream fish assemblages.

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CONFLICT OF INTEREST

The authors have declared no conflict of interest.

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Figure captions

Fig. 1 (a) Map of Sri Lanka showing river network, cathements and the three climatic zones (wet, intermediate, dry); (b) Catchment of Eswathu Oya in the wet zone (EO-WZ) showing ampling sites, e1 to e5; and (c) Catchment of Yan Oya in the dry zone (YO-DZ) showing sampling sites, y1 to y5.

Fig. 2 (a) Bray-Curtis similarity of fish species based on volumetric proportions of food items in the diets of fish species caught in Eswathu Oya (EO-WZ); (b) trophic indices; and (c) dietary breadths of the fish along the longitudinal gradient. Also shown here are major food items of fish in each cluster. Abbreviations of fish species are as given in Table 2. The number next to abbreviation denotes the sampling site.

Fig. 3 (a) Bray-Curtis similarity of fish species based on volumetric proportions of food items in the diets of fish species caught in Yan Oya (YO-DZ); (b) trophic indices; and (c) dietary breadths of the fish along the longitudinal gradient. Also shown here are major food items of fish in each cluster. Abbreviations of fish species are as given in Table 2. The number next to abbreviation denotes the sampling site.

Captions of Plates

Plate 1 The five study sites in Eswathu Oya stream. (e1) The uppermost site with thick riparian vegetation; (e2) the second site with a pool, riffle and run combination; (e3) The third site running through a cascade with smaller boulders; (e4) The fourth site running through a cascade with large boulders; and (e5) The fifth site running through a flat landscape.

Plate 2 The five study sites in Yan Oya stream. (y1) The uppermost stream site running through a karstic landscape; (y2) The second site running through a flat landscape; (y3) The third site running under a shaded area; (y4) The fourth site with slow stream-flow in shaded area; and (y5) The fifth site having a narrow channel.

Captions of Tables

Table 1 Geographic locations, altitudes, morphometric properties (bank width, channel width, average depth and maximum depth) and flow characteristics (average flow velocity, average discharge and maximum velocity) in the study sites in Eswathu Oya and Yan Oya streams.

Stream /Site	Geographical location	Altitude (masl)	Morphometric properties				flow characteristics		
			Bank width (m)	Channel width (m)	Average depth (cm)	Maximum depth (cm)	Average flow velocity (m s ⁻¹)	Average discharge (m ³ s ⁻¹)	Maximum velocity (m s ⁻¹)
Eswathu Oya									
Site 1	7°.56' 77" N 80°.45' 42" E	203	4	4	6.95±5.58	15.8	0.005±0.007	0.030	0.02
Site 2	7°.56' 35" N 80°.45' 38" E	199	2.5	2.5	9.16±7.02	19	0.14±0.160	0.065	0.37
Site 3	8°.03' 22" N 80°.44' 48" E	156	9	9	33.36±19.39	73	0.113±0.051	0.411	0.17
Site 4	8°.09' 09" N 80°.44'	152	11.5	6	23.66±12.66	44	0.299±0.167	0.493	0.53

07" E

Site 5	8°.10' 10" N 80°.44' 09" E	151	8	8	49.31±3 3.56	98	0.097±0. 042	0.419	0.14
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Yan Oya

Site 1	6°.53' 15" N 80°.11' 38" E	186	2.5	2	14.25±6. 24	18	0.013±0. 01	0.042	0.03
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Site 2	6°.53' 46" N 80°.11' 37" E	167	7.5	5	17.3±10. 0	30	0.017±0. 038	0.020	0.12
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Site 3	6°.54' 28" N 80°.11' 30" E	121	7	5	15.88±1 0.22	29	0.019±0. 035	0.023	0.12
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Site 4	6°.54' 44" N 80°.11' 08" E	75	9	6.5	42.08±1 8.50	63	0.084±0. 174	2.53	0.57
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Site 5	6°.56' 49" N 80°.10' 39" E	32	8	8	33.11±2 2.93	70	0.122±0. 232	0.648	0.77
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Table 2 Food items found in the fish guts, abbreviations, broad categories of food items, approximate trophic class of each food item and occurrence in Eswathu Oya (EO-WZ) and Yan Oya (YO-DZ). Presence of food item is denoted with “1”. Broad food categories are abbreviated as follows: ALG = filamentous algae, DT = detritus, MB = benthic macroinvertebrates, FH = fish, TIN = terrestrial insects, AMP = Amphibians and ZOO = Zooplankton.

Food item	Abbreviation	broad category	Trophic class	Presence	
				EO-WZ	YO-DZ
Filamentous algae	Fa	ALG	0.0		1
<i>Spirogyra</i>	Spr	ALG	0.0	1	1
Amphibian adults	AmA	AMP	1.5		1
Tadpoles	Tdp	AMP	1.0	1	
Coarse detritus	Cdt	DT	0.0	1	1
Fine detritus	Fdt	DT	0.0	1	1
<i>B. signata</i>	BS	FH	2.5	1	
<i>L. thermalis</i>	LT	FH	1.2		1
<i>Rasbora spp</i>	Rsp	FH	2.5		1
Fish scales	Sca	FH	2.0	1	
<i>S. notostigma</i>	SN	FH	2.1	1	
Annelida	Ann	MB	1.0	1	1
Baetidae larva type 1	BaL	MB	1.0	1	1
Baetidae larva type 2	BaLiii	MB	1.0		1
Brachyura	BrA	MB	1.0	1	1

Caenidae larva	CaL	MB	1.0		1
Ceratopogonidae larva	CeL	MB	1.5	1	1
Chironomidae larva	ChL	MB	1.0	1	1
Coleoptera larva	CoL	MB	1.0	1	
Coenagrionidae larva	CoN	MB	2.0		1
Carridean shrimps	CrA	MB	0.0	1	1
Dysticidae larva	DiL	MB	1.5	1	1
Elmidae larva	EIL	MB	1.0	1	1
Ephemera larvae type 1	EpL	MB	1.0	1	
Ephemera larvae type 2	EpLi	MB	1.0	1	1
Ephemera larvae type 3	EpLiii	MB	1.0		1
Gomphidae nymph	GoN	MB	2.0	1	1
Hydropsychidae larva	HIL	MB	1.0	1	
Heptageniidae larva	HpL	MB	1.0	1	1
Helicopsychidae larva	HsL	MB	1.0	1	1
Leptoceridae larvae	LcL	MB	1.0	1	1
Leptophlebiidae larva	LeL	MB	1.0	1	1
Mollusca	Mol	MB	0.0		1
Perlidae larva	PeL	MB	2.0		1

Polymitarcydae larvae	PoL	MB	1.0		1
Psephenidae larva	PsL	MB	1.0	1	
Simulidae larvae	SiL	MB	1.0	1	
Tanypodinae larva	TaL	MB	1.0	1	1
Tipulidae larva	TiL	MB	1.5		1
Ants	Ant	TIN	1.5	1	1
Coleoptera adults	CoA	TIN	1.0	1	
Gerridae adults	GeA	TIN	2.0	1	1
Noctuidae larva	NoL	TIN	1.0	1	1
Terrestrial insects	TnA	TIN	1.5	1	1
Ostracoda	Ost	ZOO	0.0		1

Table 3 Families of fish species, abbreviations (Abb) and total number individuals caught in the three fishing runs (i.e., relative abundance) in each site along the longitudinal gradients in Eswathu Oya (EO-WZ) (e1-e5);. Endemic species (*); nr – not recorded.

Family	Species	Abb	e1	e2	e3	e4	e5
Anguillidae	<i>Anguilla nebulosa</i>	AN	nr	nr	nr	1	nr
Aplocheilidae	<i>Aplocheilus dayi</i> *	AD	8	2	nr	nr	nr
Bagridae	<i>Mystus vittatus</i>	MV	4	3	nr	nr	6

Balitoridae	<i>Acanthocobitus urophthalmus</i> *	AU	nr	nr	nr	3	2
Balitoridae	<i>Schistura notostigma</i> *	SN	3	44	26	nr	14
Channidae	<i>Channa gachua</i>	CG	nr	nr	nr	1	1
Channidae	<i>Channa orientalis</i>	CO	10	10	nr	2	nr
Clariidae	<i>Clarias brachysoma</i> *	CB	nr	3	nr	7	nr
Cyprinidae	<i>Dawkinsia singhala</i> *	DS	nr	nr	nr	nr	2
Cyprinidae	<i>Devario malabaricus</i>	DM	nr	nr	51	6	11
Cyprinidae	<i>Garra ceylonensis</i> *	GC	nr	nr	3	nr	12
Cyprinidae	<i>Pethia nigrofasciata</i> *	PN	nr	nr	nr	1	nr
Cyprinidae	<i>Puntius bimaculatus</i>	PB	nr	nr	nr	nr	7
Cyprinidae	<i>Systemus sarana</i>	SS	nr	nr	nr	2	nr
Cyprinidae	<i>Puntius titteya</i> *	Pti	nr	nr	nr	nr	50
Cyprinidae	<i>Puntius vittatus</i>	PV	nr	nr	2	12	nr
Cyprinidae	<i>Rasbora daniconius</i>	RD	87	2	1	nr	6
Cyprinidae	<i>Systemus pleurotaenia</i> *	SP	nr	nr	nr	nr	9
Eleotridae	<i>Eleotris fusca</i>	EF	nr	nr	nr	1	2
Heteropneustidae	<i>Heteropneustes fossilis</i>	HF	5	nr	nr	8	nr
Mastacembelidae	<i>Mastacembelus armatus</i>	MA	nr	nr	nr	10	10

Osphronemidae	<i>Belontia signata</i> *	BS	37	7	3	nr	nr
Shannon-Weiner index along the longitudinal gradient			1.279	1.269	1.045	2.139	2.179
Pooled data			2.517				

Table 4 Families of fish species, abbreviations (Abb) and total number individuals caught in the three fishing runs (i.e., relative abundance) in each site along the longitudinal gradients in Yan Oya (YO-DZ) (y1-y5). Endemic species (*) and Exotic species (♦); nr – not recorded.

Family	Species	Abb	y1	y2	y3	y4	y5
Anabantidae	<i>Anabas testudineus</i>	AT	nr	nr	1	1	nr
Bagridae	<i>Mystus vittatus</i>	MV	31	7	5	2	nr
Channidae	<i>Channa gachua</i>	CG	9	nr	57	16	38
Channidae	<i>Channa striata</i>	CS	nr	nr	1	nr	nr
Cichlidae	<i>Etroplus maculatus</i>	EM	nr	1	1	nr	nr
Cichlidae	<i>Etroplus suratensis</i>	ES	nr	nr	1	nr	nr
Cichlidae	<i>Oreochromis niloticus</i> ♦	ON	nr	nr	2	3	nr
Cichlidae	<i>Oreochromis mossambicus</i> ♦	OM	nr	nr	nr	2	1
Clariidae	<i>Clarias batrachus</i> ♦	CBt	nr	nr	3	nr	nr
Cobitidae	<i>Lepidocephalichthys thermalis</i>	LT	17	nr	20	12	2
Cyprinidae	<i>Dawkinsia singhala</i> *	DS	nr	4	2	1	nr

Cyprinidae	<i>Devario malabaricus</i>	DM	16	19	18	2	3
Cyprinidae	<i>Esomus daniconius</i>	ED	nr	nr	3	3	3
Cyprinidae	<i>Garra ceylonensis</i> *	GC	8	7	nr	nr	nr
Cyprinidae	<i>Laubuka laubuca</i>	LL	nr	nr	1	3	nr
Cyprinidae	<i>Pethia ticto</i>	PT	nr	nr	1	2	nr
Cyprinidae	<i>Puntius bimaculatus</i>	PB	nr	nr	2	1	nr
Cyprinidae	<i>Puntius chola</i>	PC	40	2	3	2	nr
Cyprinidae	<i>Puntius dorsalis</i>	PD	5	nr	nr	nr	nr
Cyprinidae	<i>Systemus sarana</i>	SS	nr	nr	1	nr	nr
Cyprinidae	<i>Puntius vittatus</i>	PV	nr	nr	nr	3	nr
Cyprinidae	<i>Rasbora caverii</i>	RC	55	1	22	10	4
Cyprinidae	<i>Rasbora daniconius</i>	RD	34	1	14	5	3
Gobiidae	<i>Glossogobius giuris</i>	GG	7	5	13	13	19
Heteropneustidae	<i>Heteropneutes fossilis</i>	HF	nr	nr	3	nr	nr
Mastacembelidae	<i>Mastacembelus armatus</i>	MA	14	3	6	2	1
Siluridae	<i>Ompok bimaculatus</i>	OB	1	nr	nr	nr	nr
Shannon-Weiner index along the longitudinal gradient			2.169	1.883	2.322	2.480	1.504
Pooled data				2.526			

Table 5 Pair-wise comparison (bold: t values) of Shannon-Weiner indices between different stretches of each stream and between the two streams, using t-statistics. df- degrees of freedom; p – probability level.

(I) Eswathu oya				
	e2	e3	e4	e5
e1	0.063 (df = 128; p>0.05)	1.805 (df = 190; p>0.05)	6.371 (df = 120; p<0.05)	7.794 (df = 294; p<0.05)
e2	-	1.362 (df = 140; p>0.05)	5.146 (df = 125; p<0.05)	5.911 (df = 128; p<0.05)
e3	-	-	7.419 (df = 129; p<0.05)	8.732 (df = 186; p<0.05)
e4	-	-	-	0.296 (df = 119; p>0.05)
(II) Yan oya				
	y2	y3	y4	y5
y1	2.093 (df = 63; p<0.05)	1.591 (df = 282; p>0.05)	2.927 (df = 119; p<0.05)	4.762 (df = 94; p<0.05)
y2	-	2.848 (df = 97; p<0.05)	3.725 (df = 105; p<0.05)	2.051 (df = 121; p<0.05)
y3	-	-	1.288 (df = 198; p>0.05)	5.217 (df = 139; p<0.05)

y4	-	-	-	5.958 (df = 143; p<0.05)
(III) Between streams				
	YO			
EO	0.153 (df = 1076; p>0.05)			