Sri Lanka J. Aquat. Sci. **8** (2003): 67-83

Species Composition and Altitudinal Distribution of Fish in Upper Walawe River Basin in Sri Lanka

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Abstract

The fish assemblage and limnological factors at 154 sites of upper Walawe river basin, Sri Lanka were studied from April 1999 to March 2001. Out of the 26 species of fish recorded, 24 were indigenous and two were exotic. Of the indigenous species, six were endemic. Indigenous fish species were not present at an elevation above 1500 m MSL. The exotic species, *Onchorynchus mykiss* inhabits tributaries of Belihul Oya only in the Horton Plains at an elevation of 1900 m MSL. *Garra ceylonensis* is the most widely distributed endemic fish species. It was present at an elevation of even 1500 m MSL. Since there are no geomorphic impassable barriers, the altitudinal distribution of these fishes may be dependant on water temperature.

Introduction

The longitudinal distribution of fish in streams is characterized by massive difference in abundance both within and among species (Shelford 1911). The variation in altitudinal distribution of stream fish is an outcome of a complex relationship of channel physiography, environmental conditions and historic availability of water for fish (Vincent and Miller 1968). Since these parameters tend to vary with altitude, it is difficult to determine the precise influence of each of them on the distribution of stream fish. However, the work carried out on longitudinal succession of fish in the streams in USA revealed that the stream gradient and temperature were the major factors, which govern the fish distribution in different attitudinal levels. (Burton and Odum 1945; Trautman 1942; Kuehne 1962; Turner 1967). In Europe, different zones in streams have been identified and each zone has been found to be characterized by a typical fish assemblage (Pires et al. 1962). However, since the faunal zonation is ambiguous in many streams in North America, the fish with respect to their altitudinal distribution are categorized as plain species,

foothill species and mountain stream species (Ellis 1914). Silas (1952) was the first worker who described the speciation of fish and their habitat categories in Sri Lanka. Senanayake (1980) identified three icthyological zones in Sri Lanka, namely the Southwestern, Mahaweli and Dry zone, and described distinct faunal characteristics corresponding to each of these zones. Later, Pethiyagoda (1991) described qualitative altitudinal distribution of fish in Kalu, Kelani, Nilwala, Gin and Mahaweli river basins. However, he has left out a major river basin, namely the Walawe, which has the sixth largest catchment (2442 km^2) in the island in his quantitative approach to relate the species diversity with elevation.

This paper describes the composition and diversity of fish in the upper Walawe river basin in relation to altitudinal changes.

Material and methods

This study was conducted in the upper Walawe river basin (6° 33' - 6° 50' N and 80° 32' - 81° E) at an altitude of over 200 m above MSL. Fish samples were collected from 48 major streams and 131 rivulets in the Upper Walawe river basin (Fig. 1), from April 1999 to March 2001 using gill nets (mesh size: 1.0-3.0 cm), cast nets (mesh size: 2.0-3.0 cm), drag-nets (mesh size: 0.5-1.0 cm), and scoop nets (mesh size: 0.1-0.25 cm). The drag net was the mostly used gear in lower shallow reaches of the streams (up to a depth of 1 m) and cast nets were used in deeper and wider areas and deep pools. In small brooks, scoop net was used to collect bottom dwelling fish as well as larvae and fry.

Fish collections were made after blocking an approximately 25 m long stretch of the stream including the riffles and pools using nets (Mahon and Baton 1980). The fish were collected from these blocked areas using above gear. The collected fish were identified using in the field guides (Mendis and Fernando 1962; Pethiyagoda 1991) and their standard lengths were measured.

The number of individuals of each species was counted and pooled according to the altitude. Species present in any one location were ranked according to their numerical abundance (the most abundant species-Rank 1; the second most abundance species- Rank 2, etc.) and the rank abundance curve for different altitudes were plotted as described by Manuel (1990). Diversity of fish fauna was determined using the Shannon-Weiner index (Shannon and Weiner 1949). Simpson's dominance index was used to assess the species dominance. Species richness was determined as the number of species present in that location. Further, the similarity of fish fauna among different altitudinal levels in terms of faunal affinity was determined using SØrenson index (SØrenson 1948).

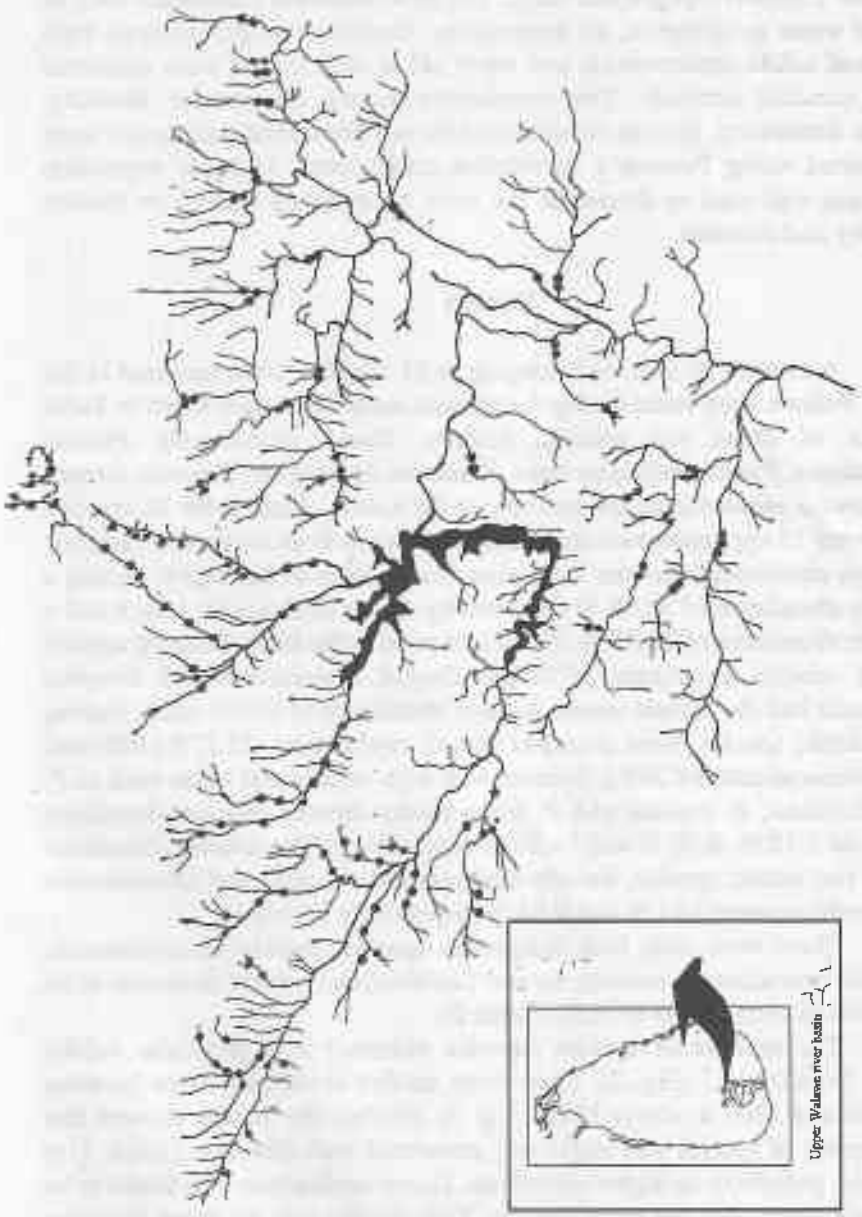

Figure 1. Study sites. Inset shows location of the Walawe river basin in Sri Lanka

Elevation of each sampling site was determined using altimeter or from the 1:50,000 topographic maps. The environmental parameters such as surface water temperature, air temperature, dissolved oxygen content, total dissolved solids concentration and water pH at each station were measured using standard methods. The correlations among the species diversity, species dominance, species richness and the environmental parameters were determined using Pearson's correlation coefficients. Multiple regression technique was used to determine the most contributing factors on species diversity and richness.

Results

A total of 26 species belonging to 11 families were recorded in the upper Walawe river basin during the present study. These are listed in Table 1. Out of them, six species, namely, *Garra ceylonensis*, *Puntius bimaculatus*, *Puntius nigrofasciatus*, *Schistura notostigma*, *Belontia signata* and *Puntius pleurotaenia* are endemic to Sri Lanka. Among the 26 species, there were 15 cyprinids, two cichlids and one each from other nine families. *Rasbora daniconius* was the most abundant species in the region having a relative abundance of 32.08 % followed by *Garra ceylonensis, which* had a relative abundance of 21.27 %. *P. pleurotaenia* is the least abundant species with a relative abundance of 0.02% *Ompok bimaculatus* and *Etroplus maculatus* had the second lowest relative abundance of 0.03% each. Among the endemic species, most abundant was *G. ceylonensis* (21.27%) followed by *P. bimaculatus* (14.26%). Species with high ornamental value such as *P. nigrofasciatus*, *B. signata* and *P. bimaculatus* showed relative abundance values of 5.12 %, 0.78 % and 14.26 % respectively. The relative abundance of the two exotic species, namely *Onhcorynchus mykiss* and *Oreochromis mossambicus* were 0.43 % and 0.04 % respectively (Table 1).

There were only four indigenous species, namely *G. ceylonensis*, *Poecilia reticulata*, *S. notostigma* and *Lepidocephalychthys thermalis* at an elevation of above 1000 m MSL (Table 2).

The number of species (species richness) in a particular habitat varied from 0 to 17 (Fig. 2). There were no fish at the elevations between 1400 m and 1900 m above MSL (Fig. 3). Further, the results showed that the number of species was negatively correlated with elevation (Table 3) ($r = -0.914$, $p<0.005$). In higher elevations, *Garra ceylonensis* was found to be more abundant than the other species. This species was the most abundant fish species at altitudes of above 600 m MSL (Table 2).

Shannon –Weiner index was negatively correlated ($r = -0.95$, $p<0.005$) with elevation (Table 3). The rank abundance curves (Fig. 4) for different elevations further showed that fish communities at 700 m, 800 m, 1000 m and 1100 m above MSL elevations had one dominating

Table 1. Species composition of fish in Upper Walawe river basin.

Family	Species	Relative abundance (%)
Cyprinidae	*Amblypharyngodon melettinus*(Valenciennes, 1844)	2.10
	Chela laubuca (Hamilton,1822)	2.12
	Danio malabaricus (Jerdon, 1849)	0.06
	Esomus thermoicos (Valenciennes,1842)	0.47
	Garra ceylonencis (Bleeker,1863) #	21.27
	Puntius amphibius (Valenciennes 1843)	0.05
	Puntius bimaculatus (Bleeker, 1863) #	14.26
	Puntius chola (hamilton,1822)	3.97
	Puntius dorsalis (Jerdon,1849)	0.10
	Puntius filamentosus (Valenciennes,1844)	0.55
	Puntius nigrofasciatus (Gunther,1868) #	5.12
	Puntius pleurotaenia (Bleeker, 1863) #	0.02
	Puntius sarana (Hamilton,1822)	0.09
	Rasbora daniconius (Hamilton,1822)	32.08
	Tor khurdee (Sykes,1841)	2.25
Balitoridae	*Schistura notostigma* (Bleeker,1863) #	5.16
Cobitidae	*Lepidocephalichthys thermalis* (Valenciennes,1846)	2.59
Bagridae	*Mystus keletius* (Bloch 1794)	0.40
Siluridae	*Ompok bimaculatus* (Bloch,1794)	0.03
Cichlidae	*Etroplus maculatus* (Bloch,1785)	0.03
	Oreochromis mossambicus (Peters,1859)	0.04
Anabantidae	*Anabas testudineus* (Bloch,1795)	0.10
Belontidae	*Belontia signata* (Gunther,1861) #	0.78
Channidae	*Channa gachua* (Bleeker,1877)	1.07
Poeciliidae	*Poecilia reticulata* (Peters,1859)	4.84
Salmonidae	*Onchorynchus mykiss (Walbaum* 1792)	0.43

endemic species

species. This species was *Garra ceylonensis* (Table 3). From the altitudes 200 m to 500 m three species were dominating fish communities (Figs 4a and b). At these altitudes, *R. daniconius* was the dominant species followed by *P. bimaculatus* and the third species changed according to the altitude (Table 2). At the altitude of 500 m above MSL, 17 species were recorded with only one dominating species, *R. daniconius* (Table 2). In comparison to other elevations, in this region fish species were evenly distributed. In the fish community at 600 m elevation, *P. bimaculatus* was the dominating species.

Table 2. Numerical rank abundance of species found at each elevation (Altitudes 1500 m, 1600 m, 1700 m and 1800 m above MSL were omitted from the analysis as no fish were found).

Elevation (m)	Rank and number of individuals in each species																	Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
200	*Rd*	*Pb*	*Pr*	*Cl*	*Pch*	*Am*	*Orm*	*Pf*	*Gc*	*Et*	*Lt*	*Tk*	*Cg*	*Pn*	*Ps*	*Bs*		
	593	243	108	107	81	64	54	51	50	43	26	13	13	12	6	4		1468
300	*Rd*	*Pb*	*Gc*	*Pn*	*Tk*	*Pr*	*Lt*	*Pch*	*Cl*	*Pf*	*Bs*	*Orm*	*Cg*	*Ps*				
	476	288	208	54	30	30	27	25	14	12	11	10	5	3				1193
400	*Rd*	*Pb*	*Gc*	*Pch*	*Pn*	*Pr*	*Lt*	*Sn*	*Bs*	*Tk*	*Cg*	*Mk*	*Pf*	*Cl*	*Ps*			
	1570	1051	441	146	135	107	80	36	31	27	26	16	14	5	1			3686
500	*Rd*	*Pb*	*Pch*	*Gc*	*Pr*	*Pn*	*Dm*	*Sn*	*Lt*	*Cg*	*Tk*	*Bs*	*Cl*	*Pa*	*At*	*Ob*	*Pp*	
	1803	876	296	291	196	149	73	61	41	28	18	12	11	8	6	5	4	3878
600	*Pb*	*Gc*	*Rd*	*Pr*	*Lt*	*Sn*	*Pd*	*Em*	*Cg*	*Pch*								
	152	112	101	25	20	20	7	6	3	2								448
700	*Gc*	*Rd*	*Sn*	*Pch*	*Lt*	*Pb*	*Pr*	*Em*										
	567	79	37	31	19	18	6	5										762
800	*Gc*	*Sn*	*Rd*	*Pr*	*Lt*													
	519	150	33	18	9													729
900	*Gc*	*Sn*	*Pr*	*Lt*														
	1150	199	50	6														1405
1000	*Gc*	*Sn*	*Pr*	*Lt*														
	318	60	35	17														430
1100	*Gc*	*Sn*	*Lt*															
	201	39	14															254
1200	*Gc*	*Lt*	*Sn*															
	97	8	6															111
1300	*Gc*																	
	67																	67
1400	*Gc*																	
	137																	137
1900	*Orm*																	
	25																	25
2000	*Om*																	
	26																	26

Am-*A. melettinus*, Cl-*C. laubuca*, Dm-*D. malabaricus*, Gc-*G. ceylonensis*, Pb-*P. bimaculatus*, Pch-*P. chola*, Pd-*P. dorsalis*, Pf-*P. filamentosus*, Pn-*P. nigrofasciatus*, Pa-*P. amphibius*, Rd-*R. daniconius*, Tk-*T. khurdee*, Ps-*P. sarana*, Et-*E. thermoicos*, Pp-*P. pleurotaenia*, Sn-*S. notostigma*, Lt-*L. thermalis*, Mk-*M. kelatius*, Ob-*O. bimaculatus*, Em-*E. maculatus*, Orm-*O. mossambicus*, At-*A. testudineus*, Bs-*B. signata*, Cg-*C. gachua*, Pr-*P. reticulata*, Om-*O. mykiss*

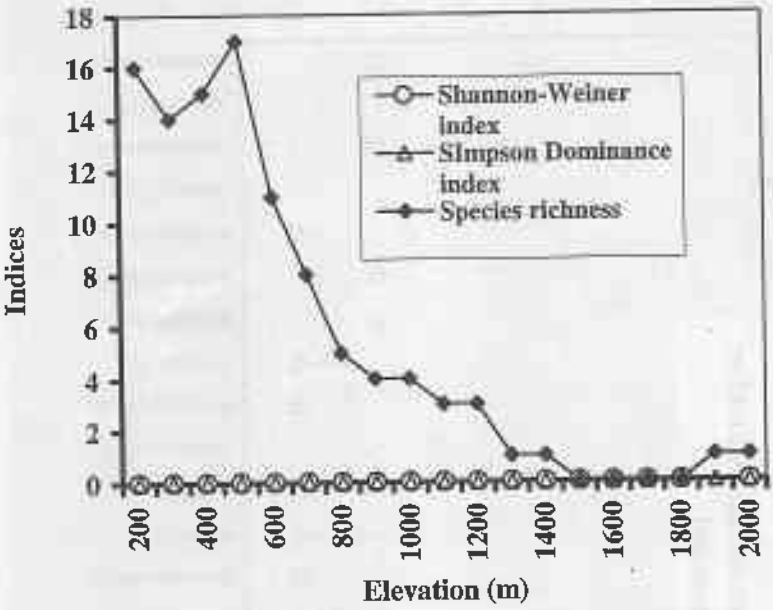

Figure 2. Variation of diversity indices and species richness with elevation.

The Pearson's correlation matrix (Table 3) indicates that the dissolved oxygen concentration of the water has a significant positive relationship with elevation. The upper region of the basin bears more rapids and falls and the aeration results in high dissolved oxygen concentrations in these regions. Water pH had the most significant downstream trend of changing from slightly acidic to neutral or slightly alkaline (Fig. 5) ($r = -0.847$, $p = 0.00$). Total Dissolved Solid (TDS) concentration significantly increased downstream. Water temperature ($r = 0.886$, $p = 0.00$) too showed the similar pattern as exhibited by TDS.

The highest values for SØrenson index were recorded for adjacent elevational ranges (Table 4). The greater the altitudinal difference, lesser the values for SØrenson index. However, the lowest value of 11 was recorded between 500 m & 1300m elevations also between 500m and 1400m elevations. The highest value of 100 was recorded for 900m–1000m, 1100m-1200m and 1300m-1400m above MSL (Table 4).

The results of the multiple regression analysis of Shannon Weiner index with environmental parameters (Table 5) revealed that only the dissolved oxygen content ($p = 0.05$), elevation ($p = 0.01$) and water temperature ($p = 0.00$) had a significant effect on determining the species

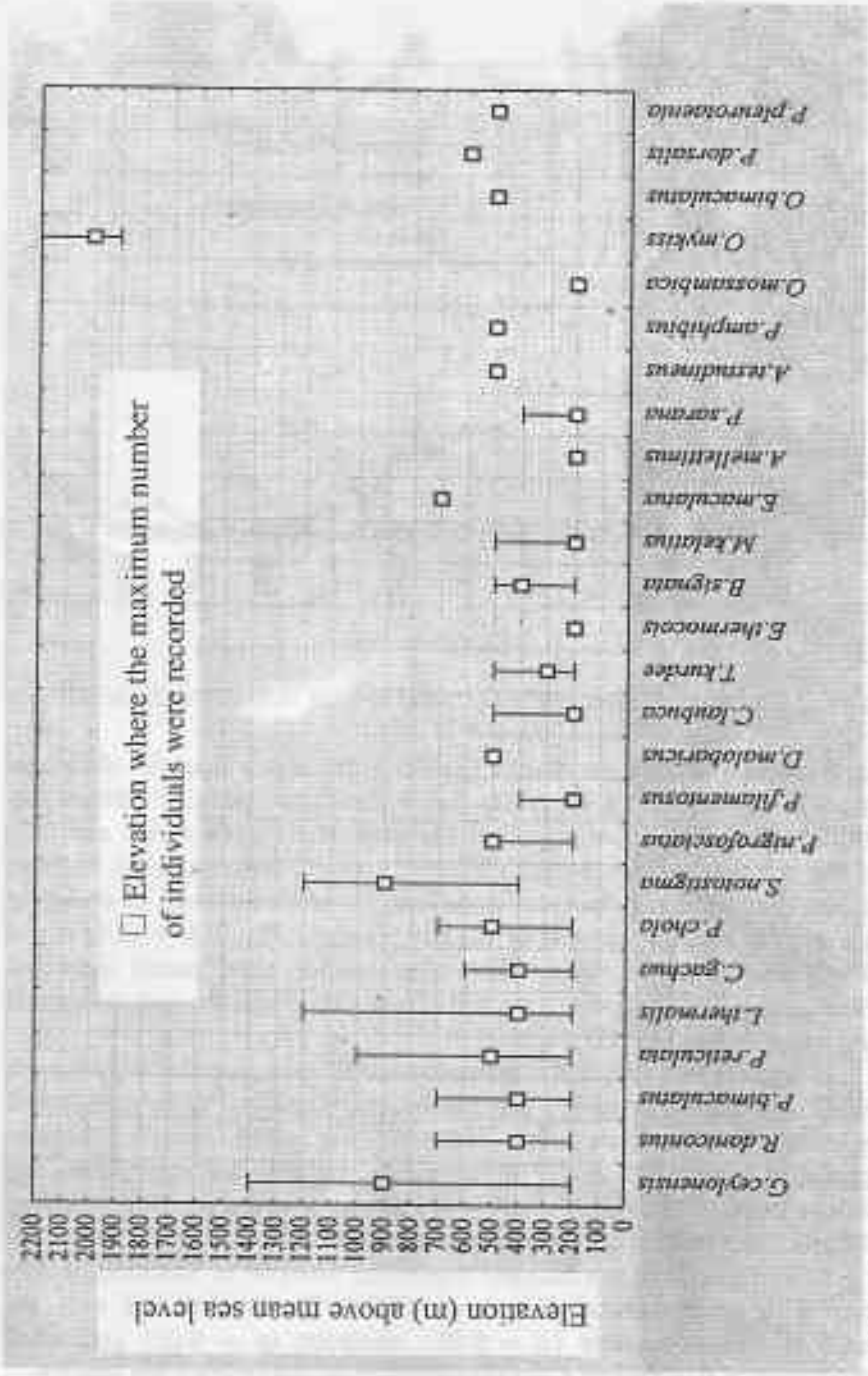

Figure 3. Altitudinal range of distribution of different species in the upper Walawe river basin. Vertical axis: Elevation (m above MSL).

Table 3. Pearson's correlation coefficients among different environmental parameters, number of species, Shannon Weiner Indices and Simpson dominance indices (Values indicated by * are significant at 5% level.).

	Elevation	PH	DO	TDS	T
Elevation	-	-	-	-	-
Water pH	-0.847*	-	-	-	-
Dissolved Oxygen concentration (DO)	0.826*	-0.877*	-	-	-
Total Dissolved solids (TDS)	-0.830*	0.883*	-0.915*	-	-
Surface water temperature (T)	-0.886*	0.812*	-0.822*	0.932*	-
Species richness	-0.914*	0.854*	-0.826*	0.904*	0.952*
Shannon Weiner index	-0.950*	0.842*	-0.865*	0.905*	0.969*
Simpson dominance index	0.098	-0.245	0.202	-0.318	-0.308

diversity in any particular study site. When the above analysis was done for the number of species at each elevation (Table 6), none of the environmental parameter appeared to have a significant effect on determining the number of species at any given location.

Discussion

A total of 24 indigenous and two exotic fish species were recorded during the present survey carried out in the streams of upper Walawe river basin at the elevations more than 200 m above MSL. Pethiyagoda (1991) considered only five river basins in preparing the distribution tables for the freshwater fishes in Sri Lanka. These were the Kelani, Kalu, Gin, Nilwala and Mahaweli river basins. He has not listed the species that are found in the Walawe river basin. Later Herath and Jinadasa (2000) listed 20 species in some selected streams of the Walawe river basin. Eventually, when considering all data available, it appears that at a particular elevation, the upper Walawe river basin supports the most number of species among all the river systems in Sri Lanka. During the present survey, *Chela laubuca* was found in the elevational range of 400 - 500 m above MSL. However,

Table 4. SØrenson indices among different elevations

Elevation (m)	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900
200	93.3	90.3	66.7	53.9	50	38.1	30	30	21.1	21.1	11.8	11.8	0	0	0	0	0
300	-	96.6	71.0	58.3	54.6	42.1	33.3	33.3	23.5	23.5	13.3	13.3	0	0	0	0	0
400		-	75	64	60.9	50	42.1	42.1	33.3	33.3	12.5	12.5	0	0	0	0	0
500			-	59.3	56	45.45	38.1	38.1	30	30	11	11	0	0	0	0	0
600				-	77.8	66.7	57.1	57.14	46.2	46.2	18.2	18.2	0	0	0	0	0
700					-	76.9	66.7	66.7	54.6	54.6	22.2	22.2	0	0	0	0	0
800						-	88.9	88.9	75	75	33.3	33.3	0	0	0	0	0
900							-	100	85.71	85.7	40	40	0	0	0	0	0
1000								-	85.71	85.7	40	40	0	0	0	0	0
1100									-	100	50	50	0	0	0	0	0
1200										-	50	50	0	0	0	0	0
1300											-	100	0	0	0	0	0
1400												-	0	0	0	0	0
1500													-	0	0	0	0
1600														-	0	0	0
1700															-	0	0
1800																-	0

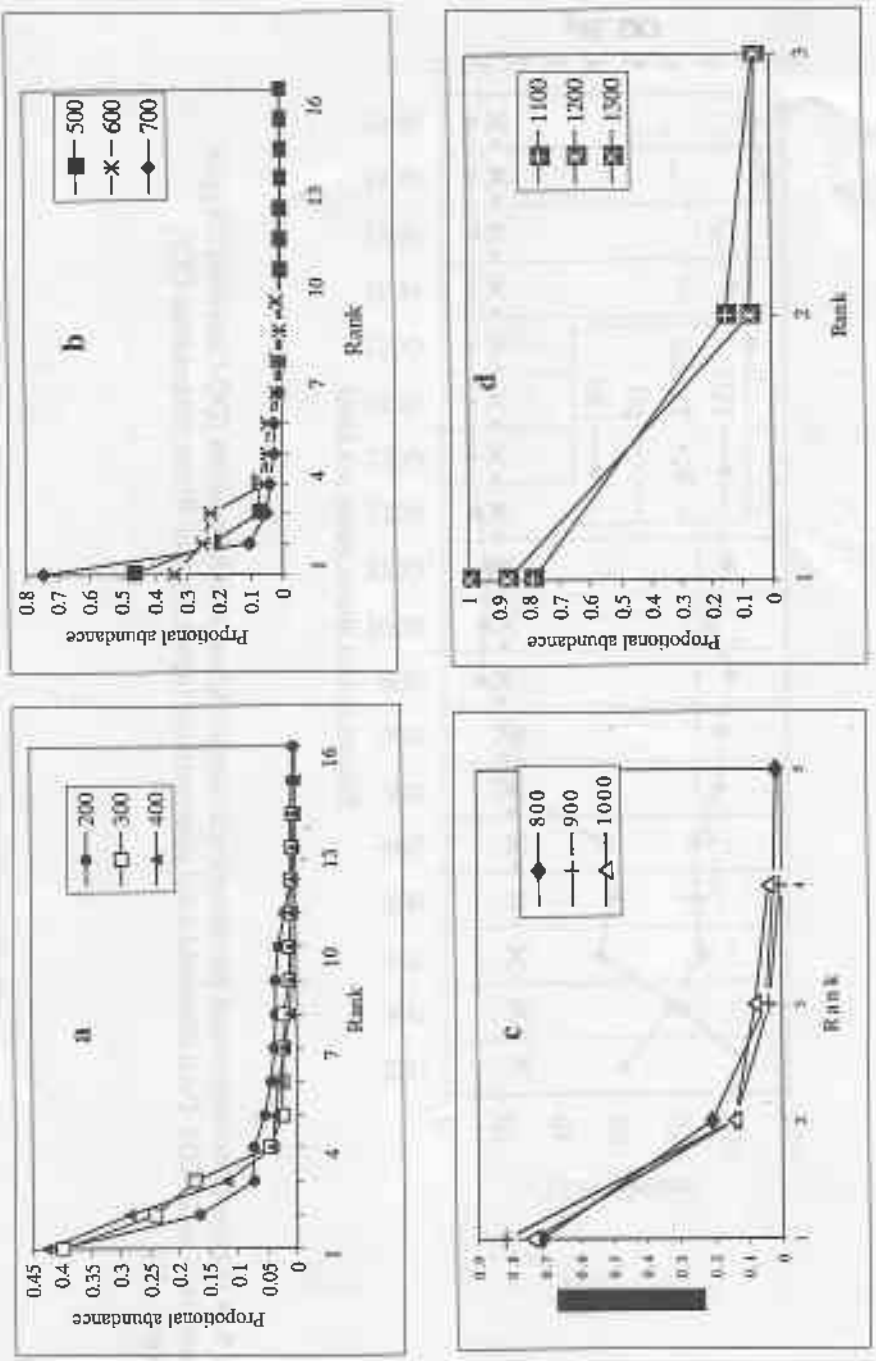

Figure 4. The rank abundance curves at different elevation ranges.

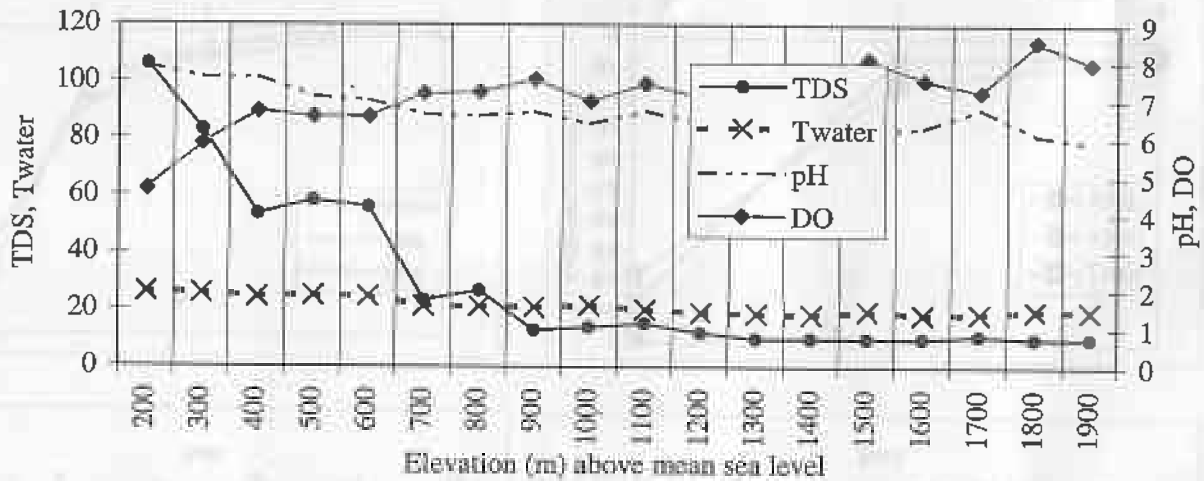

Figure 5. Variation of environmental parameters and species richness with elevation [DO-Dissolved Oxygen concentration (mg/l);TDS-Total dissolved solid concentration (ppm); Twater-Water temperature (°C); pH- Water pH].

Table 5. The results of multiple regression analysis between Shannon-Weiner Index (SHI) and environmental parameters. DO = Dissolved oxygen content; TDS = Total dissolved solids content; T_{water} = Water temperature
The regression equation:
SHI = -1.59 - 0.000692 Elevation - 0.035 pH - 0.328 DO - 0.0119 TDS + 0.325 T_{water}

Predictor	coefficient	Standard deviation	t	p
Constant	-1.5930	2.1690	-0.73	0.478
Elevation	-0.0006	0.0002	-3.20	0.009
PH	-0.0345	0.1885	-0.18	0.858
DO	-0.3284	0.1491	-2.20	0.050
TDS	-0.0119	0.0077	-1.55	0.151
T_{water}	0.3245	0.0788	4.12	0.002

Analysis of variance

Source	DF	SS	MS	F	p
Regression	6	18.7744	3.1291	119.52	0.000
Residual Error	11	0.2880	0.0262		
Total	17	19.0624			

S = 0.1618; R^2 = 0.985

Chela laubuca has not been recorded in such a high elevation perhaps because of lack of detailed studies. *Lepidocephalichthys thermalis* has been recorded by Pethiyagoda (1991) and Mendis and Fernando (1962) at elevations up to 600 m and 500 m respectively. However, during the present survey, this species was found to inhabit up to an elevation of 1200 m above msl.

Earlier studies have shown that *S. notostigma, P. bimaculatus* and *G. ceylonensis* are confined to an elevation below 1000 m (Mendis and Fernando 1962; Pethiyagoda 1991). However, during the present survey, *S. notostigma* was found to be distributed up to an elevation of 1400 m while *P. bimaculatus* and *G. ceylonensis* was found to be distributed up to an elevation of 1100 m and 1500 m respectively. Although, Pethiyagoda (1991) has reported that *A. testudineus, B. signata* and *Etroplus maculatus* are distributed in the elevations above 1000 m, results of this survey indicated that in the upper Walave river basin, these species are present in elevations below 1000 m. *P. pleurotaenia,* the endemic cyprinid was recorded only in one stream in the upper Walawe river basin. This species has been recorded only in Nilwala and Kelani river basins by Pethiyagoda (1991).

Table 6. The results of multiple regression analysis between number of species (No.Sp) and environmental parameters. DO - Dissolved oxygen content; TDS - Total dissolved solids content; T_{water} - Water temperature.
The regression equation:
No.Sp = -32.6 – 0.00345 Elevation + 1.82 pH – 0.12 DO – 0.0273 TDS + 1.83 T_{water}

Predictor	Coefficient	Standard deviation	T	P
Constant	-32.640	25.1	-1.30	0.220
Elevation	-0.003	0.002	-1.38	0.196
PH	1.820	2.182	0.83	0.422
DO	-0.123	1.725	-0.07	0.945
TDS	-0.027	0.089	-0.31	0.765
T_{water}	1.825	0.911	2.00	0.070

Analysis of variance

Source	DF	SS	MS	F	p
Regression	6	591.41	98.56	28.10	0.000
Residual Error	11	38.58	3.508		
Total	17	630.00			

S=1.873; R^2=0.939

In the upper Walawe river basin, *R. daniconius, P. bimaculatus* and *G. ceylonensis* had relatively wide distributions. These three species have also been listed as widely distributed species in Sri Lanka (Senanayaka and Moyle 1982, Pethiyagoda 1991). Species whose distribution was restricted to one location were *O. mykiss, P. pleurotaenia, O. bimaculatus, P. dorsalis, P. amphibius, E. maculatus* and *A. testudineus.*

The Pearson's correlation analysis showed that fish diversity and species richness in the upper Walawe river basin are correlated with altitude, water pH, dissolved oxygen concentration, total dissolved solids and water temperature and multiple regression analysis further revealed that dissolved oxygen and water temperature are the factors, contributing most for species diversity. These two parameters were listed as governing factors of fish distribution in Oregon, USA (Ruthert et al. 1999) and in northern Hokkaido, Japan (Mikio and Nakano 2001)

Although results of multiple regression analysis between environmental parameters and Shannon-Weiner index indicated that the elevation, dissolved oxygen and water temperature contributed most to the

fish diversity (Table 5), since the constant value for elevation is too small (-0.0006), effect from the elevation factor is negligible. The results of the multiple regression analysis between species richness and environmental factors did not reveal any significant relationship ($p>0.05$) at 95% confidence level) contributing to the species richness in the area. However, water temperature can be considered as the factor contributing most ($p = 0.07$), out of the measured parameters ($p = 0.07$). Therefore, the results of the present study indicate that the dissolved oxygen content and water temperature are the environmental factors that contribute most to the diversity of fishes in the upper Walawe river basin.

Conclusion

This study revealed that the number of species increased from the headwaters to downstream. This trend had been documented for streams in temperate regions (Pires et al. 1999). In addition, the environmental parameters such as water pH, total dissolved solids and surface water temperature increased and the dissolved oxygen content decreased in a downstream direction. In high altitudes of over 1000 m only three indigenous species, namely *G. ceylonensis, L. thermalis, and S. notostigma* were present. *G. ceylonensis* was the only endemic species found in the highest elevations. No indigenous fish species were found at an elevation of more than 1500 m above MSL.

Acknowledgement

Financial assistance provided by National Science Foundation under the research grants No. ZSSL/99/01 is highly appreciated.

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