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Importance of unregulated rivers as last refuges of native fishes; implications of habitat alteration and exotic species introduction in Sri Lanka

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Abstract
River Mahaweli in Sri Lanka was greatly altered by dams under the Mahaweli diversion Scheme. Fish assemblages in segments of five tributaries of Mahaweli; Badulu Oya, upstream of Ulhitiya Oya and Loggal Oya (unregulated streams) and, Minipe and downstream of Ulhitiya Oya (regulated streams) were compared. Sampling was carried out in three selected 100 m segments from each study stream using hand nets, drag nets and cast nets. 40 fish species in 10 families were recorded. Ulihitiya downstream recorded the lowest abundance and species richness. Unregulated streams demonstrated a higher proportion of endemics (Dry: 41 – 54% and Wet: 50 – 60%) while regulated streams had highest proportions of exotics in both seasons (Dry; 26 and 72 %; Wet: 34 and 66 % in Minipe and Ulhitiya downstream, respectively). The results suggest that native and endemic fishes are more sensitive to altered habitat conditions highlighting the importance of protecting the remaining natural habitats.

Keywords: river regulation, endemic fish, aquatic habitat conservation, dams, reservoirs

1. Introduction
The fluctuations of river flow by river regulation can affect fish assemblages in rivers through physical displacement, behavioral changes and loss of habitats [21, 1]. By the time the world reached the twentieth century, most of the major rivers have been fragmented by dams or reservoirs to generate hydropower [14]. Several studies in different parts of the world have been conducted to see the impacts of river regulation on fish populations and have identified reductions in diversity of native fish populations [11]. A study showed that the abundance of native fish was higher in the catchments of unregulated river, Paroo while the alien fish species were dominating in the catchments of highly regulated Murray and Murrumbidgee rivers in Australia [11]. A study that compared the fish diversity between a regulated river (The Deerfield river in Western Massachusetts) and an unregulated river (West river in southern Vermont) in the USA has reported that the small, shallow and slow water fishes are adversely affected by river flow regulation [3]. Another study carried out in the USA comparing two segments (regulated and un-regulated) of the River Tallapoosa revealed that during the peak of the hydropower generation, the temporal habitat stability reduces, and as a result small-bodied fish including juveniles of some species and spring spawning fish, those adapted to shallow waters, were reduced [10]. Damming in the Mekong River in China has disturbed the upstream spawning of some biologically and economically important fish species, as the juvenile life stages of some species were trapped in impoundments of the river [7]. The plan to construct a dam across the River Frazer in British Colombia in Canada was halted as a result of the interventions by the fisheries associations and the scientists after evaluating the impacts on the migration of anadromous Pacific Salmon by the construction of a dam across Frazer [9].
A study in India demonstrated a decline of native fish diversity from upstream to downstream in a study conducted in the regulated river, Betwa and suggested that these decreases are due to loss of habitats following the river regulation [17]. In India, the construction of Farakka barrage across the river Ganga has adversely affected some native fish species such as *Tenualosa ilisha* (F. Hamilton, 1822), *Catla catla* (F. Hamilton, 1822) and *Cirrhinus mrigala* (F. Hamilton, 1822) as the construction of the dam has caused considerable changes in the physical habitats of the river. As well as dam construction, introduction of exotic fish also has

been identified as a major cause for reduction in fish diversity in India [17].

The Accelerated Mahaweli Developmental Project (AMDP) is the largest river diversion program undertaken by the Government of Sri Lanka to date constructing five major dams and number of reservoirs across the longest river in Sri Lanka. In Sri Lanka, Southwestern and Mahaweli ichthyological zones show the highest freshwater fish diversity in the island [12]. At the time of inception of the AMDP, it was predicted that the reduction of flow velocity and increase in sediment loads could affect fish species, especially the threatened endemic species including Green Labeo (*Labeo fisheri* D.S. Jordan and Stark, 1917), Blotched Filamented Barb (*Puntius srilankensis* Senanayake, 1985) and Martenstyn Barb (*Puntius martenstyni* Kottelat and Pethiyagoda, 1991) [13]. Some indigenous fish species, those need to move upstream to reproduce, also were predicted to be affected by river regulation [30].

However, no comprehensive study has been carried out so far to evaluate the present status of fish population in the Mahaweli river basin since the initiation of the project in late 1970s. Not only in River Mahaweli, despite experiencing major consequences of dam construction and river regulation in the region, comparatively few studies have been undertaken so far in tropical streams [27]. Therefore, this study was designed to investigate the implications of dam construction and fish species introduction in a tropical river like River Mahaweli. A comparative study has been conducted by selecting free-flowing (un-regulated) and regulated streams in the Mahaweli downstream, as the prior information on fish assemblages lacks.

2. Methodology

2.1 Description of the study sites

Five study sites (river segments) were selected in the immediate downstream of the Randenigala and Rantambe twin reservoirs (with storage capacities of 861 and 21 million m^3, respectively). All study sites are located in the Intermediate Zone of the country with an annual rainfall of 1,500 to 1,700 mm. The terrain is more or less flat with a maximum elevation reaching up to 874 m asl and the area is characterized by relatively undisturbed natural vegetation of dry-mixed evergreen forests [22]. The study streams included three un-regulated (UR) streams namely Badulu Oya (BAD-UR), upstream of Ulhitiya Oya (ULH-UR) and Loggal Oya (LOG-UR) and two regulated (R) streams, Minipe (MIN-R) and downstream of Ulhitiya Oya (ULH-R) (Figure1). Badulu Oya (Oya = stream), Loggal Oya and Ulhitiya Oya are three major tributaries of the River Mahaweli. The area receives rainfall mainly from the north-east monsoon (from October to January) followed by a long dry spell from February to August with a minor rainy season in April and May. Mean annual temperature in the region is 31.5 °C (Hasalaka Weather Station of Irrigation Department, Sri Lanka).

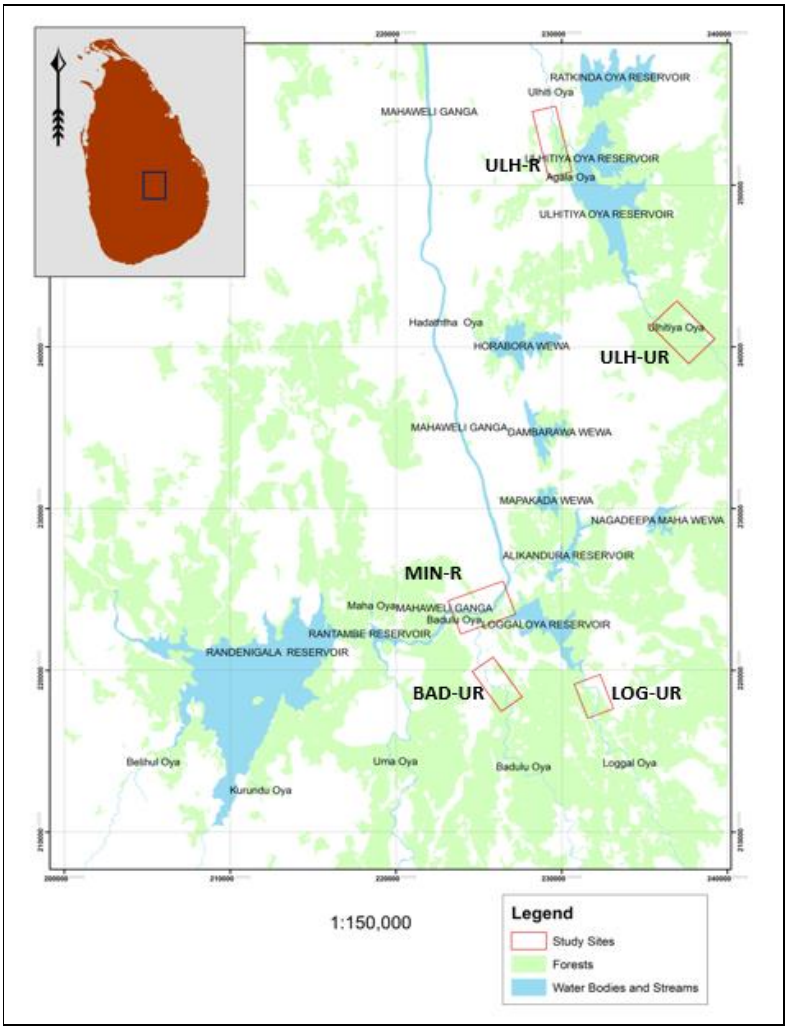


Fig 1: Locations of the three un-regulated ((BAD-UR, ULH-UR and LOG-UR) and two regulated river segments (MIN-R and ULH-R) in the immediate downstream of the Randenigala-Rantambe reservoirs in Sri Lanka.

2.2 Sampling protocol

Fish sampling was carried out in three selected 100 m segments from each study stream. Sampling was carried out six times per season (dry season from March to August 2014 and wet season from September 2014 to February 2015). Three types of nets were used to sample fish; hand nets for smaller fish in pools, drag nets for smaller fish in runs and riffles and cast nets (mesh size 1.5 cm × 1.5 cm) for bigger fish in pools, runs and riffles. At each sampling event, the sampling was carried out for one hour (an effort). At each sampling, live fish samples were taken for identification purposes. Number of individuals belonging to each species was counted and they were photographed before releasing to the same habitat. The catch per unit effort (number of fish caught per net) and the number of species collected were recorded. Riffles and runs were sampled in the opposite direction to the water flow whereas pools were sampled towards the water flow [31]. Few specimens from each species were preserved in 70% ethanol for the confirmation of identity. Preserved specimens were transferred to a laboratory in the Department of Zoology, University of Peradeniya and identified using available guides [25]. The velocity and the depth of each sampling site were randomly measured using the flow velocity meter (Valeport, Electromagnetic Flow Meter, Model 108).

3. Data analysis

The data (abundance, species richness, flow velocity and depth) was analyzed in R 3.4.1.using non parametric Kruskal Wallis (KW) test and then post-hoc analysis for pair wise comparison done with dunn's test whenever KW was significant. Shannon Diversity Index was calculated to determine the species diversity using the following formula.

$$H' = -\sum_{i=1}^{R} p_i \ln p_i$$

Where R= Number of species;
P_i= Proportion of individuals or the abundance of ith species
Ln= Log base n

4. Results

4.1 Physical features of study streams

The velocity of the water flow recorded randomly in different stream habitats (runs, riffles, and pools) showed differences between streams and seasons (Figure 2.a). During both seasons, the mean flow velocity was significantly higher in MIN-R compared to other study streams (Dry season: P= 1.01e-^{07}, Wet season: P=1.55^{e-12}) (Figure 2a). Of all study streams, ULH-R showed the slowest flow velocities in both seasons. The regulated streams (MIN-R and ULH-R) recorded significantly higher stream depths than that of unregulated streams (BAD-UR, ULH-UR and LOG-UR) (Dry season: P=0.2e-^{16}, Wet season: P=0.2e-^{16}) (Figure 2b).

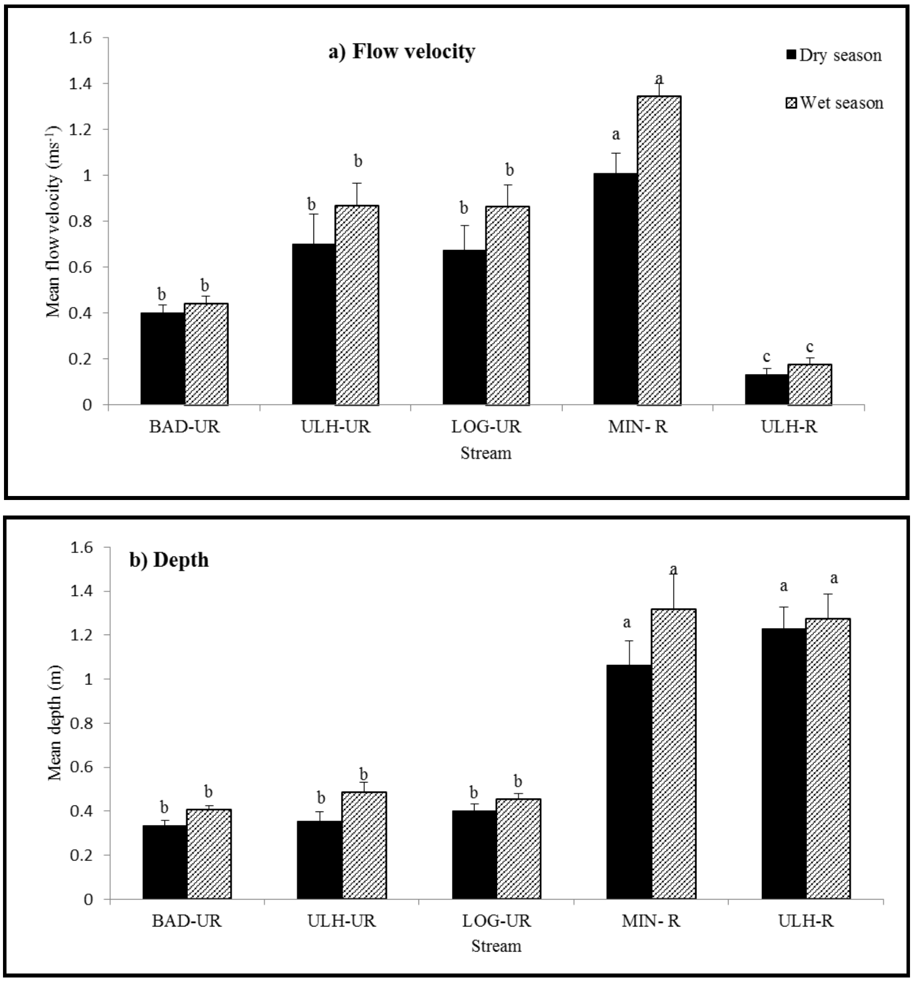


Fig 2a): Mean water flow velocity in BAD-UR, ULH-UR, LOG-UR, MIN-R and ULH-R in the dry season from March to August 2014 and wet season September 2014 to February 2015. b) Mean depth in BAD-UR, ULH-UR, LOG-UR, MIN-R and ULH-R in the dry season from March to August 2014 and wet season September 2014 to February 2015

4.2 Species diversity

A total of 40 fish species belonging to 10 families were recorded during the study (Appendix 1). Cyprinidae was the most abundant family contributing approximately 67% of the fish species recorded. *Devario malabaricus* Jerdon, 1849, *Esomus thermoicos* Valenciennes, 1842, *Puntius bimaculatus* Bleeker, 1863, *Puntius chola* F. Hamilton, 1822 were found in all study streams. *Channa orientalis* Bloch & Schneider, 1801, *Glossogobius giuris* Hamilton, 1822 were exclusively recorded in unregulated streams (UR) while *Labeo rohita* Hamilton, 1822, *Mastacembelus armatus* Lacepede 1800, *Oreochromis mossambicus* W.H.K. Peters,1852, *Oreochromis niloticus* Linnaeus, 1758 were recorded only in regulated (R) streams.

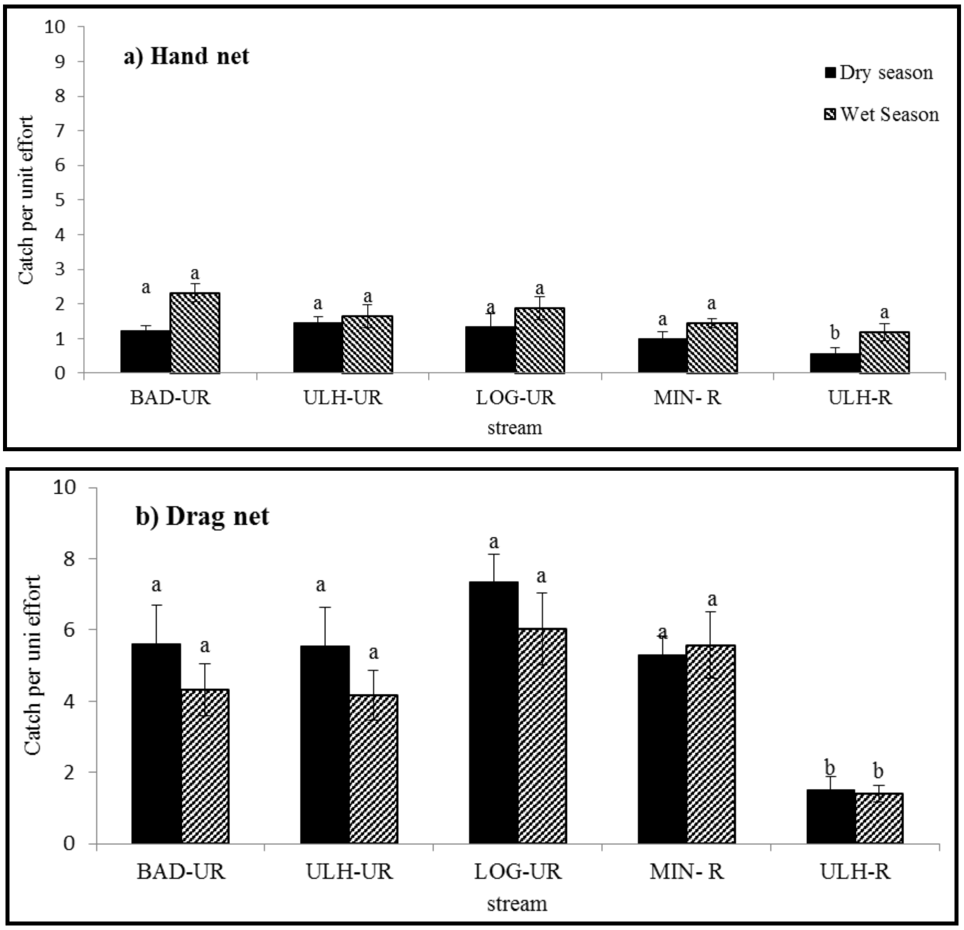
The Shannon- diversity index varied between 1.65 and 2.75, with higher values in the wet season, except at ULH-R (Table 1). While the un-regulated segment of the Ulhitiya (ULH) showed higher diversity index in both seasons (2.54 and 2.50, respectively), the regulated segment (ULH) of the same stream recorded the lowest diversity values (1.65 and 1.82, respectively).

Table 1: Number of individuals, species and families recorded during the sampling and the calculated Shannon-Weiner Diversity indices of fishes in five study streams (BAD-UR, ULH-UR, LOG-UR, MIN-R and ULH-R) during dry and wet seasons.

Study Stream	Season	Number of individuals	Number of species	Number of Families	Shannon-Weiner diversity index (H)	Peulos Eveness index (J)
BAD-UR	Wet	462	25	6	2.63	0.81
	Dry	403	25	5	2.62	0.81
ULH-UR	Wet	453	27	6	2.54	0.79
	Dry	399	20	5	2.50	0.83
LOG-UR	Wet	578	27	7	2.75	0.82
	Dry	526	23	6	2.60	0.83
MIN-R	Wet	480	30	5	2.72	0.77
	Dry	507	26	3	2.65	0.81
ULH-R	Wet	141	12	3	1.65	0.66
	Dry	192	18	3	1.82	0.66

4.3 Abundance

The drag nets yielded more catch per unit effort than the other two methods (hand and cast nets) (Figure 3). With drag and cast nets, ULH-R recorded the lowest catch per unit effort in both seasons compared to the rest of the study streams. In contrary to other study streams, ULH-R showed higher fish abundances in the wet season when sampled with the hand and cast nets (Figure 3).



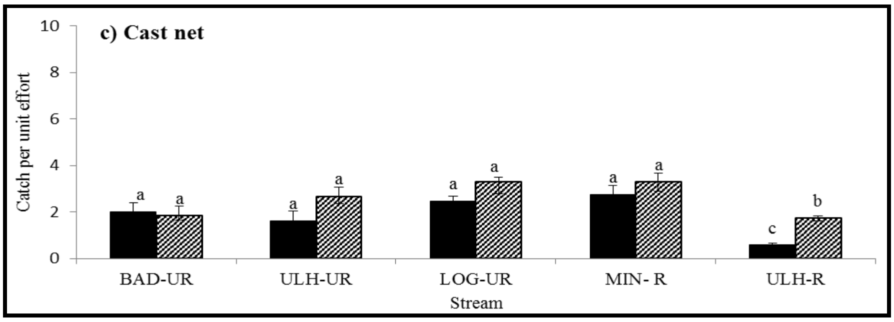


Fig 3: Mean number of individuals as catch per unit effort in fish sampling using the a) Hand net (Dry season: P= 0.0221, F=3.02, DF=4 Wet Season: P=0.036, F= 2.695 DF= 4), b) Drag net (Dry season: P= 1.88e-05, F=7.88, DF=4 Wet Season: P=3.57e-05, F= 7.418, DF= 4), c) Cast net (Dry season: P= 0.000533, F=5.521, DF=4 Wet Season: P=0.0098, F= 3.563 DF= 4), in three segments of each river during a one hour period in BAD-UR, ULH-UR, LOG-UR, MIN-R and ULH-R in the dry season from March to August 2014 and the wet season from September 2014 to February 2015. Different letters indicate significant differences between the catch per unit effort and vertical bars represent the standard errors of mean (SEM) values

4.4 Species richness

The species richness (calculated as the mean number of species per unit effort) was significantly lower in ULH-R than in other streams, and this drop was more pronounced with drag and cast nets (Drag net: Dry season P= 0.02, Wet Season: P=0.036, Cast net: Dry season=0.006, Wet season: P=0.035). In contrary to abundance, species richness showed seasonal differences. Only in un-regulated streams, the species richness was consistently higher in the dry season than that of wet season, and this was most noted with drag nets (Figure 4 b).

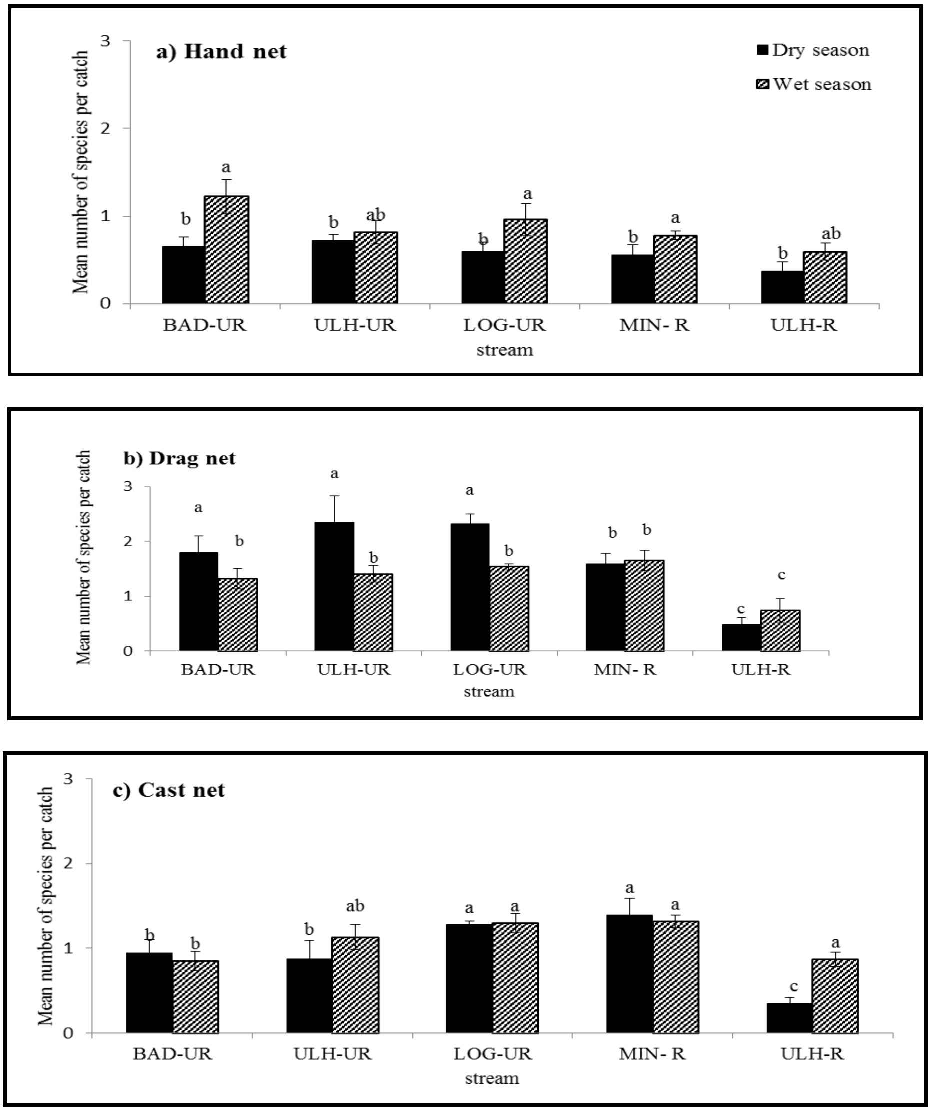


Fig 4: Richness (mean number of species per unit effort) with a) Hand net (Dry season: P= 0.132, F=1.822, DF=4 Wet season P=0.0243, F= 2.959 DF= 4), b) Drag net (Dry season: P= 0.000402, F=5.714, DF=4 Wet Season: P=0.00256, F= 4.457 DF= 4), c) Cast net (Dry season=0.006, F=4.838, DF=4 Wet season: P=0.035,F=2.716, DF=4) in three segments of each river during a one hour period in BAD-UR, ULH-UR, LOG-UR, MIN-R and ULH-R in the dry season from March to August 2013 and wet season September 2014 to February 2015. Different letters indicate significant differences between the species richness and vertical bars represent the standard errors of mean (SEM) values

4.5 Composition of fish assemblages

Interestingly, unregulated streams demonstrated a higher proportion of endemic fishes in both seasons compared to regulated streams (41 – 54% in the Dry season and 50 – 60% in the wet season). In contrast, the exotic fish was recorded in higher proportions in regulated streams during both seasons (Dry; 26 and 72 %; Wet: 34 and 66 % in MIN and ULH-R respectively) (Figure 5). Of the two regulated streams, ULH-R recorded higher proportion of exotic species during both seasons.

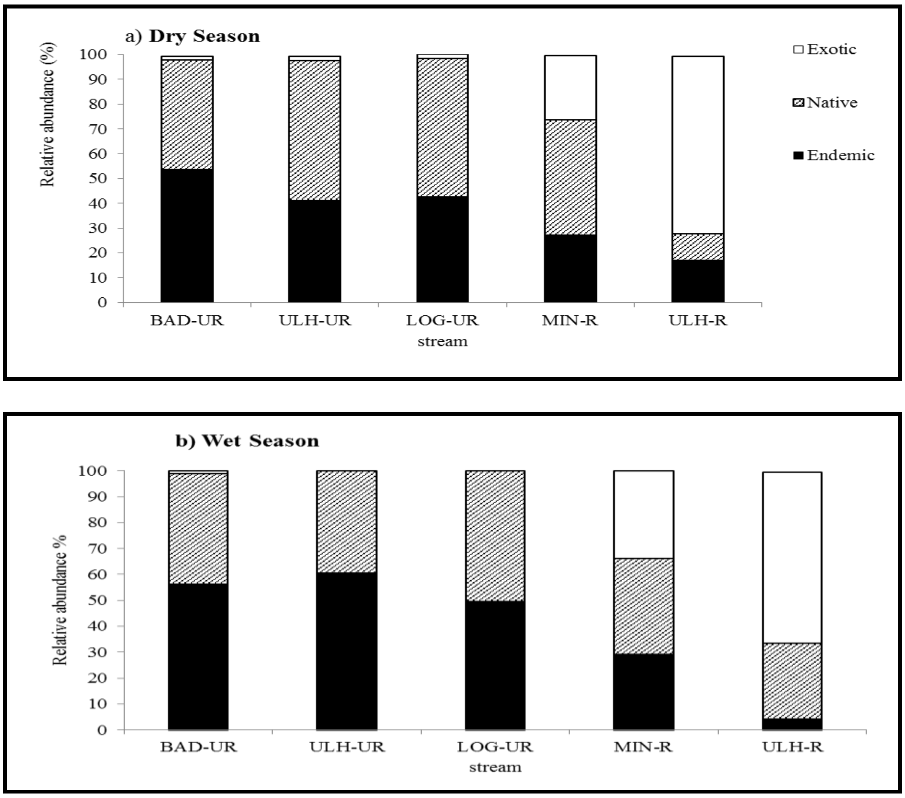


Fig 5: Relative abundance of fishes (%) belonging to three ecological statuses; endemic, native, and exotic in un-regulated and regulated study streams, BAD-UR, ULH-UR, LOG-UR, MIN-R and ULHI-R during the a) dry season from March to August 2014 and b) the wet season from September 2014 to February 2015.

Of the 40 species, 28 (70%) belonged to the 'least concerned' (LC) category, four species each (10%) as 'vulnerable' and 'critically endangered' (CR), two species as 'endangered' (EN) and only one species as 'near threatened' (NT) by National Red list 2012 [13]. Fish species belonged to CR, EN, VU and NT status were categorized as 'threatened fish species', and accordingly more than 20% of the fish species recorded in un-regulated streams can be considered as 'threatened' (Figure 6). In this study the 'endangered' and Endemic species; *Channa ara* Deraniyagala, 1945 and *Puntius kamalika* Silva *et al.,* 2008 were recorded only in unregulated streams.

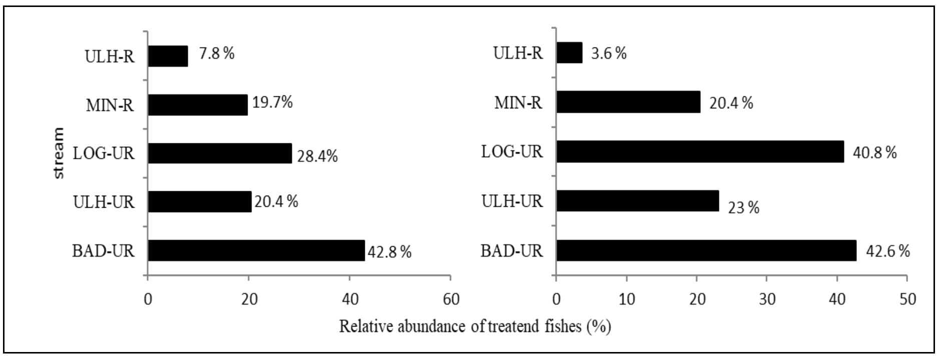


Fig 6: Relative abundance of (%) threatened fish in BAD-UR, ULH-UR, LOG-UR, MIN-R and ULHI-R (a) in the dry season from March to August 2014 (b) in the wet season from September 2014 to February 2015.

The endemic fishes such as *Laubuca insularis* Pethiyagoda, *et al.,* 2008, and *Garra ceylonensis* Bleeker, 1863 and the native fishes such as *Devario malabaricus, Amblypharyngodon melettinus* Valenciennes, 1844 were the most abundant species recorded in un-regulated (UR) streams, while the exotics, *Oreochromis mossambicus* and *O. niloticus* showed a higher abundance in regulated (R) streams irrespective of sampling methods (Table 2). However, in MIN-R *Devario malabaricus* a native cyprinid was also highly abundant when hand nets and drag nets were used for sampling. *Laubuca insularis* and *Devario malabaricus* seem to occupy similar habitats, hence sharing resources and often living as fish schools together.

Table 2: The fish species which showed the highest relative abundance in each study stream (BAD-UR, ULH-UR, LOG-UR, MIN-R and ULH-R) in the dry season and wet season in three different sampling methods (hand net, drag net, cast net). The relative abundance is given (as a percentage) within parentheses followed by the species.

	Hand net		Drag net		Cast net	
	Dry season	**Wet season**	**Dry season**	**Wet season**	**Dry season**	**Wet season**
BAD-UR	*Garra ceylonensis* (35%)	*Laubuca insularis* (27%)	*Amblypharingodon mellatinus* (38%)	*Laubuca insularis* (24%)	*Garra ceylonensis* (32%)	*Systomus martenstyni* (25%)
ULH-UR	*Amblypharingodon mellatinus* (32%)	*Amblypharingodon mellatinus* (34%)	*Amblypharingodon mellatinus* (38%)	*Amblypharingodon mellatinus* (28%)	*Garra ceylonensis* (22%)	*Dawkinsia singhala* (17%)
LOG-UR	*Laubuca insularis* (21%)	*Laubuca insularis* (32%)	*Devario malabaricus* (24%)	*Laubuca insularis* (27%)	*Garra ceylonensis* (17%)	*Garra ceylonensis* (27%)
MIN-R	*Devario malabaricus* (33%)	*Devario malabaricus* (34%)	*Devario malabaricus* (24%)	*Devario malabaricus* (25%)	*Oreochromis mossambicus* (23%)	*Oreochromis mossambicus* (27%)
ULH-R	*Oreochromis mossambicus* (43%)	*Oreochromis mossambicus* (23%)	*Oreochromis mossambicus* (42%)	*Oreochromis mossambicus* (60%)	*Oreochromis mossambicus* (41%)	*Oreochromis mossambicus* (51%)

4. Discussion

The present study revealed some interesting trends in diversity and distribution of fish assemblages in regulated and un-regulated streams in the downstream of Mahaweli. The family Cyprinidae is the largest family among vertebrate animals [5]. Vast majority of Sri Lankan freshwater fish species belonged to this family. In the present study, approximately 67% of the fish species were belonged to the family Cyprinidae. In terms of abundance and diversity of fish, ULH-R stands alone with low values compared to the rest of the streams. The un-regulated (upstream) and regulated (downstream) segments of the same stream (Ulhitiya Oya) showed contrasting results in terms of abundance and diversity of fish indicating the severity of impacts on fish assemblages following disturbances to the natural water flows due to the construction of dams and reservoirs. The situation at ULH-R was different from the other four streams possibly due to its water management strategies in Ulhitiya reservoir. The downstream of the ULH (ULH-R) stay completely dry for much of the year as the reservoir retains its water during the dry season and releases water only during the peak of the rainy season when the reservoir reaches up to its maximum capacity. However, even during the height of the dry season, some puddles and relatively deep pools remained scattered in the downstream of the ULH-R leaving some habitats for fish. The results indicate that the extreme river flow regulations can cause severe impacts on the fish population. Another study also observed higher fish diversity in the upstream of the Grayrocks reservoir of the Laramie River in Southeastern Wyoming, USA than in downstream channels of the same river [24]. Due to the alteration of regular water flow following construction of reservoirs and dams, new habitats can be created both in the upstream and downstream. As a result, fish face new challenges adapting to these newly created habitats. Mature fishes are able to shift into suitable habitats allowing the juveniles to get stranded in these newly created habitats [6].

Reservoirs can also alter the river bed characteristics by acting as a sediment trap [24]. As the water releasing from the reservoir to the downstream contains less sediments, it can alter the quality of the habitat (riverbeds) in the downstream. The changing physical characteristics of stream habitats as a result of river regulation may also influence the abundance and richness of fish negatively.

The abundance of fish showed no consistent seasonal differences. The seasonal differences are observed clearly in ULH-R compared to other study streams, with higher abundance (with hand and cast nets) during the wet season than in the dry season. The higher abundance of smaller fish caught with hand nets during the wet season is probably due to the increase in the number of juveniles as the rain triggers spawning [16]. The larger fish which can adapt to water level and flow changes may dominate during the rainy season. In contrast, the species richness of fishes showed some interesting seasonal fluctuations. With drag nets, un-regulated streams showed higher species richness in the dry season than in the wet season. The low water levels in dry season can make it easier to capture the fish in dry season than in wet season.

Minipe (MIN-R) is part of the main river channel of the river Mahaweli and is located in the immediate downstream of the Rantambe reservoir, and has been identified as ‘regulated’ in the present study. An anicut is built across the main river at Minipe to divert water through man-made left- and right-bank canals, and therefore that stretch of the river can be considered as regulated. However, in contrast to the other ‘regulated’ stream ULH-R, the abundance and species richness at MIN-R was closely resemble with that of the three un-regulated streams than with ULH-R. Results suggest that the effects of river flow regulation cannot be generalized as the impacts may differ depending on the specific conditions of the river as well as their water management strategies. In contrast to these resemblances, the composition of fish assemblages shows drastic variations between regulated and un-regulated streams. The relative abundance of endemic fishes was higher in unregulated rivers than in regulated rivers, while the exotic fishes showing results in *vice versa*. Most of these large reservoirs co structed under the AMDP are stocked with exotic fish species for fishery and when water released for agriculture, fish escape into downstream areas. These exotic fish then thrive in the downstream of regulated tributeries since the natives find it difficult to adapt into regulated conditions. These observations support the fact that the river regulation can affect mainly the native fish populations, as they are more sensitive to their habitat characteristics than the exotic fish species [18]. The regulated streams (MIN and ULH) show wide fluctuations of water flow than in unregulated streams (ULH- BAD and LOG), as the water levels in the downstream is highly dependent on the availability of water in the upstream as well as the hydropower and agricultural demand. As a result, the flow fluctuations in regulated streams are rather unpredictable. These factors may have led to unstable and altered aquatic habitats in the downstream of regulated streams, MIN-R and ULH-R. The stability and the physical characteristics in rivers play a critical role in determining the fish community structure [3.] All endemic fish species that recorded in the study belong to the families Channidae and Cyprindae. Most of these fishes are smaller in size and prefer shallow habitats with sluggish water flows. They may find difficult to adapt to these newly created micro-habitats with high water flow fluctuations [3]. Their inability to adapt to altered habitat conditions in regulated streams explains the compositional differences in fish assemblages in the present study. Another study also reported distinct differences in assemblages of native and non- native fishes and highlighted the importance of restoring the natural flow regimes in a regulated stream in the USA [3].

In Sri Lanka, 24 exotic species have been introduced to inland freshwater bodies, including Mahaweli reservoirs, to promote inland fisheries [12]. In the present study, nine of these exotic species have been recorded in regulated streams and two in unregulated streams. Of the exotic species that recorded in the study, *Catla catla* Hamilton 1822, *Cirrhinus mrigala* Hamilton, 1822, and *Ctenopharyngodon Idella* Valenciennes in Cuvier & Valenciennes, 1844 cannot breed under natural conditions in Sri Lanka, hence their populations can be controlled [26]. In contrast, *Oreochromis sp.* breeds throughout the year with higher fecundity and resilience to harsh conditions, and show omnivorous food habits. These attributes have contributed to their success in local water bodies over the native and other exotic species [26]. In favor, *Oreochromis sp.* was the most successful exotic fish species recorded in both MIN-R and ULH-R. The relatively smaller endemic fish species seem to lack the potential to compete with the successful exotic species for limited resources and altered physical conditions in regulated rivers.

Higher proportion of 'threatened' fish species (> 20%) was observed in unregulated rivers, indicating the importance of conserving rivers in their natural states. Further, critically endangered endemic species such as *Systomus martenstyni* and *Laubuca insularis* have also been recorded specifically in un-regulated streams. *Systomus martenstyni* was earlier known to be restricted in the Amban Ganga basin, one of the major tributaries of the river Mahaweli. In the present study, *Systomus martenstyni* was recorded in both LOG-UR and BAD-UR, indicating their presence in new localities [28]. The results suggest that changing connectivity between waterways as a result of constructing such large–scale river diversion projects has the potential to increase the distribution range of some fish species such as *Systomus martenstyni*. *Laubuca insularis* too was recorded in high abundance in unregulated streams in the present study. Although *Laubuca insularis* has been previously identified as a 'critically threatened' (CR) species [12] but according to the present study *Laubuca insularis* seems to be the most successful species thrive among other species in unregulated tributaries of the river Mahaweli. *Channa ara* and *Puntius kamalika*, the two known 'endangered' fish species, also recorded in unregulated streams in the present study, further emphasizing the importance of conserving natural characteristics of rivers.

5. Conclusions and recommendations

River regulation has caused negative impacts on the fish assemblages in the downstream tributaries of the river Mahaweli. However, impacts of river regulations cannot be generalized as they may vary depending on site-specific conditions and water management strategies of the reservoir. The results suggest that native and endemic fishes are more sensitive to altered habitat conditions following river regulation than that of exotics, possibly due to their lack of ability to compete with the exotic fishes that thrive in regulated streams. The results highlight the importance of protecting the remaining natural rivers in order to conserve the last refuge of the native and endemic fish species. The study also noted that unregulated streams are facing other anthropogenic disturbances (excessive sand mining and illegal fishing) in addition to river regulation. The establishments of mini-hydro development projects in some of these un-regulated tributaries are also in discussion [2]. Therefore, it is imperative to evaluate potential impacts of these proposed activities on these delicate ecosystems prior to permitting any developmental activities.

Appendix I: The detailed list of fish species recorded during the study in un-regulated and regulated streams in the immediate downstream of Rantambe-Randenigala reservoirs. (Presence or absence of the species in study sites are denoted by √ and × respectively. Family, Origin and Global Conservation Status of each species is given in the table). NCS= National Conservation Status, GCS = Global Conservation Status

Family	Species name	Origin	NCS	GCS	BAD-UR	ULH-UR	LOG-UR	MIN-R	ULH-R
Adrianichthyidae	*Oryzias melastigma*	Native	-		√	×	√	√	√
Bagridae	*Mystus vittatus*	Native	LC	LC	√	√	√	√	×
Channidae	*Channa ara*	Endemic	EN		×	√	×	×	×
Channidae	*Channa gachua*	Native	LC	LC	×	√	×	√	×
Channidae	*Channa orientalis*	Endemic	VU		√	√	√	×	×
Channidae	*Channa striata*	Native	LC	LC	×	×	√	×	×
Cichlidae	*Etroplus suratensis*	Native	LC	LC	√	√	√	√	×
Cobitidae	*Lepidocephalichthys thermalis*	Native	LC		×	×	√	√	√
Cyprinidae	*Amblypharyngodon melettinus*	Native	LC	LC	√	√	√	√	×
Cyprinidae	*Catla Catla*	Exotic	LC	LC	×	×	×	√	×
Cyprinidae	*Cirrhinus mrigala*	Exotic		VU	×	×	×	√	×
Cyprinidae	*Ctenopharyngodon idella*	Exotic	LC	LC	×	×	√	√	×
Cyprinidae	*Cyprinus carpio*	Exotic		VU	×	√	×	√	×
Cyprinidae	*Dawkinsia singhala*	Endemic	LC		√	√	√	√	×
Cyprinidae	*Devario malabaricus*	Native	LC	LC	√	√	√	√	√
Cyprinidae	*Esomus thermoicos*	Endemic	LC	LC	√	√	√	√	√
Cyprinidae	*Garra ceylonensis*	Endemic	VU	EN	√	√	√	√	√
Cyprinidae	*Labeo dussumieri*	Native	LC	LC	×	×	×	√	×
Cyprinidae	*Labeo fisheri*	Endemic	CR	EN	√	×	×	√	×
Cyprinidae	*Labeo rohita*	Exotic		LC	×	×	×	√	√
Cyprinidae	*Laubuca insularis*	Endemic	CR		√	√	√	√	×
Cyprinidae	*Oreochromis mossambicus*	Exotic	LC	NT	×	×	×	√	√
Cyprinidae	*Oreochromis niloticus*	Exotic		LC	×	×	×	√	√
Cyprinidae	*Pethia melanomaculata*	Endemic	VU		√	√	√	√	×

Cyprinidae	*Puntius bimaculatus*	Native	LC	LC	√	√	√	√	√
Cyprinidae	*Puntius chola*	Native	LC	LC	√	√	√	√	√
Cyprinidae	*Puntius dorsalis*	Native	LC		√	√	√	√	×
Cyprinidae	*Puntius kamalika*	Endemic	EN		√	√	√	√	×
Cyprinidae	*Systomus sarana*	Native	LC	LC	√	√	√	√	×
Cyprinidae	*Puntius vittatus*	Native	LC	LC	×	√	√	√	×
Cyprinidae	*Rasbora dandiya*	Native	LC		√	√	√	√	×
Cyprinidae	*Rasbora microcephalus*	Native	LC	LC	√	√	√	√	×
Cyprinidae	*Systomus martenstyni*	Endemic	CR	EN	√	√	√	√	×
Cyprinidae	*Systomus timbiri*	Endemic	DD		√	√	√	√	×
Cyprinidae	*Tor khudree*	Native	NT	EN	√	√	√	√	×
Gobiidae	*Glossogobius giuris*	Native	LC		√	√	√	×	×
Gobiidae	*Sicyopterus griseus*	Native	CR	LC	√	√	√	√	×
Mastacembelidae	*Mastacembelus armatus*	Native	LC	LC	×	×	×	√	√
Poeciliidae	*Poecilia reticulata*	Exotic	LC	LC	√	√	√	×	×
Siluridae	*Ompok bimaculatus*	Native	LC	NT	√	√	√	√	×

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7. References

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