

## Diversity and Distribution of Fin-fish and Prawn Species Assemblages of the Catch in Five Perennial Reservoirs in Northern Province, Sri Lanka

R. Rajeevan <sup>1\*</sup>, U. Edirisinghe <sup>1</sup> and A.R.S.B. Athauda <sup>2</sup>

<sup>1</sup>Postgraduate Institute of Agriculture, University of Peradeniya, Peradeniya, Sri Lanka

<sup>2</sup>Department of Animal Science, Faculty of Agriculture, University of Peradeniya, Peradeniya, Sri Lanka

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Rajeevan, R.   
<https://orcid.org/0000-0003-4934-494X>



### ABSTRACT

Present study was carried out to assess the abundance and diversity of fin-fish and prawn species in the selected five reservoirs in the Northern Province, Sri Lanka. Fin-fish and prawns caught by multi-mesh gillnets, and rod and hooks, were sampled from January to December 2017. Relative abundance and diversity indices were calculated and, differences and similarities among reservoirs in different months were assessed. The hierarchical clustering was used in constructing dendrogram. Of the 27 finfish species and two freshwater prawn species identified in total, the highest number of species were observed in Muthayankattu reservoir (26 species) while Puthumurippu reservoir had the lowest (14 species). *Oreochromis niloticus* was the dominant species in all the reservoirs. Small reservoirs (Puthumurippu, Kalmadu and Muhathankulam) showed high Shannon-Weiner diversity index and evenness, though low in dominance index, compared to large reservoirs (Vavunikulam and Muthayankattu). Selective harvest methods, number of fishers and seasonal variation of hydro-climatic factors such as rainfall, strong wind and water level significantly influenced the diversity of fish species. Increasing fishing pressure and use of destructive fishing methods during low water level were the main contributors for diversity loss in the five perennial reservoirs studied.

\*Corresponding author : [r.rajeevan88@gmail.com](mailto:r.rajeevan88@gmail.com)

## INTRODUCTION

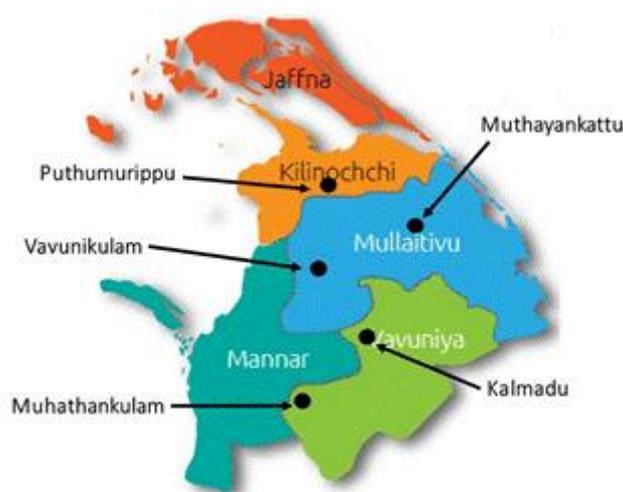
Reservoirs in tropics are primarily used for irrigation and/or hydroelectricity, and can cause high water level depletion since fisheries is a secondary activity (De Silva, 1996). Each reservoir is unique. Majority of reservoir fisheries are artisanal and highly seasonal in many parts of the world (Welcomme, 2001). Sri Lanka does not possess any natural lakes whereas its fish population is dominated by traditionally unexploited fish species (De Silva, 1988; Pet et al., 1999). These endemic and indigenous fish species are not completely adapted to lacustrine conditions. Therefore, native fish species alone cannot produce an adequate catch. As a result, exotic species play a major role in reservoir fisheries (De Silva, 1996).

Sri Lanka has approximately 137 species of freshwater fish fauna comprised of 90 true freshwater fishes including 53 endemics, 23 estuarine and 24 exotic species. Most of exotic fishes are well established in the island and account for an overwhelming share of fish biomass (Wildlife conservation society – Galle, 2015). Fishing methods in Sri Lankan reservoirs are mostly limited to gillnets, which are highly selective, and towing or surrounding nets are prohibited according to inland fisheries regulations (Amarasinghe and

Pitcher, 1986; Amarasinghe et al., 2014). Gillnets which are passive standard gear (Hamley, 1980) are commonly used in sampling fish in reservoirs. Studies of freshwater fish species are essential for planning reservoir fisheries development and management, and especially studies on small-sized fish species which are in high abundance in most tropical reservoirs are vital. Future demand for fish can be partly met by exploiting these untapped fish resources. The objective of this study was to assess and compare the abundance and diversity of fin-fish and prawn species in fish catch of five reservoirs in Northern Province of Sri Lanka.

## MATERIALS AND METHODS

The study was conducted in five perennial reservoirs (Figure 1) in Northern Province of Sri Lanka, viz., Vavunikulam, Muthayankattu, Puthumurippu, Kalmadu and Muhathankulam with areas of 1275 ha, 1255 ha, 151 ha, 74 ha and 211 ha, respectively at Full Supply Level (FSL). Reservoirs were categorized into two groups for comparison according to areas at FSL. Vavunikulam and Muthayankattu, which showed FSL above 1,000 ha were considered as large reservoirs and Puthumurippu, Kalmadu and Muhathankulam, with FSL less than 1,000 ha, were grouped as small reservoirs.



**Figure 1. Locations of selected reservoirs**

Fish and prawns caught by multi-mesh gillnets (50.8 mm, 63.5 mm, 88.9 mm, 101.6 mm, 114.3 mm 127 mm, 152.4 mm and 177.8 mm, knot to knot) and rod and hooks were sampled from January to December 2017. These gillnets were set in almost all parts of each reservoir by local fishermen in the evenings around 4.00 p.m. to 6.00 p.m., and collected on the next day morning around 5.00 a.m. to 9.00 a.m. It was assumed that all the reservoirs used nets with same mesh size. All fish and prawn species were sorted and identified to species level according to Pethiyagoda (2006). Total number of species and individual numbers were recorded for each month.

Species diversity was assessed by using four indices namely, species richness, Shannon-Wiener diversity, Evenness and Dominance. Shannon-Weiner diversity index ( $H'$ ) (Shannon and Weaver, 1963) was calculated by the equation (1)

$$H' = -\sum_{i=1}^S P_i * \ln P_i \dots\dots\dots(1)$$

where, S = the total number of species

$P_i$  = the relative cover of  $i^{th}$  species.

Species richness was calculated by using Margalef index ( $d$ ) (Margalef, 1968) using the equation (2)

$$d = (S-1)/\ln(N) \dots\dots\dots(2)$$

where, S = the total species

N = the total individuals.

Evenness ( $J'$ ) was calculated using Shannon's diversity index using the equation (3)

$$J' = H'/\ln S \dots\dots\dots(3)$$

where, S = the total number of species.

The dominance index (Harper, 1999) was measured to identify whether particular species was dominating in the specific aquatic

resource. Dominance index was calculated by using equation (4)

$$D = \sum_i^S \frac{n_i(n_i-1)}{N(N-1)} \dots\dots\dots(4)$$

where,  $n_i$  = the number of individuals of species  $i$

N = the total number of individuals.

The relative abundance of each species was calculated using equation (5)

$$\text{Relative abundance} = \left(\frac{a_i}{A}\right) 100 \% \dots\dots\dots(5)$$

where,  $a_i$  = the number of individuals caught in the  $i^{th}$  species

A = the total number of individuals

One-way analysis of variance (ANOVA) was used to identify difference of diversity indices among the reservoirs and among months of the year. Tukey comparison was used to compare means (Spjotvoll and Stoline, 1973). Similarity percentages analysis (SIMPER) (Clarke, 1993) was performed to determine the percentage of similarity among reservoirs and among months of the year. The hierarchical clustering (Clarke and Warwick, 1994; Hossain *et al.* 2012) was calculated to produce a dendrogram. All statistical procedures were performed using Microsoft Excel 2016, Minitab 17 statistical software and Paleontological Statistics (PAST) version 3.0.

**RESULTS AND DISCUSSION**

A total of 43,408 individuals were quantified, comprised of 27 fin-fish species and 2 freshwater prawn species (Table 1). High species numbers were observed in large reservoirs; Muthayankattu (26) and Vavunikulam (23), followed by small reservoirs; Muhathankulam (22), Kalmadu (21) and Puthumurippu (14). Vavunikulam (67.5%) and Muthayankattu (57.9%) reservoirs dominated with introduced species, while Kalmadu (61.9%) and

Muhathankulam (66.6%) dominated with native species. Puthumurippu recorded (55.7%) stocked species (*M. rosenbergii* and exotics). In all the five reservoirs *O. niloticus* was in the highest abundance.

In Vavunikulam reservoir, *O. niloticus* was the most abundant species, comprised of 63.2%, followed by *L. dussumieri* (7.2%), *O. bimaculatus* (4.6%), *S. timbiri* (4.0%), *G. giuris* (3.9%) *M. gulia* (3.4%), while *M. rosenbergii* contributed only 2.6% to the total catch. Muthayankattu reservoir was also dominated by *O. niloticus*, which made nearly half (49.5%) of the catch. Other species in catch of Muthayankattu reservoir were *P. dorsalis* (6.2%), *A. melettinus* (5.0%), *A. bengalensis* (4.9%) and *S. timbiri* (4.9%) and *M. rosenbergii* (2.6%). In Puthumurippu reservoir, *O. niloticus* and *M. rosenbergii* were the most dominating species, accounting for 21.8% and 21.7%, respectively in the total catch, followed by *M. zeylancicus* (12.4%) and *G. giuris* (9.8%). In Kalmadu reservoir, *O. niloticus* (12.3%) and *A. testudineus* (11.7%) almost equally contributed to the catch, while *S. timbiri* and *M. rosenbergii* represented 10.0% and 9.7%, respectively. In Muhathankulam reservoir, *O. niloticus* dominated (18.0%) followed by *S. timbiri* (10.7%) and *M. gulia* (10.4%) which were in equal percentage in the catch and *M. rosenbergii* contributed only 4.1%.

Present study consisted of 29 species in total compared to Amarasinghe et al. (2014) who observed 30 species in Minneriya reservoir, 21 species in Udawalwe and 18 species in Victoria reservoir, with 12 different families dominated by Cyprinidae where fishing was done by using beach seines (1, 5 and 7 mm mesh size) and multi-mesh monofilament gillnets (12.5, 16, 20, 25, 33, 37, 50, 60, 76 90 mm stretched mesh size). Chandrasoma et al. (2015) reported that species composition in the catch significantly varied after stocking with Indian major carps, where *O. niloticus* contributed to 80-90% before the year 2004, and then reduced in 2004 up to 64.6% in smaller reservoirs and 57.1% in larger

reservoirs. Indian major carps *C. catla*, *L. rohita* and other carp species were reported contributing to 41.9% in minor and 39.5% in medium reservoirs. Their contribution was also reported, 29.1% in Senanayaka Samudra and 38% in Jayanthi wewa which are major perennial reservoirs, while *M. rosenbergii* contributed to only 1.6%, 0.5%, 0.4%, 1% in major, minor, Senanayaka Samudra and Jayanthi wewa reservoirs, respectively. Dematawewa et al. (2008) reported that catch was dominated by *O. niloticus* (78.5%) in Sorabora reservoir. Similarly, Chandrasoma et al. (2015) reported that in 2009, *O. niloticus* (81.7%) was the dominant species in Ampara reservoir, where *C. catla* (12.5%), *L. rohita* (2.3%) and *M. rosenbergii* (0.3%) contributed only by small percentage in the total catch.

SIMPER analysis between large reservoirs (Vavunikulam and Muthayankattu) and small perennial reservoirs (Puthumurippu, Kalmad and Muhathankulam) revealed that the major contributory species was *O. niloticus* (59.2%) and other contributory species were *P. dorsalis* (4.2%), *L. dussumieri* (4.0%), *S. timbiri* (3.9%), *A. bengalensis* (3.1%), *M. gulia* (3.0%), *G. giuris* (2.6%), *M. rosenbergii* (2.6%), *O. bimaculatus* (2.6%), *E. suratensis* (2.2%), *A. testudineus* (1.6%), *M. zeylancicus* (1.5%), *A. mamarota* (1.4%), *O. mossambicus* (1.4%), *C. striata* (1.1%). All the other species contributed by less than 1%.

At the similarity level of 22%, the relative abundance data identified two major clusters in cluster analysis (Figure 2). Results revealed that larger reservoirs had very distant similarities (22%) with smaller reservoirs except from August to October in Muhathankulam. The reason could be that, high fishing pressure was applied by fishers during those three months through using less selective gear due to the low water level resulting from poor rainfall and high water drainage from the sluice to irrigate paddy.

**Table 1. Relative abundance and total sample size of species in the five perennial reservoirs (R1 – R5)†.**

Species	R1	R2	R3	R4	R5	Sample
<i>Amblypharyngodon melettinus</i>	2.09	4.99	0	2.26	2.54	1237
<i>Anabas testudineus</i>	0.22	2.15	0	11.73	4.90	909
<i>Anguilla bengalensis</i>	0.56	4.93	0	1.20	1.55	806
<i>Anguilla bicolor</i>	0.68	0.68	0	0.37	0.37	260
<i>Anguilla mamarota</i>	0.32	2.10	0	0.80	0.75	374
<i>Etroplus suratensis</i>	0.37	3.49	0	0	0	481
<i>Pseudetroplus maculatus</i>	0	0.22	0	1.76	0	78
<i>Glossogobius giurus</i>	3.91	1.53	9.76	7.31	6.21	1730
<i>Labeo dussumieri</i>	7.17	0	3.33	0	4.59	1890
<i>Mystus gulia</i>	3.38	3.85	9.54	4.19	10.40	2005
<i>Mystus zeylanicus</i>	1.80	2.36	12.35	8.37	6.15	1419
<i>Ompok "bimaculatus"</i>	4.59	0	0	0	2.33	1148
<i>Puntius dorsalis</i>	2.39	6.18	0	2.46	7.31	1702
<i>Systomus timbiri</i>	3.99	4.85	0	10.0	10.65	2314
<i>Channa kelrtii</i>	0	0.12	0	0	0	14
<i>Channa punctate</i>	0	0.17	0	0	0	19
<i>Channa striata</i>	0.43	1.79	3.40	7.21	3.32	741
<i>Clarias brachysoma</i>	0.39	0.65	1.33	2.79	3.62	458
<i>Heteropneustes fossilis</i>	0.18	0.34	0	1.43	1.94	226
<i>Hyporhamphus limbatus</i>	0	0.23	4.59	0	0	88
<i>Catla catla*</i>	0.47	1.07	6.29	2.56	2.76	537
<i>Labeo rohita*</i>	0.39	1.19	2.22	6.61	2.01	560
<i>Cirrhinus mrigala*</i>	0.11	0	1.48	0	1.53	127
<i>Cyprinus carpio*</i>	0.30	0.51	1.26	1.56	1.21	253
<i>Hypophthalmichthys molitrix*</i>	0	0.40	0	0.50	0	61
<i>Oreochromis mossambicus*</i>	0.52	2.67	0.96	4.89	3.79	783
<i>Oreochromis niloticus*</i>	63.16	49.46	21.82	12.26	17.98	21342
<i>Macrobrachium rosenbergii**</i>	2.59	2.64	21.67	9.74	4.10	1684
<i>Macrobrachium spp.</i>	0	1.42	0	0	0	162
<b>Total individuals</b>	22291	11393	1352	3009	5363	43408
<b>Number of species</b>	23	26	14	21	22	29

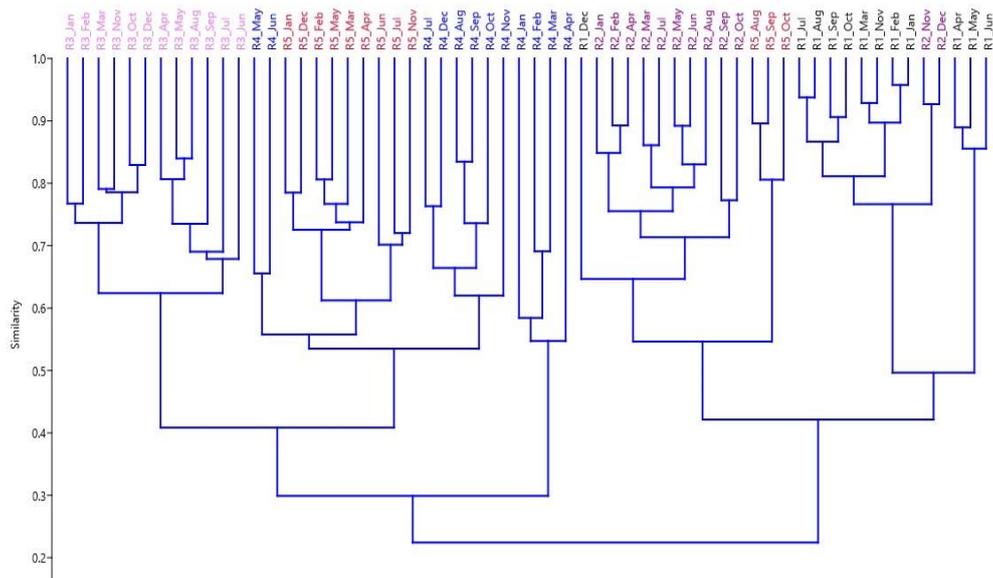
†R1-Vavunikulam; R2-Muthayankattu; R3-Puthumurippu; R4-Kalmadu; R5- Muhathankulam

\*Exotic species

\*\*Native stocked species

The highest Shannon-Weiner diversity index (2.7382) was observed in Muhathankulam major reservoir in October and the lowest value was observed in Vavunikulam reservoir (0.7374) in February. Dominance index value was highest in Vavunikulam major reservoir (0.7557) in February and the lowest value was observed in Kalmadu (0.0684) in July. The highest evenness (0.9266) was observed at

Puthumurippu minor perennial reservoir in November and the lowest value was found at Vavunikulam major reservoir (0.2504) in February. The highest and lowest Margalef species richness values were observed in Muthayankattu large reservoir in January (3.899) and in Kalmadu small reservoir (1.739) in April, respectively.



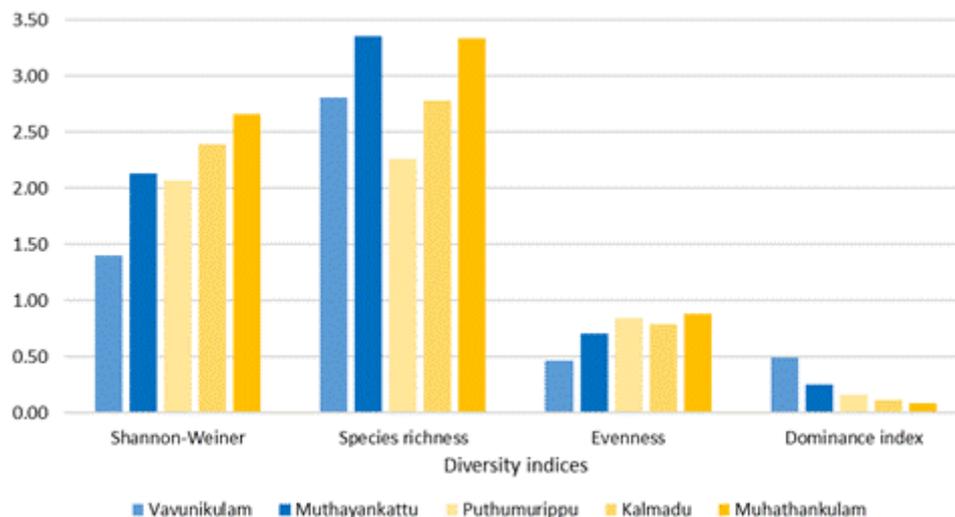
**Figure 2. Clusters of fish assemblage based on Bray-Curtis similarity matrix in Vavunikulam (R1), Muthayankattu (R2), Puthumurippu (R3), Kalmadu (R4) and Muhathankulam (R5) reservoirs.**

In comparison, Vavunikulam large reservoir indicated the highest dominance index (0.4903), while occurring the lowest in Shannon-Weiner diversity index (1.3992) and Evenness (0.4646). Muhathankulam small reservoir recorded the highest Shannon-Weiner index (2.6611) and Evenness (0.883) while recording the lowest dominance index (0.4903). Muthayankattu large and Puthumurippu small reservoirs were the highest (3.3551) and the lowest (2.3162) in species richness respectively (Figure 3).

Small reservoirs recorded high Shannon-Weiner diversity index and evenness compared to those recorded by large reservoirs, whereas the dominance index in large reservoirs were higher than that in smaller reservoirs. Means of Shannon-Weiner diversity index, dominance index, evenness and species richness significantly differed among reservoirs ( $P = 0.000$ ) but not among months. Four diversity indices of Vavunikulam and Muhathankulam reservoirs significantly differed from all other reservoirs except species richness of Kalmadu reservoir.

Though reservoirs of Northern Province have short development history of culture based fisheries, findings revealed that exotic species

dominated the catch throughout the year. Present study was purely based on catch from multi-mesh gillnets, where minimum mesh size was 88.9 mm regulated by National Aquaculture Development Authority (NAQDA), Sri Lanka. Species composition of catch in the present study would have been influenced by fishing methods and gear used for target species. Vavunikulam and Muthayanakttu Fisheries Societies had their own regulations on mesh size, where minimum size was 101.6 mm and 114.3 mm, respectively. However, such regulations on gear size did not exist in Puthumurippu, Kalmadu and Muhathankulam reservoirs. Even though mesh size limitation is there, fishers used 50.8 mm and 63.5 mm, during two to three months every year mainly targeting *L. dussumieri*, *Ompok bimaculatus* at Vavunikulam reservoir. Use of rod and hooks mainly targeting for freshwater eels (*Anguilla spp.*) also have been recorded in few seasons. This could be one of the reasons for low species diversity observed in the present study as most of the minor cyprinids, which are smaller in size did not get caught in this type of gear.



**Figure 3. Mean value of four species diversity indices at selected reservoirs in 2017.**

Use of multi mesh gillnets is often found in Sri Lankan reservoir fisheries, and it varied from season to season, due to seasonal variation of catchability of target species (Dematawewa *et al.*, 2008). Engagement of part-time fishers in agricultural and the other activities depends on several external factors, especially the rainfall and other weather conditions (Dematawewa *et al.*, 2008) which may also be the reason for seasonal variation of fishing pressure in reservoirs. Seasonal variation of hydro-climatic factors such as rainfall and wind related factors, water level, waves, turbidity and water chemistry highly influence the productivity of reservoirs (Moses *et al.*, 2002) and catch per unit effort in many inland reservoirs (Hontela and Stacey, 1990; Moses *et al.*, 2002). Intense exploitation is common during low water levels whereas recovery of fish stock occurs during wet season (Dematawewa *et al.*, 2008).

Increasing fishing pressure in Kalmadu and Muhathankulam reservoirs during low water level was observed. This is one of the main triggering factors for fisheries diversity loss. There are few technical factors, which influenced gillnet selectivity and catch size such as mesh size, hanging ratio (Fonseca *et al.*, 2005), twine thickness (Holst *et al.*, 2002) and colour of twine (Tweddle and Bodington, 1988). Further, presence of body projections such as teeth or spines,

facilitated significant proportion of fish being entangled in gillnets (Sparre and Venema, 1998). High swimming activity of fish is another biological characteristic which can result in high probability of encounters (Rudstam *et al.*, 1984).

The number of species or richness and the distribution of individuals among species are the two components of species diversity (Magurran, 1988). Low diversity in Vavunikulam in February could be due to high contribution of *O. niloticus* (87.38%) owing to highly selective harvest of tilapia. However, the high diversity observed in Muhathankulam during October could be because of high fishing pressure using mostly multi-mesh gillnets of 63.5 mm, 76.2 mm and 88.9 mm mesh. In addition, fishers tend to practice destructive water beating fishing method since water levels are low.

High dominance index involved with highly selective harvest methods and low dominance involved with less selective harvesting methods practiced by fishers. Fishers in larger reservoirs mostly practiced high selective harvest methods especially for *O. niloticus*. When the temporal variation of dominance status was compared, fluctuation in a narrow range was observed except in Vavunikulam during April-June where application of small mesh gillnet targeting *L. dussumieri* was practiced. The reason for

high evenness recorded in Puthumurippu in November could be the low number of species and individuals recorded during the period. Similarly, low evenness was recorded in Vavunikulam in February because of target highly towards *O. niloticus*. Muthayankattu showed a high richness in January due to the use of gear of different mesh sizes together with rod and hooks, whereas Kalmadu recorded low richness in April due to low fishing intensity.

There was strong positive correlation (0.93) between Shannon-Weiner and Evenness index confirming the observation of Nair *et al.* (1989) who showed the similar relationship of fish species diversity in the Nair river of the Western Ghats of India. However, strong negative correlation (-0.935) was found between Shannon-Weiner and Dominance index in the present study, confirming the findings of the study in Naaf river estuary by Chowdhury *et al.* (2010).

Variations in biodiversity indices could be due to seasonal variations of nutrients affecting the coexistence of many fish species, atmospheric air currents, environmental conditions and seasonal fish migrations (Huh and Kitting, 1985). Ajith Kumara *et al.* (2009) indicated possibilities of inshore-offshore migration of species associated with the water level fluctuations, and poor breeding in lacustrine habitat. Although indigenous cyprinid species require riverine habitats for spawning, similar to the African cichlid species they exploit the lacustrine habitats of reservoirs for feeding grounds, colonizing and due to anthropogenic effects (De Silva, 1983; De Silva, 1988).

According to Keskin and Unsal (1998), the reason for showing lower species diversity in the catch in their study was due to the fishing gears which had high selectivity. In most reservoirs of Sri Lanka, fishers beat the water with wooden poles or weighted ropes to drive fish towards gillnets. The efficiency

of this water beating technique is significantly higher than that of normal gillnetting, (Amarasinghe and Pitcher, 1986), and is a common method during dry season. Cichlids exhibit depth preferences according to body size, where small individuals prefer shallow littoral zones while adults prefer deeper pelagic zones (Caulton and Hill, 1973; Ribbink and Hill, 1979). Juveniles of exotic cichlids in Sri Lankan reservoirs have spatially segregated from the minor cyprinids. Therefore, when the fishing intensity targeting *O. niloticus* is high, it may cause low diversity in the catch (Pet *et al.*, 1999; Ajith Kumara *et al.*, 2008). Hence, as recommended by Amarasinghe and Pitcher (1986) and Ajith Kumara *et al.* (2009) introduction of an additional gillnet (< 52 mm stretched mesh) for minor cyprinids without harming juvenile cichlids is feasible in these reservoirs too.

## CONCLUSION

Selected five reservoirs are valuable for fisheries and they provide favorable condition for fish abundance and diversity. High species numbers were observed in larger reservoirs, which were dominated with exotic species, while smaller reservoirs were dominated with native species, though *O. niloticus* was highest abundance in the catch. Smaller reservoirs have higher Shannon-Weiner diversity index and evenness than larger reservoirs, while larger reservoirs have high dominance index than smaller reservoirs. Anthropogenic factors such as fishing pressure, selective harvest methods and water effluent for irrigation act as driving forces for the abundance and diversity of fish and prawn species in the catch.

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## REFERENCES

- Amarasinghe, U.S. and Pitcher, T.J. (1986). Assessment of fishing effort in Parakrama Samudra, an ancient man-made lake in Sri Lanka. *Fisheries Research*. 4, 271-282.
- Amarasinghe, U.S., Vijverberg, J., Weliange, W.S. and Vos, M. (2014). Food-web patterns and diversity in tropical fish communities. *Lakes & Reservoirs: Research and Management*. 19(1), 56-69.
- Ajith Kumara, P.A.D., Amarasinghe, U.S., Schiemer, F.G., Winkler, G. and Schabuss, M. (2009). Gillnet Selectivity of Small Cyprinids in Three Sri Lankan Reservoirs. *Asian Fisheries Science*. 22, 885-900.
- Caulton, M.S. and Hill, B.J. (1973). The ability of *Tilapia mossambica* (Peters) to enter deep water. *Journal of Fish Biology*. 5, 783-788.
- Chandrasoma, J., Pushpalatha, K.B.C., and Fernando, W.A.J.R., (2015). Impact of introduction of culture-based fisheries on fish production in perennial reservoirs of Sri Lanka. In: Sena S. De Silva, B.A. Ingram and S. Wilkinson (eds.), *Perspectives on culture-based fisheries developments in Asia*, pp. 83-90. Network of Aquaculture Centers in Asia-Pacific, Bangkok, Thailand.
- Chowdhury, M.S.N., Hossain, M.S., Das, N.G. and Barua, P. (2010). Environmental variables and fisheries diversity of the Naaf river estuary, Bangladesh. *Journal of Coastal Conservation*. 15 (1), 163-180.
- Clarke, K.R. (1993). Non parametric multivariate analyses of changes in community structure. *Australian Journal of Ecology*. 18, 117-43.
- Clarke, K.R. and Warwick, R.M. (1994). Change in Marine Communities. An Approach to Statistical Analysis and Interpretation. Natural Environment Research Council, Plymouth, 144 p.
- De Silva, S.S. (1983). Reproductive strategies of some major fish species in Parakrama Samudra reservoir and their possible impact on the ecosystem – a theoretical consideration. In: *Limnology of Parakrama Samudra – Sri Lanka: A Case Study of an Ancient Man-Made Lake in the Tropics* (ed. F. Schiemer), pp. 185-91. *Developments in Hydrobiology* 12, Dr. W. Junk Publishers, The Hague.
- De Silva, S.S. (1988). Reservoirs of Sri Lanka and their fisheries. *FAO Fish. Tech. Pap.* 298, 128.
- De Silva, S.S. (1996). The Asian inland fishery with special reference to reservoir fisheries: A reappraisal. Pp. 321- 332. In: Schiemer F., Boland K.T. (eds.) *Perspectives in tropical limnology*. SPB Academic Publishing, Amsterdam, the Netherlands.
- Dematawewa, C.M.B., Wickramasinghe, E.S. and Edirisinghe, U. (2008). Some Effects of Seasonal Hydro-Climatic Factors on Catchability of Fish in Minor-Perennial Sorabora Reservoirs, Sri Lanka. *Sri Lanka Journal of Animal Production*. 04, 39-53.
- Fonseca, P., Martins, R., Campos A. and Sobral, P. (2005). Gill-net selectivity off the Portuguese western coast. *Fisheries Research*. 73 (3), 323-339.
- Hamley, J.M. (1980). Sampling with gillnets. In: *Guidelines for sampling fish in inland waters* (ed. T. Backiel and R.L. Welcomme), pp. 37-53. EIFAC Technical Paper 33.
- Harper, D.A.T. (1999). *Numerical Palaeobiology*. John Wiley and Sons.
- Holst, R., Wileman, D. and Madsen, N. (2002). The effects of twine thickness on the size selectivity and fishing power of Baltic cod gill nets. *Fisheries Research*. 56 (3), 303-312.

- Hontela, A. and Stacey, N.E. (1990). Cyprinidae. In: A.D. Munro, A.P. Scott and T.T. Lam (eds.). Reproductive seasonality in Teleosts: Environmental influences. CRC Press Inc., USA. Pp 53-78.
- Hossain, M.S., Gopal Das, N., Sarker, S. and Rahaman, M.Z. (2012). Fish diversity and habitat relationship with environmental variables at Meghna river estuary, Bangladesh. *Egyptian Journal of Aquatic Research*. 38(3), 213-226.
- Huh, S.H. and Kitting, C.L. (1985). Trophic relationships among concentrated populations of small fishes in seagrass meadows. *Journal of Experimental Marine Biology and Ecology*. 92, 29-43.
- Keskin, C. and Unsal, N. (1998). The Fish Fauna of Gokceada Island, NE Aegean Sea, Turkey. *Italian Journal of Zoology*. 65, 299-302.
- Magurran, A. E. (1988). *Ecological Diversity and its Measurement*. Princeton University Press, Princeton.
- Margalef, R. (1968). *Perspectives in Ecological Theory*. University of Chicago Press, Chicago, IL, 111 p.
- Moses, B.S., Udoidiong, O.M. and Okon, A.O. (2002). A statistical survey of the artisanal fisheries of South-Eastern Nigeria and the influence of hydroclimatic factors on catch and resource productivity. *Fisheries Research*. 57(3), 267-278.
- Nair, N.B., Arunachalam, M., Madhusoodanan, N.K.C., and Suryanarayanan, H. (1989). Seasonal variation and species diversity of fishes in the Neyyer river of the Western Ghats. *Tropical Ecology*. 30 (1), 69-74.
- Pet, J.S., van Densen, W.L.T. and Vijverberg, J. (1999). Management options for the exploitation of introduced tilapia and small indigenous cyprinids in Sri Lankan reservoirs. In: Fish and fisheries of lakes and reservoirs in Southeast Asia and Africa (ed. W.L.T. van Densen and M.J. Morris), pp. 159-185. Westbury Publishing, Otley.
- Pethiyagoda, R. (2006). Conservation of Sri Lankan freshwater fishes. In: Bambaradeniya, C.N.B. (ed.). *The Fauna of Sri Lanka: Status, Taxonomy, Research and Conservation*. The World Conservation Union (IUCN), Colombo, Sri Lanka and Government of Sri Lanka.
- Ribbink, A.J. and Hill, B.J. (1979). Depth equilibration by two predatory cichlid fish from Lake Malawi. *Journal of Fish Biology*. 14, 507-510.
- Rudstam, L.G., Magnuson, J.M. and Tonn W.L. (1984). Size selectivity of passive fishing gear: A correction for encounter probability applied to gill nets. *Canadian Journal of Fisheries and Aquatic Sciences*. 41 (8), 1252-1255.
- Sparre, P. and Venema, S.C. (1998). *Introduction to tropical fish stock assessment. Part 1. Manual*. FAO Fisheries Technical Paper No. 306.1: Rev. 2. FAO, Rome.
- Shannon, C.E. and Weaver, W. (1963). *The Mathematical Theory of Communications*. University of Illinois Press, Urbana, IL, 125 p.
- Spjotvoll, E. and Stoline, M.R. (1973). An extension of the T-method of multiple comparisons to include the cases with unequal sample sizes. *Journal of the American Statistical Association*. 68, 976-978.
- Tweddle, D. and Bodington, P. (1988). A comparison of the effectiveness of black and white gillnets in Lake Malawi, Africa. *Fisheries Research*. 6(3), 257-269.

Welcomme, R.L. (2001). Inland fisheries: Ecology and management. FAO Rome and Fishing News Books, Blackwell Science, Oxford, UK.

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