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Cover: Fish species recorded in the Gowthami-Godavari Estuary, Andhra Pradesh: *Lutjanus johnii* (top left), *Triacanthus biaculeatus* (top right), *Acentrogobius cyanomos*, *Elops machnata*, *Trypauchen vagina*, *Oxyurichthys microlepis*. © Paromita Ray.

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COMMUNICATION

Can the Sri Lankan endemic-endangered fish *Labeo fisheri* (Teleostei: Cyprinidae) adapt to a new habitat?

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Abstract: *Labeo fisheri* is an endemic and endangered freshwater fish of Sri Lanka. Mainly restricted to the upper reaches of the Mahaweli River basin, it has been previously reported living in deep rapids and among large rocks and boulders. An accidental record of a *Labeo fisheri* specimen from Victoria Reservoir led us to further study this habitat during the period from January to August 2017. This study was carried out to confirm the presence of a population of *Labeo fisheri* within the Victoria Reservoir and report its new habitat type in deep stagnant waters. We further investigated the food habits by analyzing the gut contents of *L. fisheri* in the Victoria Reservoir. Seven individuals were recorded from fishermen's gill net catch in three fish landing sites along Victoria Reservoir, with an average total length of 24.80 ± 4.30 cm, average standard length of 19.70 ± 3.86 cm and average body weight of 197.69 ± 107.12 g. Based on gut content analysis, only phytoplankton, especially diatoms and cyanobacteria, were found in the gut of *L. fisheri*. This new population is facing the direct threat of fishing. Effective conservation measures are doubtful, since a fishery is well established in the Victoria Reservoir and the fishing gear used is not species-specific. More research is necessary to understand the population dynamics of *L. fisheri* in the Victoria Reservoir. In order to conserve it at this locality, community-based conservation measures are recommended.

Keywords: Adaptation, habitats, feeding habit, freshwater fish, gut analysis, *Labeo fisheri*, new locality, stagnant water, Victoria Reservoir.

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Author contributions: DT—specimen identification and measuring, data analysis and manuscript writing; GH—specimen collection, measuring and manuscript writing.

INTRODUCTION

Sri Lanka and the Western Ghats of India collectively are one of the 34 biodiversity hotspots in the world (Bossuyt et al. 2004; Gunawardene et al. 2007). Sri Lanka is situated at the southeastern tip of the Indian peninsula between 6^o & 9^o north of the equator and 79^o & 82^o east of the Greenwich mean line. It is a small island (65,610 km^2) with rich biological diversity. Its proximity to the equator, heterogeneity of topography and climatic conditions help to support vast diversity of both flora and fauna (Weerakoon 2012). Sri Lanka harbors a rich ichthyofaunal diversity comprising 127 species, including 61 endemics and 30 introduced species (De Silva et al. 2015; Goonatilake et al. 2020). Exotic species have been introduced to the island mainly to increase the inland fisheries, and the rest are from aquarium escapes (Goonatilake 2007). According to the distribution patterns of freshwater fish, four major zones have been identified: transition, southwestern, Mahaweli, and dry (Senanayake & Moyle 1982). Of these four zones, the Mahaweli zone and southwestern zone have the highest species diversity. This is due to the high heterogeneity of the habitats, rainfall patterns and the topography of these regions. Although the fish of the Mahaweli zone are relatively well known, it continues to produce significant discoveries despite widespread habitat destruction (Senanayake & Moyle 1982).

Taxonomic nomenclature is an important tool to identify fish species. Nomenclature of Sri Lankan freshwater fish has been extensively revised during the past two decades. For example, the genus *Rasbora* (Silva et al. 2011; Sudasinghe et al. 2020), genus *Rasboroides* (Batuwita et al. 2013; Sudasinghe et al. 2018), genus *Puntius* (Pethiyagoda et al. 2012; Sudasinghe et al. 2020, 2021), genus *Devario* (Batuwita et al. 2017; Sudasinghe et al. 2020), genus *Labeo* (Sudasinghe et al. 2018), and genus *Esomus* (Sudasinghe et al. 2019) were revised and new species have been described. Taxonomy has been always important as scientists struggle to identify species in order to understand the evolutionary relationships and complex interactions of ecosystems threatened due by anthropogenic activities. The genus *Labeo* is one such fish group that was recently revised by Sudasinghe et al. (2018).

Labeo fisheri (Jordan & Starks, 1917), commonly called Sri Lankan Mountain Labeo, is an endemic and endangered freshwater fish species (MOE 2012; Goonatilake et al. 2020). It is mainly confined to the upper reaches of the Mahaweli River, and is also recorded at a few locations of the lower reaches of the river. It has not been recorded from any other river basin in Sri Lanka (Sudasinghe et al. 2018). It is found in deep, rocky areas with rock crevices where the water current is strong with rich oxygen. It is reported that *L. fisheri* is highly sensitive to these microhabitat conditions (Pethiyagoda 1991). The alteration of river morphology as a result of different hydropower projects since the 1980s has caused habitat loss for *L. fisheri*. This has probably led to a population fragmentation. In the inland fishery sector, there is a high demand for this fish not only for its delicacy, but also for perceived aphrodisiac effect of its flesh (NARA 2017). Initially an accidental observation of a specimen of *L. fisheri* in a fisherman's catch was made in 2017 from the Victoria Reservoir. This catch was otherwise composed of *Oreochromis niloticus* (around 30 individuals) and a 9 cm stretched mesh size gill net was used by the fishermen. This accidental finding prompted us to investigate the presence of *L. fisheri* in Victoria Reservoir, with the aim of establishing a new distribution record and determining diet preference in the new habitat.

MATERIALS AND METHODS

Study Site and study period

Fieldwork was conducted from January to August 2017. The study sites were in the Victoria Reservoir between Thennekumbura (7.281 N, 80.666 E) and Anuragama (7.247 N, 80.731 E), Sri Lanka (Figure 1; Image 1). These sites are located in the intermediate zone with elevation ranging 641–764 m. The mean annual rainfall in this area is 50–200 mm.

Survey of *Labeo fisheri* in the Victoria reservoir

Fishermen were advised to collect any specimens of *L. fisheri* found in their daily catch and inform the members of our research team, who in turn collected the specimens during the study period. Specimens collected by fishermen were photographed using a Nikon (5300) digital camera and brought to the aquarium in the Department of Zoology, University of Peradeniya for further study. Caudal fin samples of each individual specimen were collected into 100% ethanol vials onsite, and stored at 4^{o}C for molecular analysis. After taking the meristic and morphometric measurements, the collected specimens were dissected and the gut was separated into 90% ethanol containers for diet analysis.

Taxonomic identification

The fish were identified using available fish guides and literature (Pethiyagoda 1991; Goonatilake 2007;

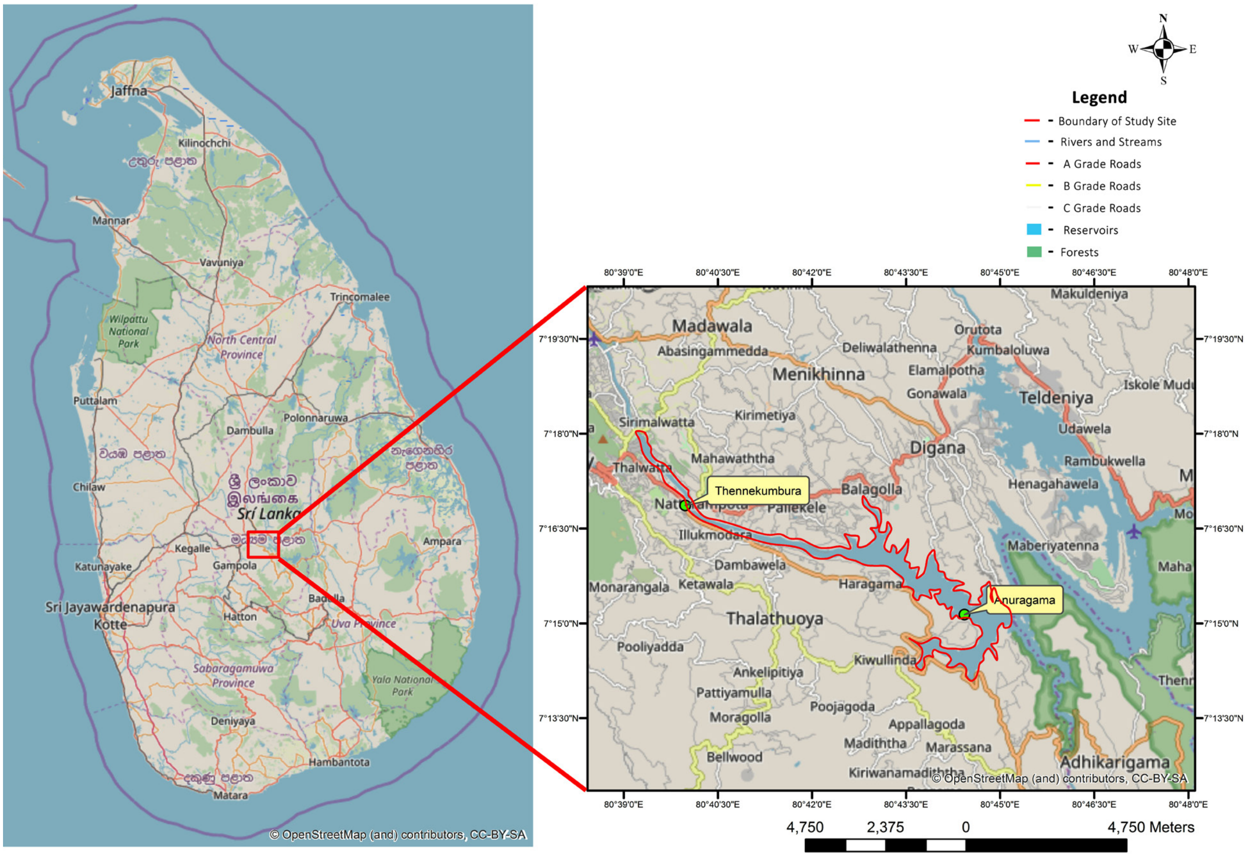

Figure 1. A Geographical map of the Victoria Reservoir where the new locality of *Labeo fisheri* was found starting from Thennekumbura to Anuragama, Sri Lanka.

Image 1. Habitat of *Labeo fisheri* in Victoria Reservoir between Thennekumbura and Anuragama, Sri Lanka. © Tithira Lakkana.

De Silva et al. 2015; Sudasinghe et al. 2018). Taxonomic analysis was done for further confirmation of the *L. fisheri* captured from Victoria Reservoir.

The morphometric measurements (total body length, standard body length, body depth, caudal peduncle depth, caudal peduncle length, pre-dorsal length, length of dorsal fin base, length of anal fin base, height of dorsal fin, height of anal fin, length of pectoral fin, length of pelvic fin, length of longest dorsal fin, spine, head length, head width, snout length, suborbital width, length of orbit to pre-opercular angle, eye diameter, upper jaw length, and gape width) of the collected fish were measured using a digital Vernier caliper. The following meristic characters (dorsal fin spines, dorsal fin rays, anal fin spines, anal fin rays, pectoral fin rays, scales along lateral line, scales above lateral line, scales below lateral line, scales before dorsal fin and scales around caudal peduncle) of the fish were also noted (Armbruster 2012). These morphometric measures were used in principal component analysis (PCA) in Minitab® 17.1.0 (©2013 Minitab Inc.) to compare the morphometric characters of individuals collected from Victoria Reservoir.

Analysis of food habit of *Labeo fisheri*

The anterior part of the gut was crushed adding distilled water and the gut content was extracted. The crushed solution was used to analyze the food habit of the fish. The gut solution was mixed well and 0.05 ml was pipetted onto a clean glass slide, covered with a cover slip and observed under a Primo-star light microscope. Ten drops (0.05 ml each) of gut solution were analyzed for each individual captured from the Victoria Reservoir. Types of plankton species present in the samples were identified using plankton guides (Fernando & Weerewardhena 2002; Yatigammana & Perera 2009) and photographed using a Zeiss Primo star inverted microscope attached with camera. The relative abundance of each plankton species was calculated as follows:

$$\text{Relative abundance} = \frac{\text{Number of individuals of a particular plankton species}}{\text{Total number of individuals of all plankton species}} \times 100\%$$

Comparisons were determined using one-way ANOVA in R version 3.6.1 (R foundation for statistical computing) using 95% confidence intervals ($\alpha = 0.05$).

RESULTS

A total of seven *Labeo fisheri* specimens were collected during this period. The specimens showed two distinct coloration patterns. Adults with olive green body coloration dorso-laterally, the color becoming lighter in the ventral region. Sub adults (<~220 mm snout length) have yellowish-brown color dorso-laterally and white ventrally. Base of the fins show dark green color and it eventually turn into the reddish-orange color towards the top. All specimens have a black blotch at the base of the caudal peduncle which is 6–7 scales long and 4–5 scales high. There is a single pair of barbels which is maxillary in position. Its mouth is ventrally positioned and has a well-developed rostral fold with thick fleshy lips. The snout was covered with white color tubercles (Image 2).

The average total body length of the seven specimens collected was 24.80 ± 4.30 cm and the average standard length was 19.70 ± 3.86 cm (Table 1). The maximum recorded standard length and the body weight of *Labeo fisheri* from Victoria reservoir was 24.00 cm and 333.00 g, respectively. The average body weight of the seven specimens was 197.69 g. Morphometric characters

Table 1. Body length and body weight of captured *Labeo fisheri* in Victoria Reservoir, Sri Lanka (N = 7).

	Average total body length / cm	Average standard length / cm	Average body weight / g
Mean	24.80	19.70	197.69
SD	4.31	3.86	107.12
SE	0.62	0.55	15.30

SD—Standard Deviation | SE—Standard Error

expressed as a ratio to the standard length are given in the Table (2). Principal component analysis (PCA) carried out for the Victoria population revealed that this population share the same morphometric characters compared to the *L. fisheri* populations in some other Mahaweli tributaries such as Moragolla and Gatambe (Figure 2).

The dorsal fin comprised of two simple rays and 10–12 branched rays. The anal fin had two simple rays and five branched rays. The pectoral fin comprised of one simple ray and 15–18 branched rays. Ventral fins composed of one simple and eight branched rays. The lateral line is complete with 38–39 lateral line scales. There are 16–18 scales along the pre dorsal region. The formula for meristic characters could be given as; D ii/10-12; A ii/5; P i/15-18; V i/8; LL 38-39; L. lat 7 ½ / 5½.

According to the food habit analysis, a total of 21 phytoplankton species belonging to five classes were identified in the gut contents of *Labeo fisheri* recorded from the Victoria Reservoir. Bacillariophyceae (diatoms) and Cyanophyceae (cyanobacteria) were the dominant classes, although the preference for species each differed ($F = 3.01$; $p < 0.05$). The most preferred were *Aulacoseira* sp., followed by *Chlorococcus* sp. and *Staurastrum cingulum*. It is also found that the diatoms *Closterium* sp., *Cyclotella* sp., *Lyngbya* sp., *Merismopedia* sp., *Nostoc* sp., *Oscillatoria* sp., *Staurastrum megacanthum*, and *Tabellaria* sp. were least preferred (Image 3; Figure 3).

DISCUSSION

Labeo fisheri has been exclusively recorded from Mahaweli river basin and mostly in the upper reaches of the river. Highest recorded elevation is Ulapane-Gampola at 562 m and lowest is Angammedilla-Polonnaruwa at 80 m (NARA 2017; Sudasinghe et al. 2018). It had been earlier recorded along the Mahaweli River (upstream of the Victoria Reservoir) at Ulapane-Gampola, Getambe, Lewella, Polgolla, and Digana. They were also earlier recorded downstream of the Victoria reservoir at Randenigala, Minipe anicut, and Badulu Oya (Sudasinghe

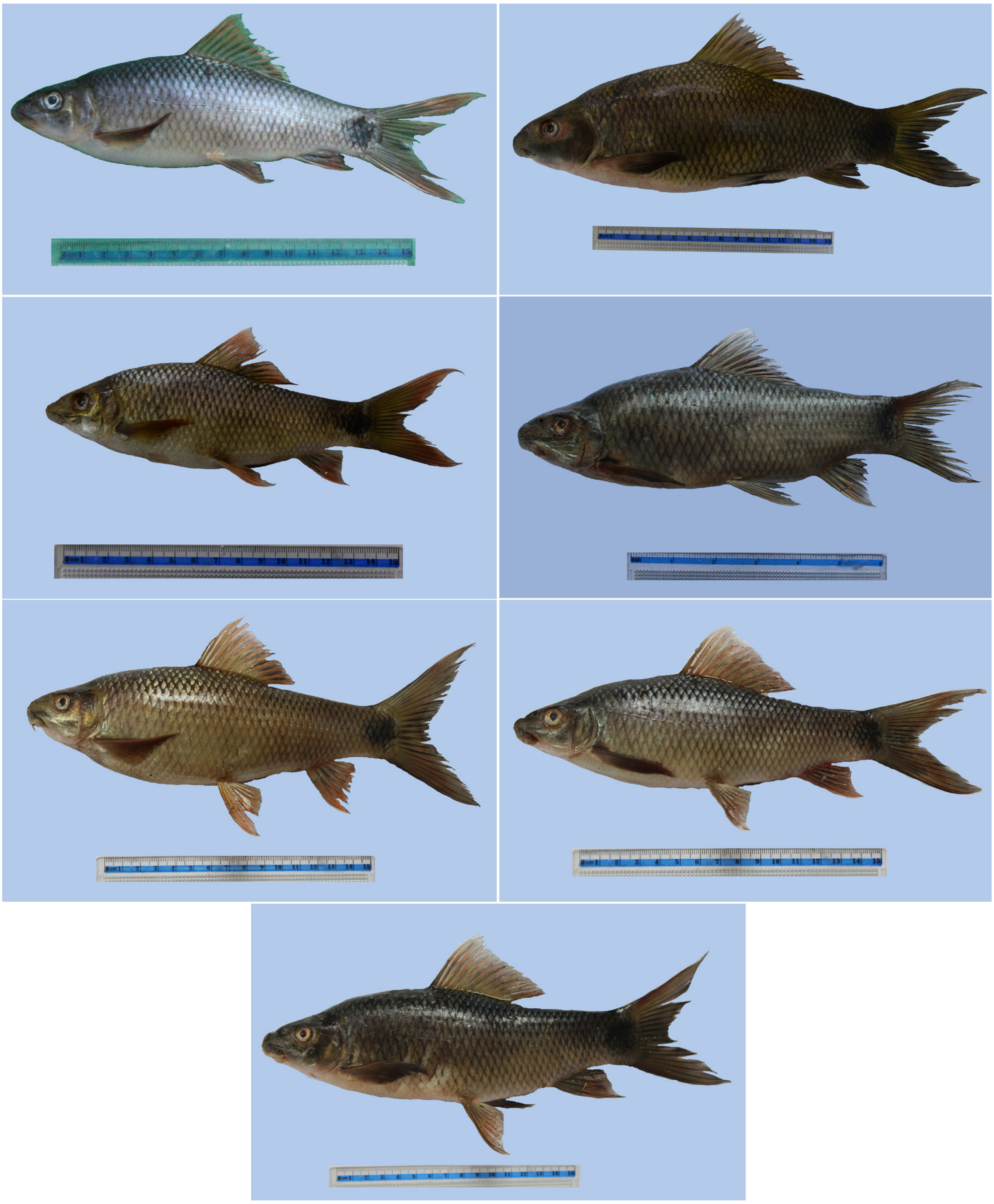

Image 2. Seven captured specimens of *Labeo fisheri* in the Victoria Reservoir, Sri Lanka show mainly two colorations. Adults have olive green dark color body on dorso-laterally and sub-adults have yellowish brown dorso-laterally. © Dinelka Thilakarathne & Gayan Hirimuthugoda.

et al. 2018). *Labeo fisheri* was also recorded in the Mahaweli tributaries at Heen Ganga, Thelgamu Oya, and Amban Ganga (NARA 2017; Sudasinghe et al. 2018). *Labeo fisheri* was last recorded in 1952 at Lewella (type locality) and in 1991 at locations around Victoria Reservoir such as Randenigala, Digana, and Polgolla. In this study, for the first time we confirm a presence of a well-established population of *L. fisheri* in the Victoria Reservoir.

In the past *L. fisheri* was found in lentic habitat conditions. This is a strong indication that *L. fisheri* can change habitat from lotic to lentic, and introduction of exotic species such as Tilapia and tank cleaners may have played a role. *L. fisheri* was earlier recorded in deep rapids among large rock crevices and boulders, whereas juveniles and sub-adults were common in shallow regions with a moderate, non-turbulent flow (Sudasinghe et al. 2018). Specimens in this study were collected from the middle of the reservoir in stagnant waters, and the depth they were entangled in the net is around 10 m. It is possible that there are more recordings of *L. fisheri* from the Victoria Reservoir, because we only collected specimens from three landing sites out of a total of ten around the Reservoir. Therefore, more research work has to be done to confirm the presence of a viable population in the reservoir. Since fisheries in the reservoir are being monitored by National Aquaculture Development Authority (NAQDA), Sri Lanka, they are able to collect such extensive fisheries data.

Gut content analysis is the best method to get a proper understanding of fish feeding habits. Previous studies have shown that *L. fisheri* scrapes submerged rocks using thick and horny lips in the ventral mouth. Earlier Pethiyagoda (1991) reported that they only feed on algae. It is believed that *L. fisheri* in Ulapane and Gatambe feed on an aquatic plant belonging to the family Podostemaceae (NARA 2017). However, according to our findings they mainly feed on diatoms and cyanobacteria. This may be due to inadequate submerged vegetation and algae in the Victoria Reservoir.

Water entering to the Victoria reservoir during the rainy season is highly turbid due to wash off from upstream areas. At the reservoir where water is stagnant, soil particles start to settle at the bottom. Sedimentation increases and reduces the production of algae and macrophytes due to lack of oxygen in the bottom of the reservoir. Sedimentation also increases eutrophication of the reservoir. Both these factors affect the transparency of the water and limit sunlight penetration to the bottom, which can damage the food source of *L. fisheri*.

Many people use Mahaweli River for washing, bathing and dumping garbage. All these pollutants are collected and concentrated at the reservoir. Thus water pollution is observable in the reservoir. The gut content analysis of *L. fisheri* also confirmed that this reservoir was highly polluted because *Aulacoseira* sp. and some cyanobacteria were the most prominent phytoplankton species in the gut of the *L. fisheri*. *Aulacoseira* sp., and *Navicula* sp. often attain high biomass in eutrophic rivers and reservoirs (Akinyemi et al. 2007). Thus, it is a useful indicator species

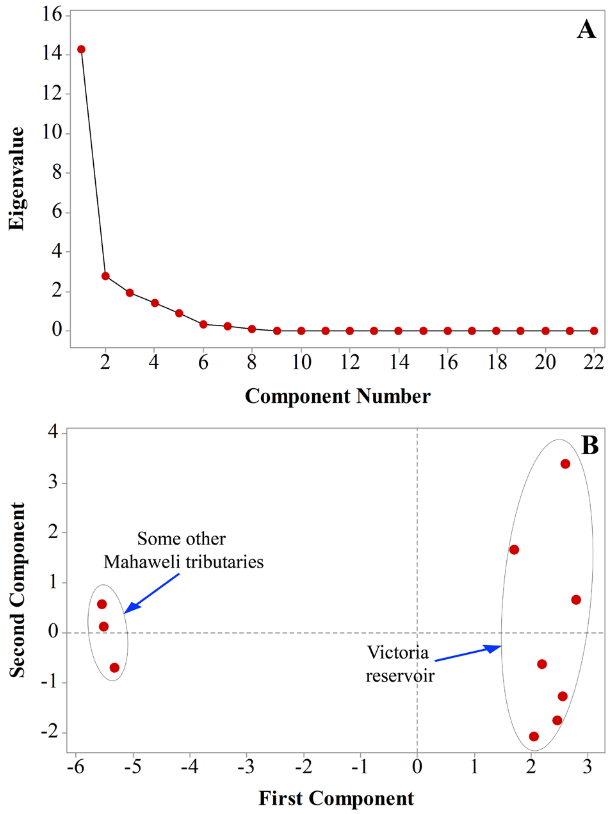

Figure 2. PCA analysis of morphometric characters of seven specimens of *Labeo fisheri* obtained from Victoria reservoir, Sri Lanka: A—Scree plot | B—Score plot.

for trophic conditions (Akinyemi et al. 2007). So, this is a clear indication that water in the Victoria Reservoir is polluted and it may have adverse effects on the native species living there. Some of the areas of Victoria Reservoir have been used as dumping sites for garbage which also contributes to the water pollution of the reservoir.

Sometimes illegal small-meshed gill nets were used to capture fish, especially at the shallow areas and at mouths of tributaries. These are potential habitats of juveniles and sub adults of *L. fisheri* though they migrate up streams for spawning and they are subjected to be caught. This new population is facing the direct threat of inland fisheries. Effective conservation measures are doubtful since fisheries are well established in the Victoria reservoir and the fishing gear is size specific but, not species specific. During the dry season from February to September, the reservoir water level goes down and they are highly vulnerable to be captured by the gill nets.

Victoria Reservoir has several invasive species of fish such as *Pterygoplichthys disjunctivus* (tank cleaner), potentially invasive *Oreochromis mossambicus* and *Oreochromis niloticus*. *Pterygoplichthys* sp. was initially an aquarium escapee, which later became well-established in

Table 2. Morphometric characteristics of *Labeo fisheri* in Victoria Reservoir, Sri Lanka (N = 7).

	Ratio to standard length																		
	Body depth	Caudal peduncle depth	Caudal peduncle length	Pre-dorsal length	Length of dorsal base	Length of anal base	Height of dorsal fin	Height of anal fin	Length of pectoral fin	Length of pelvic fin	Length of longest dorsal spine	Head length	Head width	Snout length	Suborbital width	Length of orbit to pre-opercula angle	Eye diameter	Upper jaw length	Gape width
Mean	0.30	0.14	0.16	0.44	0.20	0.08	0.19	0.16	0.23	0.19	0.11	0.23	0.16	0.09	0.05	0.09	0.09	0.06	0.14
SD	0.02	0.01	0.02	0.02	0.01	0.01	0.02	0.02	0.01	0.01	0.03	0.02	0.01	0.01	0.01	0.01	0.13	0.01	0.01
SE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00

SD—Standard deviation of sample | SE—Standard error of sample.

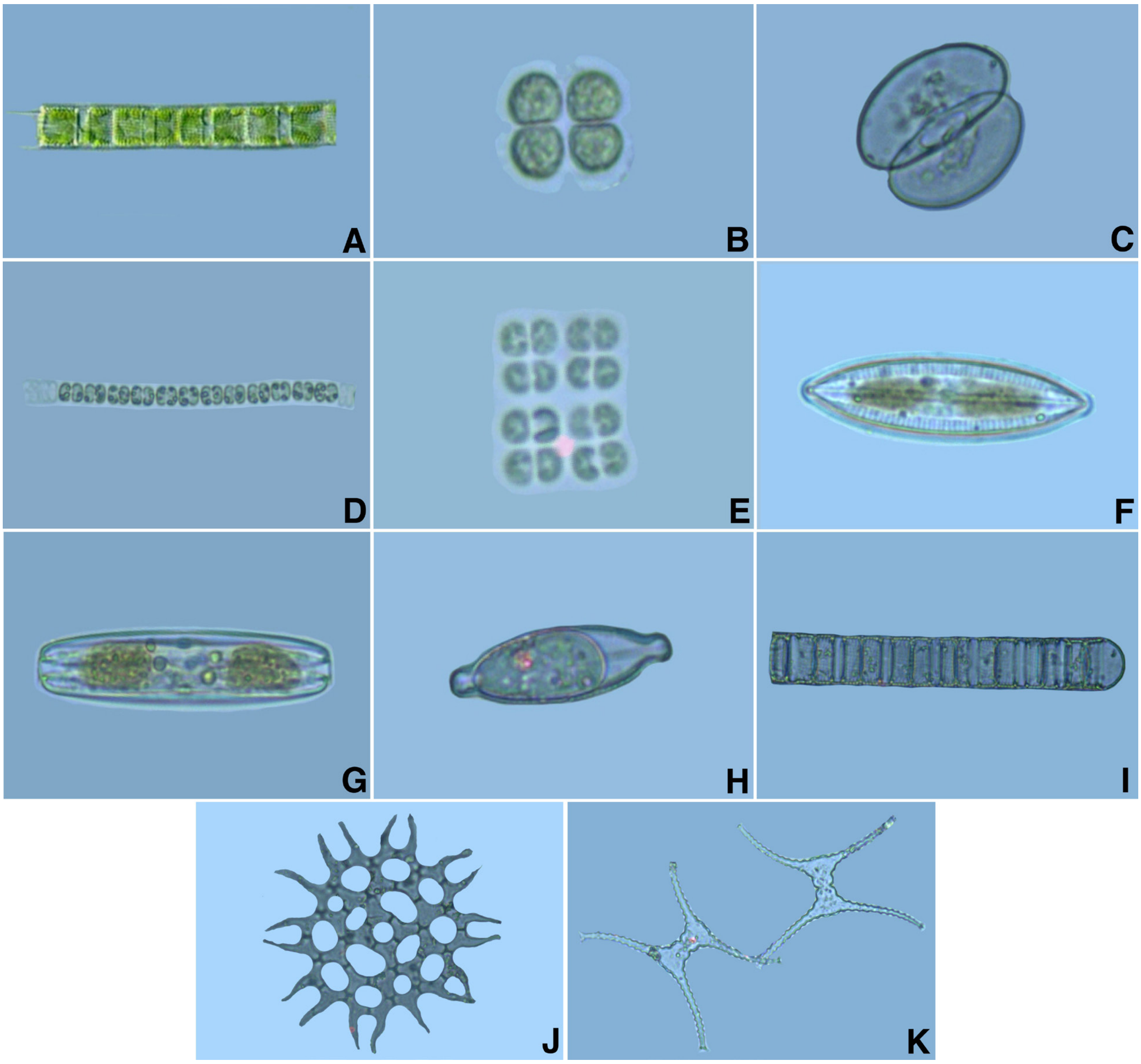

Image 3. Gut contents of *Labeo fisheri* in the Victoria Reservoir, Sri Lanka: A—*Aulacoseira* sp. | B—*Chlorococcus* sp. | C—*Cosmarium* sp. | D—*Lyngbya* sp. | E—*Merismopedia* sp. | F—*Navicula lanceolate* | G—*Navicula* sp. | H—*Navicula* sp. | I—*Oscillatoria* sp. | J—*Pediastrum duplex* | K—*Staurastrum cingulum*. © Dinelka Thilakarathne & Nayanaka Wickramasinghe.

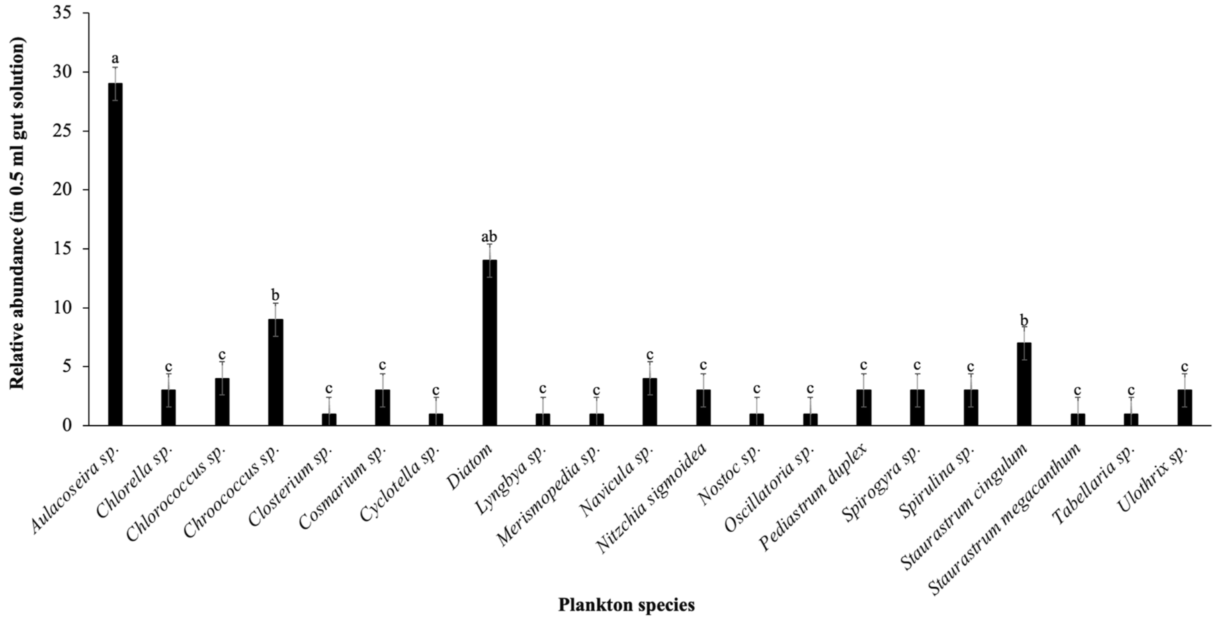

Figure 3. Relative abundance of phytoplankton in the gut contents of *Labeo fisheri* recorded from Victoria Reservoir, Sri Lanka. (a, b and c denote the significant different among relative abundance of the plankton species; $F = 3.01$; $p < 0.05$).

the river and reservoir systems of the country. They have a high rate of reproduction and high rate of survival during harsh environmental conditions. *Pterygoplichthys* sp. is piscivorous and feeds on the native species, especially fry, fingerling and juvenile stages (Bambaradeniya et al. 1999). *Oreochromis mossambicus* and *Oreochromis niloticus* were introduced in to reservoirs as food fish and to encourage a commercial capture fishery (De Silva 1988). They are competitive species for the food and space in the reservoir. Due to their high natality rates, survival rate and voracious feeding habit, the native fish populations declined. In the dry zone, *Oreochromis mossambicus* is considered responsible for the extinction of *L. lankae*, due to overlapped habitats and niches in the dry zone reservoirs (Pethiyagoda 2006). In the same way *Oreochromis* sp. might pose risk for the extinction of *Labeo fisheri* as well due to the niche overlapping. Unlike the *Oreochromis* sp., *L. fisheri* cannot adapt well to the new habitats. They have to compete for their usual food and other resources in the reservoir. That may cause the population reduction of *Labeo fisheri* from the reservoir in the future. Other than the *L. fisheri*, *L. rohita* was recorded from the Victoria reservoir and *Labeo heladiva* was recorded from the Rantambe reservoir downstream of the Mahaweli River. This indicates that the some of the species in the genus *Labeo* can adapt to the lentic conditions.

Most of the endemic and threatened freshwater fish are found outside protected areas with high anthropogenic activities. Therefore, they need to be protected by protecting habitats (their catchment areas and the quality of water). Any type of development that cause harm to these habitats (such as mini hydro projects) needs to be clearly assessed. Species oriented and habitat-oriented conservation programs should be established at least for the endangered species. When the species are located outside of the protected areas, the local communities must be made aware and have to be involved in conservation programs. Such community awareness program has been successfully implemented for *Pethia bandula* (MOE 2012; Goonatilake et al. 2020). Ex situ breeding programs, translocation, reintroduction should be established with the aim of increasing the wild population. Some of these translocation programs have been highly successful while others have failed (Goonatilake 2012; Sudasinghe et al. 2018). Therefore, we need to find proper conservation measures and implement early to help safeguard the *Labeo fisheri* in the Victoria Reservoir.

CONCLUSIONS

Endemic and endangered *Labeo fisheri* is recorded in a new locality (Victoria Reservoir) where it has not been previously recorded and this appears to be a new habitat. It is interesting that this fish was able to adapt for stagnant water apart from its original habitat (fast flowing waters).

Not only that, their food habit is slightly changed from algae to diatoms and cyanobacteria due to the availability in this reservoir. However, more research work has to be done to ensure the existence of a viable population in the reservoir and since fisheries in the reservoir is being monitored by National Aquaculture Development Authority (NAQDA), they are in a better position to collect such extensive fisheries data. Water pollution and direct exposure to the fisheries poses greatest threat to its survival. Community based conservation efforts should be taken if this species needs to be conserved at this locality.

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