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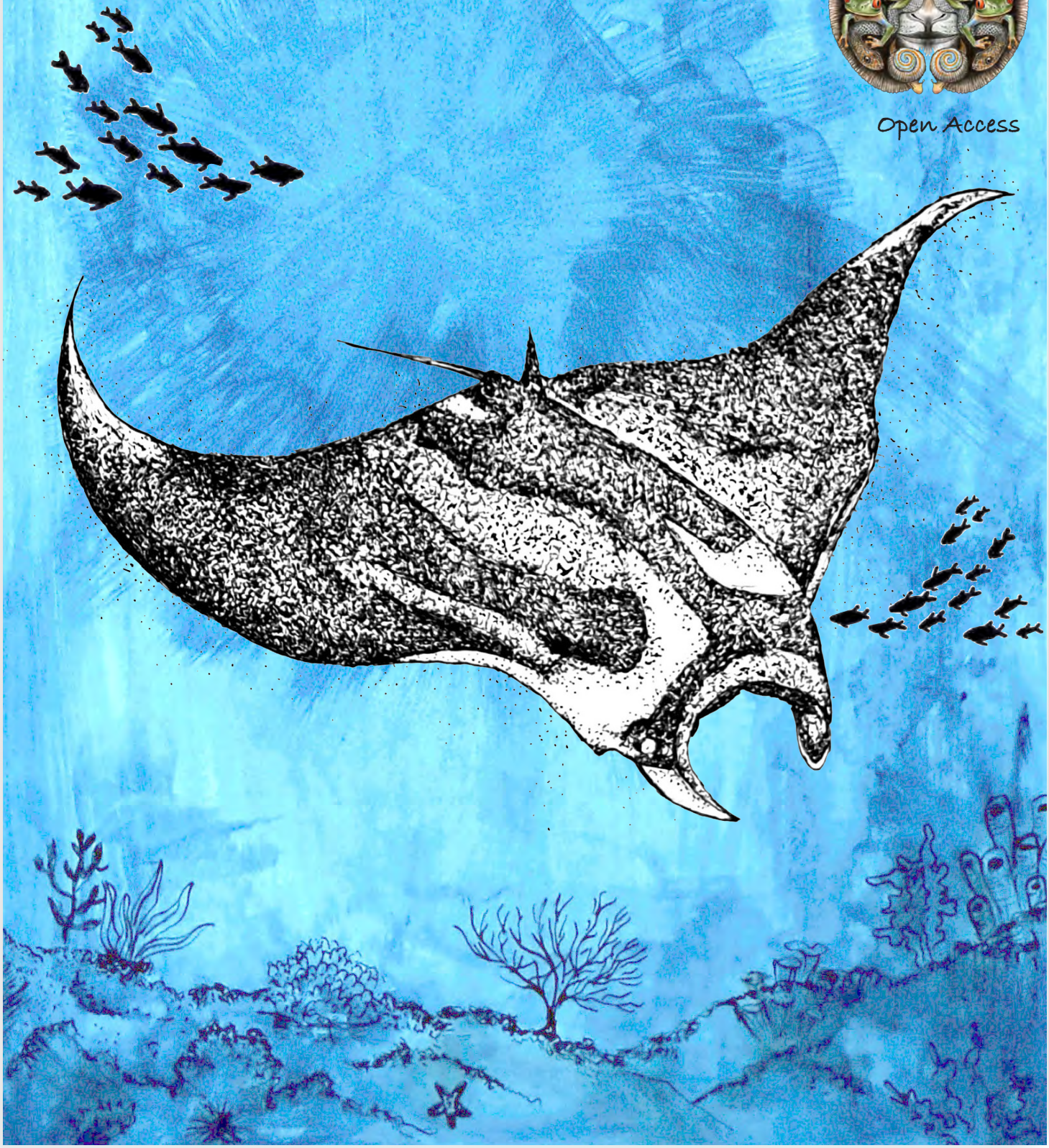
Journal of Threatened Taxa

10.11609/jott.2023.15.5.23139-23282
www.threatenedtaxa.org

26 May 2023 (Online & Print)
15(5): 23139-23282
ISSN 0974-7907 (Online)
ISSN 0974-7893 (Print)

Open Access



ISSN 0974-7907 (Online); ISSN 0974-7893 (Print)

Publisher
Wildlife Information Liaison Development Society
www.wild.zooreach.org

Host
Zoo Outreach Organization
www.zooreach.org

43/2 Varadarajulu Nagar, 5th Street West, Ganapathy, Coimbatore, Tamil Nadu 641006, India
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Cover: Giant Oceanic Manta Ray *Mobula birostris* in ink on acrylic wash by Elakshi Mahika Molur adapted from scientific illustration by Roger Hall.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 May 2023 | 15(5): 23164–23189

ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)

https://doi.org/10.11609/jott.7980.15.5.23164-23189

#7980 | Received 18 April 2022 | Final received 03 April 2023 | Finally accepted 17 April 2023

OPEN ACCESS

ARTICLE

Diversity, distribution, and conservation status of fish species in Kallar Stream, Achankovil River, Western Ghats of Kerala, India

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Abstract: The current study presents the findings of fish species inventories conducted at 12 locations in 'Kallar', the perennial tributary of the undammed Achankovil River that flows through the Achankovil Reserve Forest in Kerala State. A new checklist of ichthyofauna is prepared, by adding the updated scientific names, which comprises 35 species from 27 genera, 13 families, and eight orders. In order of abundance, *Opsarius bakeri*, *Salmostoma boopis*, and *Garra surendranathanii* were the most prevalent species in the Kallar tributary. Eight of the total species documented are listed as threatened on IUCN Red List. The study reports the presence of a poorly known smiliogastrin cyprinid, *Dawkinsia lepida* for the first time in the Achankovil River as well as the range expansion of the threatened catfish, *Batasio travancoria,* and the Malabar Spiny Eel *Macrognathus guentheri* to the Kallar tributary. The study also reports a species of *Balitora* from Kallar, distinct from its congeners in several morphometric and meristic characteristics. The absence of any non-native fish species in the study area revealed the pristine nature of the stream habitat. A comparison of diversity indices with the available pre-flood study revealed that the fish species composition in Kallar stream has not altered as a result of the 2018 catastrophic flood. The main existing threat is the practice of destructive fishing at high levels by local communities adjacent to but outside the forest area during the dry season by damming the streamlets and then applying plant-based piscicides. It is recommended that fishing be banned during dry season because this is the time of year when the majority of the upstream fishes breed. The existing environment and fisheries acts should also be strictly enforced. For the sake of future conservation, the competent authorities should see to it that the last remaining natural forest cover in the Kanayar and Kallar ranges are safeguarded from being converted to forest plantations.

Keywords: Fish species inventory, flood, forest cover, habitat heterogeneity, lepida barb, non-native fish, rheophily, river linking.

Editor: Neelesh Dahanukar, Shiv Nadar Institution of Eminence, Delhi-NCR, India. **Date of publication:** 26 May 2023 (online & print)

Citation: Vishnu, A.S., M. Lal, J.C. Tharian, M.P. Prabhakaran & P.H.A. Ali (2023). Diversity, distribution, and conservation status of fish species in Kallar Stream, Achankovil River, Western Ghats of Kerala, India. *Journal of Threatened Taxa* 15(5): 23164–23189. https://doi.org/10.11609/jott.7980.15.5.23164-23189

Funding: There is no specific fund pertaining to this manuscript.

Competing interests: The authors declare no competing interests.

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Author contributions: VA— field sampling, collection of data, analysis and preparation of manuscript; ML— collection of data, photography, analysis and preparation of manuscript; JT- field sampling, photography and preparation of manuscript; PM- statistical analysis of data and interpretation; AA- field sampling, preparation of manuscript, reviewing and editing.

Acknowledgements: The authors are extremely thankful to the principal chief conservator of forests, Kerala Forests and Wildlife Department for providing permission to conduct scientific research in Achankovil Reserve Forests. The authors also thank the head of the department, Department of Fisheries Resource Management and the dean, Faculty of Fisheries Science, Kerala University of Fisheries and Ocean Studies for providing the facilities.

INTRODUCTION

Documenting fish faunal diversity at periodic intervals, even within fluviatile systems inside the protected forests facilitates informing conservation status, designing specific management strategies, assessing the impacts of recent or ongoing natural hazards like flash floods and landslides, and forewarning the effects of proposed river interlinking projects and dams. Achankovil forest division, part of the Agathyamala Biosphere Reserve in Western Ghats, India has been recognised as a site that requires immediate attention in order to set up mechanism for inclusion into the protected area network by the Critical Ecosystem Partnership Fund Program (CEPF 2007). Although home to large number of native Western Ghats species, this area suffers considerable levels of forest degradation and conversion (Vijayan et al. 2021). As part of the Government of India's mega project-India Interlinking of Rivers (IIR), the Pamba-Achankovil-Vaippar water transfer link initiative, covering a portion of the forest area is proposed (NWDA 1995; Rani et al. 2016). Although, multiple researches on fish diversity of the Achankovil River have been undertaken, the main tributary, the Kallar, where the project proposed to be implemented, lacks a thorough account on the diversity and micro-level distribution of fish species.

Previous studies on the fish diversity of the Achankovil River, have either focused on the mid and downstream sections or were fractional surveys (Swapna 2009; Johnson & Arunachalam 2009). Species inventory studies pertaining to the upstream areas of Achankovil River have also either concentrated on the main Achankovil stream (Varghese 1994), or without covering all the streamlets of Kallar (Radhakrishnan 2006; Baby et al. 2011; Sabu el al. 2013), the major and the only perennial tributary inside the Achankovil Reserve Forest (ARF). Moreover, no research on the diversity of fish species has been done in the Achankovil River's headwaters following the devastating flood of 2018 to determine the effects. The current study aims to analyse the diversity and distribution pattern of ichthyofauna in Kallar Stream and prepare an updated checklist (by adding the revised scientific names) and photographic atlas, in order to address future conservation initiatives. The study also seeks to determine whether the devastating flood of 2018 had any effects on the diversity of fish species.

MATERIALS AND METHODS

Study Area

Achankovil River, originates from two Western Ghats hill ranges: Kottavasal (by streams from Pasukkidai Mettu, Rishi Malai, and Ramakkal Teri) at an elevation of 700 m in Kollam District and Devarmalai at an elevation of +1,200 m in Pathanamthitta District (Image I). The rocky, undulating, and extremely rough Achankovil forest area is located on the western face of the Western Ghats (Hosagoudar et al. 2010). Two distinct and prominent valleys are found within the study area: (1) Kallar and (2) Achankovil valleys. The tract's southernmost portion is drained by the Achankovil Stream, while its northernmost portion is drained by the Kallar Stream, which eventually unites to form the Achankovil River at Mukkadamuzhi. The Kallar Stream is the principal tributary of the Achankovil River; the name is derived from the rocky nature of its bed (Pillai & Muhammad 2007). After its origin at Devarmalai, Kallar flows for 30 km in east-west direction before taking a southern turn to join the Achankovil Stream. During summer, the Achankovil tributary, which flows from Kumbhavurutty and Manalar is left with no water, while the perennial Kallar tributary remains to be the only stream to feed water to the Achankovil River. Also, the Kallar and its associated streams originate from a greater elevation compared to the Achankovil tributary. Considering all these above factors, the perennial Kallar tributary flowing through the Achankovil Reserve Forest (ARF) was selected for investigating the ichthyofaunal diversity. Sites for species inventory and diversity were chosen to cover the maximum streamlets adjoining the mainstream as well as stream mesohabitats associated with it. Accordingly, 12 sites (Table 1; Image 1) were fixed in the mainstream and streamlets; commencing from Mukkadamuzhi (54 m), the lower elevation site to Kattikkuzhi (331 m), the higher elevation site. Among the sites, Mangala, Pulikkayam, Aramba muzhi, and Mukkadamuzhi were the sites at the confluence points of streamlets. The maps for denoting the sites for species inventory were prepared using QGIS Version 3.24 (Image 1).

Fish Species Inventory

Species inventory was carried out through rapid sampling following Abd et al. (2009) by effectively deploying possible fishing contrivances and covering possible mesohabitats in order to minimize the costs and logistics for multiple sampling over a lengthy period. The sampling was resorted to one time at each site;

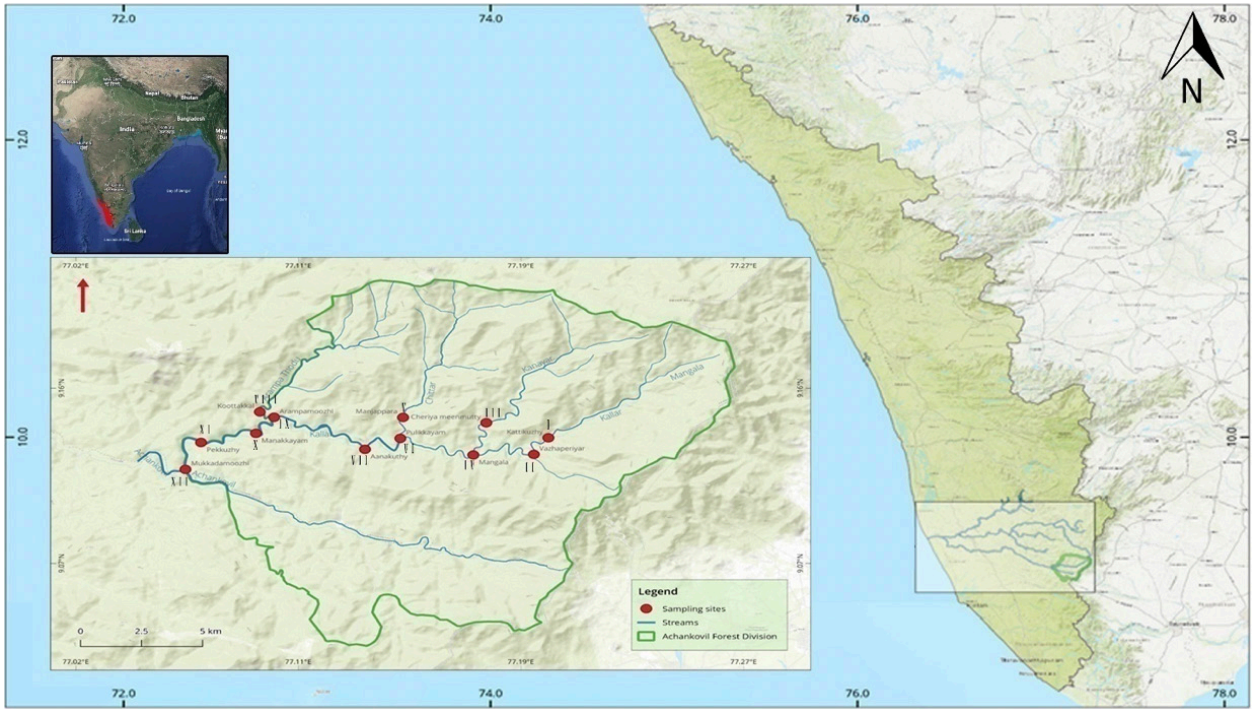


Image 1. Sampling sites in Kallar Stream inside Achankovil Reserve Forest, Kerala.

sites I to VII were covered in January and sites VIII to XII were covered in April 2019, due to logistical constraints. At each site, experimental fishing operations were performed over a distance of 100–150 m using a diverse array of fishing gears such as cast net (length 3 m, mesh size 2.5 cm, nylon webbing, lead weight 4k g), seine net (length 25 m, depth 1.63 m, mesh size 1 cm, nylon webbing, plastic floats, and lead sinkers), mosquito net of standard size, scoop net (60 x 30 cm with stainless steel frame and nylon/mosquito netting material) and hook & lines alone or in combination. Immediately after capture, fishes were counted and identified to species level following Jayaram (1999) and taxon-specific revisions (Jayaram 2006; Silva et al. 2010; Knight et al. 2015; Katwate et al. 2020). The species names and their conservation status adhere to Eschmeyer's 'Catalogue of Fishes' (Fricke et al. 2022) and IUCN (2021), respectively. Individuals of all species were photographed in the field while still alive. After being anaesthetized with clove oil, representative specimens were first fixed in 10% neutral buffered formalin and then moved to 70% ethanol for long-term storage. Specimens of each species are catalogued with voucher numbers for accession in the museum collection of the Kerala University of Fisheries and Ocean Studies (KUFOS), Kochi. Single specimen of each species was taken for preservation and genetic analysis and rest of the individuals were released back into the stream. The vernacular names of fishes were obtained from tribal communities and staff of the forest department. Identification and terminology of stream mesohabitats, follow Armantrout (1998).

Diversity Indices

Community structure analysis indices such as Margalef richness (d) Pielou's evenness (J'), Shannon diversity (H'log2), and Simpson dominance (λ), for the 12 sites were evaluated using Primer 6, following Clarke & Gorley (2006). Correlation between altitude of sampling stations and species diversity as well as richness was analysed using simple linear regression model.

RESULTS

A total of 1,808 individual fish specimens of 35 species belonging to 27 genera, 13 families, and eight orders were obtained during the study period from the Kallar Stream (Table 2 & Images 2–13 (1–35)). Of these, 27 (77%) fish species are found to be endemic to the Western Ghats, including eight species strictly restricted to streams and rivers of Kerala (Table 2). Three species reported, viz., *Rasbora dandia*, *Pseudetroplus maculatus*, and *Aplocheilus lineatus* are endemic to the brackish and freshwaters of India and Sri Lanka. *Opsarius bakeri*

Table 1. Geomorphological and habitat features of samling stations in Kallar tributary of Achankovil River, Kerala.

	Sampling station number, name, & coordinates	Elevation (m)	Stream width (m)	Mesohabitat type	Substrate and cover type
1	Site I- Kattikuzhi 9.1361 N 77.2007 E	331	29	Deep pools, cascades	Bedrock, boulders, and cobbles
2	Site II- Vazhaperiyar 9.1267 N 77.1915 E	275	28	intermittent slow to fast flowing riffles and pool- riffles	Cobble, pebble, gravel and sand with intermittent patches of shrubs in the main stream channel
3	Site III- Cheriya Minmutty 9.1421 N 77.1773 E	306	18	Cascades, pool- riffles	Boulders, cobbles and pebbles with thick canopy cover
4	Site IV- Mangala 9.1262 N 77.1694 E	214	30	Cascades, run, glides, slow and fast flowing riffles, deep pools	Cobbles, pebbles and gravel in the fast flowing habitats and silt and sand with leaf litter in the pool habitats. Canopy cover in pool areas and shrub patches in the fast flowing habitats.
5	Site V- Chittar Manjappara 9.1429 N 77.1469 E	214	25	Slow flowing riffle	Cobbles and pebbles as substrates with leaf litter deposition along the banks
6	Site VI- Pulikkayam 9.1363 N 77.1469 E	169	44	Wide streamlet with shallow to moderately deep pools	Silt, sand and silt covered bedrocks and boulders as substrates with large wooden logs across the stream and leaf litter along the shoreline. Luxuriant canopy cover along both banks
7	Site VII – Anakuthi 9.1302 N 77.1324 E	158	36	Moderate to deep pool habitats	Silt and sand as substrates with leaf litter deposition
8	Site VIII - Koottakkal 9.1488 N 77.092 E	141	26	Pool – riffle, run	Cobbles and pebbles
9	Site IX - Aramba muzhi 9.1444 N 77.0975 E	131	58	Glide, run, Pool- riffle, cascades, shallow-moderately deep pools	Bedrock, cobbles and boulders in the main stream course and silt plus sand along the banks and pools
10	Site X - Manakkayam 9.1366 N 77.0914 E	114	35	Rapids and fast flowing riffles	Bedrock, boulders and cobbles
11	Site XI – Pekkuzhi 9.1328 N 77.0711 E	93	38	Cascades, pool- riffles, glides and run	Bedrock, boulders and cobbles
12	Site XII – Mukkadamuzhi 9.1196 N 77.0645 E	54	76	Moderate to deep pool with extensive shallow marginal area at both the banks	sandy and silty substrata and leaf litters

was found to be the most common species found in almost all the sites, whereas *Channa gachua* (1), *Ompok malabaricus* (1), and *Systomus sarana* (3) were the rare species obtained from single sites.

Taxon wise, order Cypriniformes (60 %) dominated in Kallar Stream with 21 species in 15 genera, seven subfamilies and four families; followed by Siluriformes (14.2%) with five species in four genera and three families (Figure 1). Among Cypriniformes, family Cyprinidae dominated with 11 species (53%) followed by Danionidae with six species (29%) and Balitoridae with four species (19%). At subfamilial level, Smiliogastrinae dominated with seven species (41%) followed by Chedrinae (17%), Danioninae (12%), Labeoninae (12%), Torinae (12%), and Rasborinae (6%).

Number-wise, Cypriniformes constituted 90% of the total catch followed by Siluriformes (6.5%), Cyprinodontiformes (1.1%) and the rest by other five orders. Among Cypriniformes, family Danionidae contributed the most (42.6%) and out of which *Opsarius bakeri* marked the highest abundance with 287 individuals followed by *Salmostoma boopis* (254), *Opsarius gatensis* (89), *Devario malabaricus* (60), *Rasbora dandia* (48), and *Laubuka fasciata* (33). Family Cyprinidae represented 40% of the fish sampled, dominated by *Garra surendranathanii* (150), *G. mullya* (117), *Dawkinsia denisonii* (106), and *D. lepida* (103).

Community structure analysis indices for the 12 sampling sites (Table 3) revealed that site VI has the highest species richness (d) value of 4.13, followed by Site XII having a value of 4.07. Pielou's evenness index research revealed that Site III had the maximal value (0.96), followed by Sites V and X, but Site VII had the lowest value of 0.67 due to the uneven distribution of

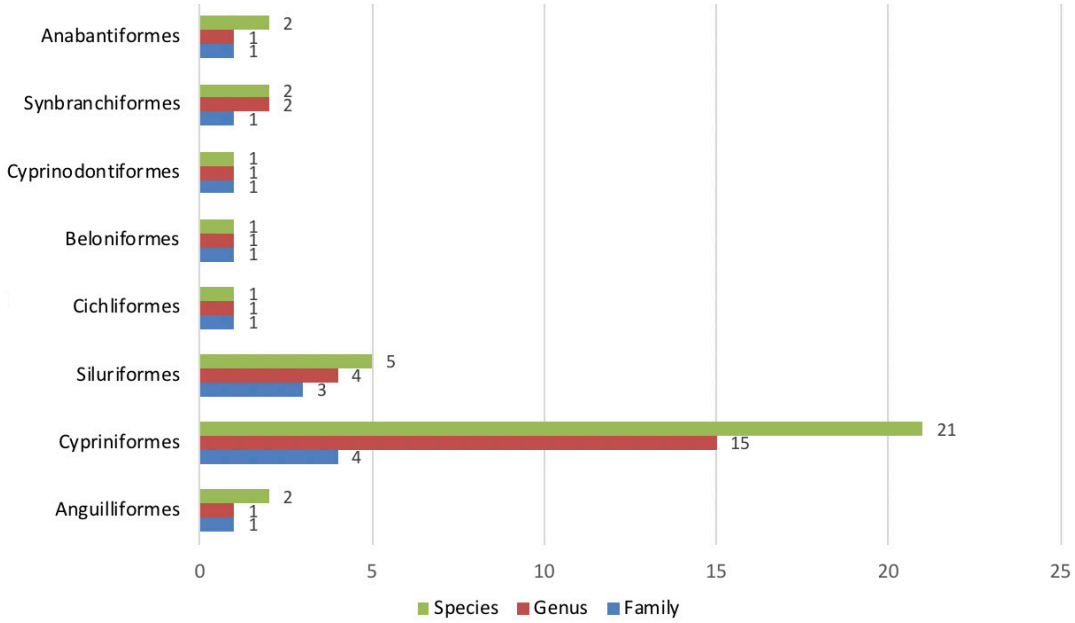


Figure 1. Taxon-wise fish species diversity in Kallar Stream.

nine species. The highest species diversity (H'(log)2) was recorded at Site XI, followed by Site VI, and Site IX, whereas Site I had the lowest value. Site VII had the highest Simpson dominance index of value 0.31, followed by Site I (0.30), and the lowest for Site XI. The results of the regression analysis (Figure 4a, b) revealed significant relationships with diversity and altitude ($r = 0.59$, $t = 2.32$, $p = 0.0427$) and species richness and altitude ($r = 0.62$, $t = 2.5$, $p < 0.0317$).

Comparing the diversity indices with the previous study by Sabu et al. (2013) revealed that diversity, as far as Shannon index is considered, has increased in the current study except at two sites. Mean Shannon diversity index value of 3.12 ±0.61 recorded during the present study showed an increasing trend in comparison (2.43±0.69) with Sabu et al. (2013). Though the maximum number of species and individuals were collected from Arampamoozhi (Site IX) the diversity values were low due to the dominance of *Salmostoma boopis* (n = 138) and *Dawkinsia denisonii* (n = 60). A maximum Shannon diversity index of 3.79 was recorded in Site XI, which belongs to the lower elevation zone. Whereas, rest of the higher diverse areas follow the river confluence points such as Site VI (3.76) and Site IX (3.70).

Evenness has increased in the current study except for two locations in comparison with the previous report by Sabu et al. (2013). Overall Margalef species richness seems to decline along the Kallar stream when comparing with the previous study (Sabu et al. 2013) and is prominent in two sites such as Site VII and Site X.

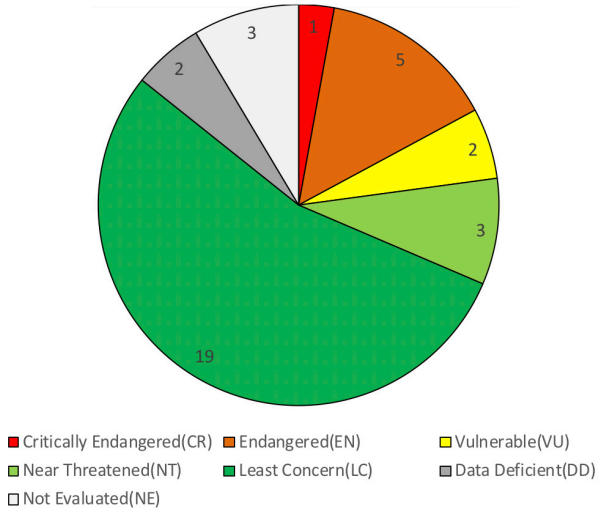


Figure 2. Conservation status of fish species in Kallar Stream (number).

Simpson's dominance index showed that the dominance of certain species has increased in the current study especially in Site VII (Anakuthy) showing a higher value (λ = 0.31) when compared to previous records (Sabu et al. 2013). The higher dominance value of Site VII is mainly due to the higher number of *Salmostoma boopis* (n = 48) in the specified area.

Of the 35 species encountered, eight species (22.9 %) belong to IUCN threatened categories (Table 2; Figure 2) with one Critically Endangered (CR) (*Mesonoemacheilus herrei*); five Endangered (EN) (*Dawkinsia chalakudiensis*,

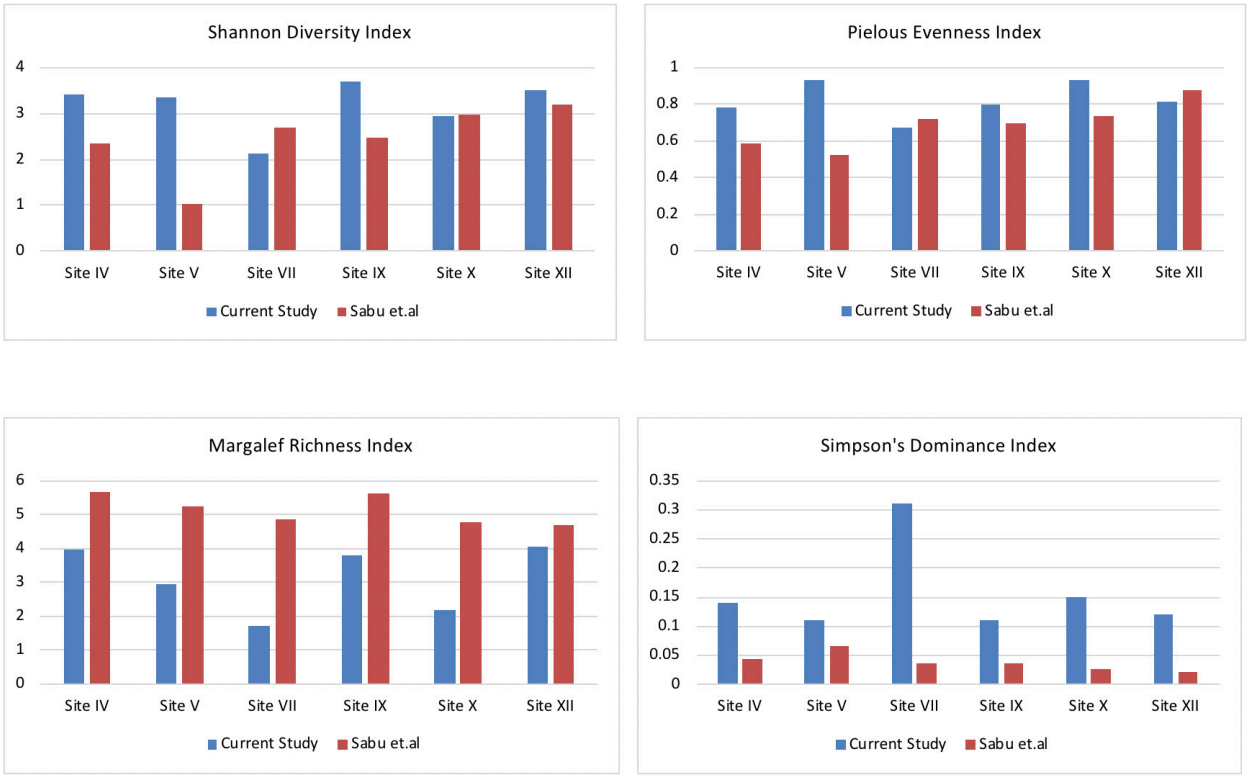


Figure 3. Comparison of diversity indices with the previous study (Sabu et al. 2013) in Kallar Stream.

D. denisonii, Garra surendranathani, Tor malabaricus, and *Glyptothorax anamaliensis*), and two Vulnerable (VU) (*Laubuka fasciata* and *Batasio travancoria*) species. Distribution of *Mesonemachrilus herrei* was found to be restricted to Pulikkayam (Site VI) and Arambamuzhi (Site IX); while the two species of the genus *Dawkinsia (D. denisonii* and *D. chalakkudiensis*) were co-occurring and distributed abundantly in seven sites with good population frequency (Table 2). Despite being gathered from five sites, the Endangered bagrid catfish, *Batasio travancoria* had a comparatively weak population compared to the good population of endangered mahseer, *Tor malabaricus*, at six sites. Among the Endangered species, *Laubuka fasciata* was the second most restricted species found only at two sites (Table 2).

The study reports the presence of the poorly known Lepida Barb *Dawkinsia lepida* for the first time from Achankovil River and is the second report of the endangered Chalakudy Redline Torpedo Barb *D. chalakudiensis*. The current study verifies the existence of *Macrognathus guentheri*, *Anguilla bicolor*, and *Batasio travancoria* in greater elevation gradients of the Achankovil River, despite the fact that these species had previously only been recorded by researchers from the mid and downstream areas of the river.

One positive result experienced was the absence of any records of *Oreochromis mossambicus*, an alien cichlid, from Kallar tributary including the site Mukkada, where the species had previously been reported. The major threat observed during the study period was the practice of destructive fishing at intense level by local communities during dry season, in streams very adjacent to but outside the forest area, by damming the channel including shallow pools followed by the application of plant-based piscicides.

DISCUSSION

Except 10 low land tolerant fish species including two catadromous eels—*Anguilla bicolor*, *A. bengalensis*, *Channa pseudomarulius*, *Puntius mahecola*, *Rasbora dandia*, *Dawkinsia filamentosa*, *Pseudetroplus maculatus*, *Macrognathus guentheri*, *Systomus sarana* and *Xenontodon cancila*—rest of the species were of intolerant fluviatile forms ranging from extreme rheophily with attachment organs in the form of oral adhesive disc (*Garra* sp.), thoracic friction pad (*Glyptothorax* sp.); without attachment organs but, with, really depressed body (*Bhavania* sp., *Balitora*

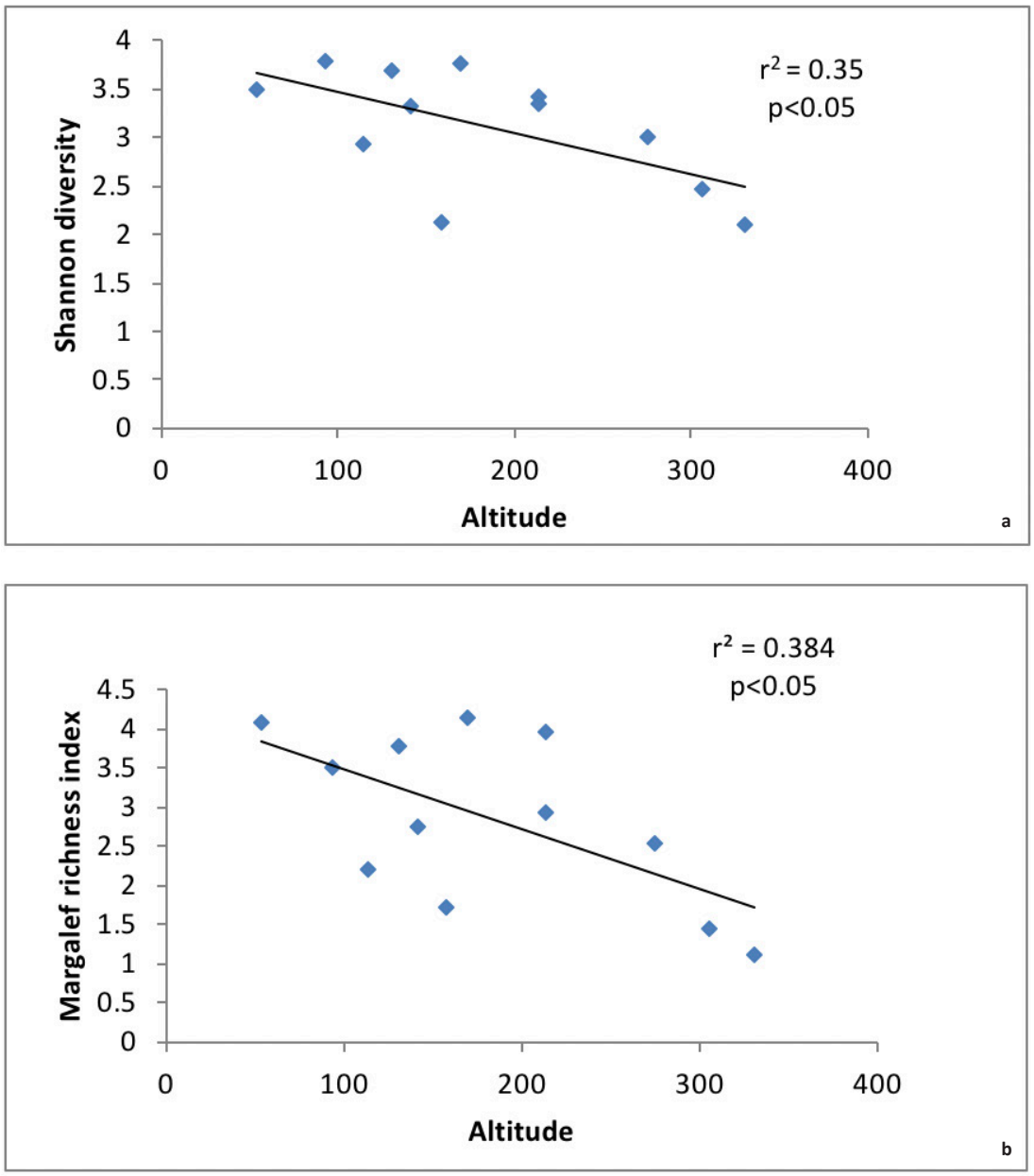


Figure 4. Regression plot of, a—species richness vs altitude (r = 0.50, t = 2.32, p = 0.0427) and | b—species diversity vs altitude (r = 0.62, t = 2.5, p = 0.0317) among the sampling stations in Kallar Stream.

sp.); elongate, anguilliform body (*Mesonoemacheilus* sp., *Mastacembelus* sp.) and compressed - high body (*Hypselobarbus kurali* and *Tor malabaricus*) (Lujan & Conway 2015; Arunachalam 2000).

From six sampling sites distributed along the inundated to elevated zones of the Achankovil River, including one site in the Achankovil tributary inside the ARF, Varghese (1994) recorded a total of 64 species, including 48 primary and 16 secondary freshwater forms, belonging to 43 genera, 28 families, and 10 orders. With the exception of *Channa striata*, all of the species recorded by Varghese (1994) have been reported from Kallar tributary under the current inventory, along with 19 additional species. In summary, of the 48 principal freshwater fish species found in the entire Achankovil River as reported by Varghese (1994), 24 species as well as 11 additional species have been found in the upstream Kallar tributary.

Radhakrishnan (2006) reported 49 fish species, while carrying out an exhaustive ichthyofaunal inventory in 23 sites ranging from the potamonic to rhithronic zones of Achankovil River including three upstream sites-

Table 2. List and details of fish species recorded from Kallar tributary of Achankovil River, Kerala.

	Scientific name	Common name	Vernacular name (Malayalam)	IUCN Red List status	Sites of occurrence & total number of individuals observed	Previous studies which haven't recorded the species	Endemism	Voucher numbers
	Order: Anguilliformes							
	Family: Anguillidae							
1	*Anguilla bengalensis* (Gray, 1831)	Indian Mottled Eel	നെടുമീൻ	NT	IV, VI, IX, XI, XII (5)	1,3,4,5,6	WD	KUFOS.2019.04.A.32
2	*Anguilla bicolor* McClelland, 1844	Indonesian Shortfin Eel	നെടുമീൻ	NT	IV, VI, IX, XI, XII (5)	2,3,4,5,6	WD	KUFOS.2019.04.A.33
	Order: Cypriniformes							
	Family: Danionidae							
	Subfamily: Chedrinae							
3	*Opsarius bakeri* (Day, 1865)	Baker's Baril	ചാലൻ	LC	All sites (287)	Recorded by all previous authors	KL	KUFOS.2019.04.A.1
4	*Opsarius gatensis* (Valenciennes, 1844)	Emerald Baril	ചാലൻ	LC	II, IV, V, VI, VIII, IX, XI, XII (89)	1,6	WG	KUFOS.2019.04.A.2
5	*Salmostoma boopis* (Day, 1874)	Boopis Razorbelly Minnow	പരവൽ	LC	IV, V, VII, IX, X, XI, XII (254)	2	WG	KUFOS.2019.04.A.12
	Subfamily: Danoninae							
6	*Devario malabaricus* (Jerdon, 1849)	Malabar Danio	വാലാട്ടി	LC	I, II, IV, V, VI, VIII, IX, XI (60)	1	WG	KUFOS.2019.04.A.5
7	*Laubuka fasciata* (Silas, 1958)	Malabar Leaping Barb	പരവൽ	VU	VI, VII (33)	1,2,3,5,6	KL	KUFOS.2019.04.A.9
	Subfamily: Rasborinae							
8	*Rasbora dandia* (Valenciennes, 1844)	Black Line Rasbora	തുപ്പല്കൊത്തി	LC	IV, V, VI, VII, VIII, IX, XI (48)	1,2,3,4,5	SIS	KUFOS.2019.04.A.16
	Family: Cyprinidae							
	Subfamily: Smiliogastrinae							
9	*Dawkinsia lepida* (Day, 1868)	Lepida Barb	പൂവാലി	NE	II, IV, V, VI, VIII, IX, X, XI, XII (103)	1,2,3,4,5,6	WG	KUFOS.2019.04.A.3
10	*D. filamentosa* (Valenciennes, 1844)	Filament Barb	പൂവാലി	LC	III, IV, V, VI, IX, XI, XII (19)	Recorded by all previous authors	WG	KUFOS.2019.04.A.4
11	*Sahyadria denisonii* (Day, 1865)	Denison's Redline Torpedo Barb	ചെങ്കണിയാൻ	EN	IV, VI, VIII, IX, X, XI, XII (106)	Recorded by all previous authors	WG	KUFOS.2019.04.A.11
12	*Sahyadria chalakkudiensis* (Menon, Rema Devi & Thobias 1999)	Chalakudy Redline Torpedo Barb	ചെങ്കണിയാൻ	EN	IV, VI, VIII, IX, X, XI, XII (58)	1,2,3,5,6	KL	KUFOS.2019.04.A.10
13	*Haludaria melanampyx* (Day, 1865)	Melon Barb	വാഴയ്ക്കാവരയൻ	DD	II, V, VIII, IX, XI (61)	1	KL	KUFOS.2019.04.A.8
12	*Puntius mahecola* (Valenciennes, 1844)	Mahe Barb	ഉരുളൻ പരൽ	DD	XII (8)	1,2,3,4,5	KL	KUFOS.2019.04.A.34
13	*Systomus sarana* (Hamilton, 1822)	Olive Barb	കുറുവ	LC	IX (3)	3,5,6	WG	KUFOS.2019.04.A.13
	Subfamiy: Labeoninae							
16	*Garra mullya* (Sykes, 1839)	Striped Stone Sucker	കല്ലേമുട്ടി, കൈപ്പ	LC	I, II, III, IV, V, VIII, IX, XI, XII (117)	Recorded by all previous authors	WG	KUFOS.2019.04.A.6
17	*Garra surendranathanii* Shaji, Arun & Easa, 1996	Surendran's Stone Sucker	കല്ലേമുട്ടി, കൈപ്പ	EN	I, II, IV, V, VI, VIII, IX, XI, XII (150)	1,3,6	KL	KUFOS.2019.04.A.7
	Subfamily: Torinae							
18	*Hypselobarbus kurali* Menon & Rema Devi, 1995	Kurali Barb	കൂരൽ	LC	I, III, VII, VIII, XI (47)	1,2,3,4,5	WG	KUFOS.2019.04.A.15
19	*Tor malabaricus* (Jerdon, 1849)	Malabar Mahaseer	കറി	EN	I, II, IV, VI, VIII, IX (42)	1,2,3,4,5,6	WG	KUFOS.2019.04.A.14
	Family: Balitoridae (stone loaches)							
	Subfamily: Balitorinae							
20	*Balitora* sp.	Slender stone loach	കല്ലട്ട	NE	II, IV, IX, XI (23)	1,2,3,4,5,6	KL	KUFOS.2019.04.A.20

	Scientific name	Common name	Vernacular name (Malayalam)	IUCN Red List status	Sites of occurrence & total number of individuals observed	Previous studies which haven't recorded the species	Endemism	Voucher numbers
21	*Bhavania australis* (Jerdon, 1849)	Bhavani Stone Loach	കല്ലട്ട, കൽനക്കി	LC	III, IV, VI, X (25)	1,3	WG	KUFOS.2019.04.A.17
	Family: Nemacheilidae							
22	*Mesonoemacheilus herrei* Nalbant & Bănărescu, 1982	Anamalai Loach	മണലാരി	CR	VI, IX (6)	1,2,3,4,5,6	WG	KUFOS.2019.04.A.19
23	*Mesonoemacheilus triangularis* (Day, 1865)	Zodiac Loach	മണലാരി	LC	II, III, IV, V, VI, VIII, IX, XI, XII (84)	1,2,6	WG	KUFOS.2019.04.A.18
	Order: Siluriformes							
	Family: Sisoridae							
24	*Glyptothorax anamalaiensis* Silas, 1952	Anamalai Mountain Catfish	കൽക്കൂരി, നെയ്കൂരി	EN	VI, IX, X, XI, XII (29)	2,3,6	WG	KUFOS.2019.04.A.24
25	*Glyptothorax annandalei* Hora, 1923	Annandale's Mountain Catfish	കൽക്കൂരി, നെയ്കൂരി	LC	II, III, IV, V, VI, VIII, IX, X (48)	1,3,4,6	WG	KUFOS.2019.04.A.25
	Family: Siluridae							
26	*Ompok malabaricus* (Valenciennes, 1840)	Malabar Butter Catfish	ചൊട്ടാവാള	LC	IV (1)	1,2,4,6	WG	KUFOS.2019.04.A.23
	Family: Bagridae							
27	*Batasio travancoria* Hora & Law, 1941	Travancore Batasio	നീലകൂരി	VU	VI, VII, IX, XI, XII (13)	1,2,3,4,5	KL	KUFOS.2019.04.A.22
28	*Mystus malabaricus* (Jerdon, 1849)	Malabar Mystus	ചില്ലാൻ കൂരി	NT	IV, VI (26)	2,5,6	WG	KUFOS.2019.04.A.21
	Order: Cichliformes							
	Family: Cichlidae							
	Subfamily: Etroplinae							
29	*Pseudetroplus maculatus* (Bloch, 1795)	Orange Chromide	പളളത്തി	LC	XII (15)	Recorded by all previous authors	IS	KUFOS.2019.04.A.30
	Order: Beloniformes							
	Family: Belonidae							
30	*Xenentodon cancila* (Hamilton, 1822)	Needle Fish	കോലാൻ	LC	VI, VII, IX, XII (4)	6	WD	KUFOS.2019.04.A.26
	Order: Cyprinodontiformes							
	Family: Aplocheilidae							
31	*Aplocheilus lineatus* (Valenciennes, 1846)	Striped Panchax	പൂഞ്ഞാൻ, നെറ്റിയേപൊട്ടൻ	LC	XII (20)	Recorded by all previous authors	IS	KUFOS.2019.04.A.31
	Order: Synbranchiformes							
	Family: Mastacembelidae							
32	*Macrognathus guentheri* (Day, 1865)	Malabar Spiny Eel	ആരൽ, മണലാരകൻ	LC	VI,VII (2)	2,3,4,5,6	WG	KUFOS.2019.04.A.27
33	*Mastacembelus armatus* (Lacepède, 1800)	Zig-Zag-Eel	ആരൽ, പനയാരകൻ	LC	II, V, VI, VII, IX, X, XII (10)	6	WD	KUFOS.2019.04.A.28
	Order: Anabantiformes							
	Family: Channidae							
34	*Channa gachua* (Hamilton, 1822)	Dwarf Snakehead	വട്ടോൻ	LC	XII (1)	2,3,5,6	WD	KUFOS.2019.04.A.35
35	*Channa pseudomarulius* (Günther, 1861)	Giant Snakehead	വാക	NE	XI, XII (7)	6	PI	KUFOS.2019.04.A.29

CR—Critically Endangered | EN—Endangered | VU—Vulnerable | NT—Near Threatened | LC—Least Concern | DD—Data Deficient | NE—Not Evaluated | WD—Wide Distribution | KL—Kerala | WG—Western Ghats | SIS—Southern India and Sri Lanka | IS—India and Sri Lanka | PI—Peninsular India | 1—Varghese (1994) | 2—Radhakrishnan (2006) | 3—Swapna (2009) | 4—Baby et al. (2011) | 5—Sabu et al. (2013) | 6—Johnson & Arunachalam (2009).

Table 3. Diversity indices of fishes recorded from the study area.

Sites	S	N	d	J'	H'(log2)	λ
Site I	6	85	1.13	0.81	2.09	0.3
Site II	12	76	2.54	0.84	3	0.16
Site III	6	32	1.44	0.96	2.48	0.19
Site IV	21	158	3.95	0.78	3.41	0.14
Site V	12	42	2.94	0.93	3.34	0.11
Site VI	24	261	4.13	0.82	3.76	0.1
Site VII	9	103	1.73	0.67	2.12	0.31
Site VIII	14	111	2.76	0.87	3.32	0.12
Site IX	25	565	3.79	0.8	3.7	0.11
Site X	9	38	2.2	0.93	2.93	0.15
Site XI	20	230	3.49	0.88	3.79	0.09
Site XII	20	107	4.07	0.81	3.5	0.12

Low value — Higher value

S—Number of species from each site | N—Total number of individuals from each site | d—Margalef richness index | J'—Pielou's evenness index | H' (log2)—Shannon diversity index | Lambda (λ)—Simpson dominance index.

Vazhaperiyar and Kallar in Kallar Stream and a third site in the neighbouring Achankovil Stream. All but three of the 15 species listed by Radhakrishnan (2006) (five from Kallar, seven from Achankovil, and four shared by both the streams) were collected under the current inventory. The possible reason for the absence of three rheophilic species - *Barbodes carnaticus*, *Garra hughi*, and *Pristolepis marginata* in the current study might be attributed to their restricted distribution within the Achankovil stream, which is supported by Baby et al. (2011). The current study added nine species additionally to the fish faunal list of Achankovil prepared by Radhakrishnan (2006).

Swapna (2009) reported 52 species belonging to five orders and 18 families from four sampling locations spread along the low and midland areas of Achankovil River. Although Swapna (2009) regarded the station 'Thura' (9.124N, 77.042E) as a high land area, the altitude was below that of the lowest elevation site (54 m) fixed for sampling in the present study. In the current investigation, the Kallar tributary was found to contain 23 of the species listed by Swapna (2009), 12 additional species, including nine rheophilic forms. Among these 12 species, except *Anguilla bicolor*, *A. bengalensis*, and *Channa gachua* all other species were typical rheophilic forms. The reasons for the non-record of other species in the current study which were reported by Swapna (2009) might be attributed to the potamonic or secondary freshwater affinity, as these species are mostly reported from lowland inland waters in Kerala (Renjithkumar et al. 2011).

Johnson & Aruncahalam (2009) recorded 17 species of fishes from a single location in the downstream area outside the ARF including new record of *Batasio travancoria* from Achankovil River. Except for three species (*Aplocheilus panchax*, *Puntius arenatus*, and *P. dorsalis*) reported by Johnson & Arunachalam (2009), all other species including *B. travancoria* were obtained in the current study. The three species might very well be misidentified with other species of the corresponding genera in Achankovil River.

Baby et al. (2011) prepared a checklist of fishes of ARF to consist of 46 species of freshwater fishes, belonging to 17 families and 31 genera, after sampling seven and four sites in the main Achankovil and Kallar streams, respectively. Seven species—*Angilla bicolor*, *A. bengalensis*, *Macrognathis guentheri*, *Batasio travancoria*, *Glyptothorax annandalei*, *Dawkinsia lepida*—and an unidentified *Balitora* species that were not reported by Baby et al. (2011) from the Achankovil Reserve Forest were collected in the current study from Kallar Stream. Also, six species—*Labuka fasciata*, *Hypselobarbus kurali*, *Aplocheilus lineatus*, *Channa gachua*, *Mystus malabaricus*, and *Ompok malabaricus*—that Baby et al. (2011) described from only the Achankovil Stream were also reported in the current study. Through repeated sampling in all the stations with maximum efforts in terms of time and number of fishing operations, the current study failed to obtain individuals of *Barbodes carnaticus* and *Pristolepis*

marginata, inferring the restricted distribution of these species to the Achankovil tributary.

Sabu et al. (2013) reported 32 species of fish at 10 locations inside the Achankovil Reserve Forest as part of an ichthyofaunal survey. Eight of the 10 locations sampled by Sabu et al. (2013) belonged to the Kallar tributary and these sites are also investigated in the present study. The site with maximum elevation sampled by Sabu et al. (2013) was Kanayar (170 m), but the current study covered five additional sites >170 m. A comprehensive comparison on tributary as well as site-wise distribution of fish species was not possible with the findings of Sabu et al. (2013) as the researchers had not provided any detailed information. The current study failed to record five species recorded by them, viz., *Puntius vittatus*, *Mystus vittatus*, *M. cavasius*, *Pseudopshromenus cupanus*, and *Carinotetraodon travancoricus*; but reported 11 species additionally. The existence of those species in the Kallar tributary needs to be confirmed as Sabu et al. (2013) did not provide the stream-wise distribution of the fish species inside the ARF.

Swapna (2007) and Kurup et al. (2004) reported *Balitora brucei* Gray, a species endemic to northern and northeastern India from the Achankovil River. Radhakrishnan (2006) reported this species as *B. mysorensis* from two localities in Kallar tributary, viz., Chittar and Pulikkayam. Swapna (2009) reported the species as *B. mysorensis* from two localities outside the Achankovil Reserve Forest. The current study could obtain this species of *Balitora* from four locations in Kallar Stream inside the ARF. On detailed examination, the species was found to differ from all extant species of *Balitora* from peninsular India as well as from *B. brucei* in several morphomeristic aspects. Hence, we tentatively consider it as an undescribed species of *Balitora* in the fish species list presented here. The previously known records of the Lepida Barb *Dawkinsia lepida* are from Bhavani River in Tamil Nadu, Chalakudy, and Muvattupuzha drainages in Kerala (Katwate et al. 2020) and the current study confirms the presence of this species in Kallar tributary of Achankovil River and it may be inferred that the species enjoys a wide distribution range and may occur beyond south of Achankovil River.

The ichthyofaunal diversity in the upstream areas of Achankovil, especially the Kallar tributary within the ARF is rich and comparable to other protected areas in Kerala in terms of the number of species reported (N) such as the Neyyar (N = 38) and Idukki (N = 40) wildlife sanctuaries (Thomas et al. 2000a); Chinnar Wildlife Sanctuary (N = 20) (Thomas et al. 1999); Chimmony (N = 34) and Peechi-Vazhani (N = 35) wildlife sanctuaries (Thomas et al. 2000b); Parambikulam National Park (N = 41) (Biju et al. 1999) and Aralam Wildlife Sanctuary (N = 33) (Shaji et al. 1995). The number of species recorded in the current study (N = 35) was equal to or higher than those encountered in several protected areas in Kerala, necessitating the conservation significance of the perennial Kallar tributary.

The lowest diversity was found at higher altitudes, and the same trend followed in Margalef richness confirmed the hypothesis of Reves-Gavilan et al. (1996), that diversity and species richness declines with increasing altitude, and was also matching with results of previous researches made in rivers of Western Ghats (Raghavan et al. 2008; Johnson & Arunachalam 2009). Fluctuations in evenness may be due to disturbances resulted by the flood. The increased number of fish species in the confluence points are attributed to the high habitat diversity or habitat heterogeneity and the observation is in agreement with Arunachalam (2000); Johnson & Arunachalam (2009).

The comparison of diversity indices with Sabu et al. (2013), revealed that the fish faunal composition has not altered due to the 2018 catastrophic flood and this might be attributed to the non-significant alterations caused due to the 2018 catastrophic flood on stream bed substrata and canopy cover in the head waters within forest areas (Raghavan 2019) as compared to large scale multiple negative consequences occurred in the downstream areas (Pereira 2018). Among the forest ranges encompassing the headwaters of Achankovil River (Achankovil, Kallar, Kanayar, and Mannarathara), Kallar and Kanayar are the ones that retain the remaining natural forest cover in the Achankovil River basin, the other two forest jurisdictions have been widely converted into teak plantations (Vijayan et al. 2021). These patches of forest might have minimised the effects of the flash flood-assisted landslides, fish habitat loss, and species displacement to a great extent in the catchment areas of the Kallar sub-basin as against the multiple adverse impacts caused in the mid and downstream areas of the Achankovil River basin and other river basins in Kerala (Pereira 2018; Cheriyan & Oommen 2020). Resistance and resilience are recognised as two crucial elements of fish species assemblage stability (Pearsons & Lamberti 1992). The current study's findings are in line with those of other studies (Meffe & Minckley 1987; Pearsons & Lamberti 1992), which have highlighted the importance of meso- and micro-habitat heterogeneity as playing a critical role in the ability of fish in streams' headwaters to withstand flash floods. Forested streams offer distinctive microhabitats for many endemic rheophilic

species and it can be presumable that the degradation or conversion of riparian vegetation can lead to biotic homogenization that may reduce species diversity and ecosystem services (Casatti et al. 2012).

The absence of any kind of non-native fish species including transplanted and exotic fish species from the study area, in contrast to the records of such species from other protected areas in Kerala including Periyar National Park (Biju et al. 1999; Radhakrishnan & Kurup 2010; Thomas et al. 2000a,b), revealed the pristine nature of the habitat within ARF and the efficacy of aquatic habitat conservation under forest protection. Though the presence of Mozambique Tilapia *Oreochromis mossambicus* has been reported by Baby et al. (2011) from Mukkadamuzhi, our detailed sampling with multiple fishing contrivances failed to obtain a single individual of the species from any of the sampling stations in Kallar tributary. Also, the indigenous Etroplin Cichlid *Pseudeptroplus maculatus* is found abundant (with plenty of juveniles being cared by parents) in the stream stretch at Mukkadamuzhi. The flood may have a positive impact on the displacement of tilapias to lower elevation zones, as evidenced by the reports of increased landing of tilapias from the downstream areas (Raghavan et al. 2019). The absence of non-native fish species qualifies Kallar Stream, as a reference site for future ecosystem health assessments using fish-based index of biotic integrity (IBI) for Achankovil River as used in temperate and tropical aquatic systems (Angermeier & Karr 1986; Ganasan & Hughes 1998).

Though a large share of the population of the species including threatened ones are protected within the reserve forest area, destructive fishing practices employed by the local people outside the forest area targeting mainly the migratory and nocturnal fish species such as the catadromous anguillid eels, spiny eels, and catfishes may certainly result in disruption of proper recruitment to the stock and subsequent population decline. Moreover, this type of fishing practice may have a serious negative impact on the breeding and recruitment of non-targeted species; as the majority of the hill stream fishes including most of the threatened fishes are known to breed during the post monsoon months of November to February (Ali & Prasad 2007; Thampy 2009; Solomon et al. 2011). Hence, there is an urgent need for declaring a fishing ban or closed season during these months for protecting the breeding populations and ensure proper recruitment. Also, such destructive fishing practices need to be monitored and regulated with the provisions of the Kerala Inland Fisheries and Aquaculture Act 2010, and the Environmental Protection Act 1986, Government of India. Awareness has to be created among local communities on the negative impacts of fishing during the dry season and the protection of stream habitats.

In the context of the past reduction of protected forest area in the catchment areas of Achankovil River basin by 53% from 1978 to 2015 (Vijayan et al. 2021), forest-associated habitat heterogeneity in streams supporting a rich fish diversity, conservation status and endemism of the species inhabiting, and other numerous functions offered by the riparian vegetation; the remaining natural forest cover, specifically in the Kanayar and Kallar ranges need to be protected as such from being converted to forest plantations. Also, construction of a concrete dam across the Kallar tributary (3 km upstream from the confluence point of Kallar tributary) has been envisaged in the proposed Pamba-Achankovil-Vaippar link project (NWDA 1995; Rani et al. 2016), for diverting surplus water in Pamba and Achankovil rivers in central Kerala to the deficit Vaippar in Tamil Nadu State. The location of the dam and the tunnel that is proposed to be built within the Kallar tributary includes three most species-diverse sites (Pulikkayam, Pekkuzhi, and Mukkadamuzhi) housing populations of seven threatened species, including five 'Endangered' (*Dawkinsia denisonii*, *D. chalakudiensis*, *Glyptothorax anamalaiensis*, *Garra surendranathathanii*, and *Tor malabaricus*) and two 'Vulnerable' (*Batasio travancoria* and *Laubuca fasciata*) species. The implementation of the proposed project could have negative effects on the natural forest cover and its dependent biodiversity, especially in the catchment areas of Kallar, which is also the type locality for the 'Critically Endangered' Tuberous Geophyte *Arisaemia sarracenioides* and the only known location outside the type locality for the endemic orchid species *Denrobium kallarensis* (Mathew et al. 2016). Considering the warning on 'the complete loss of natural forest cover within near future as the current conversion continues at the present scale' (Vijayan et al. 2021), proper environmental and ecological impact assessment studies have to be carried out prior to consideration. Given the ecological significance of the forest area associated with the Kallar tributary in relation to the endemism and threat status of the fauna and flora inhabiting it, the livelihood support that the specific forest provides to the tribal community, and the fact that the study area harbour the only remaining natural forest cover in the Achankovil River basin, the water diversion project should be abandoned.

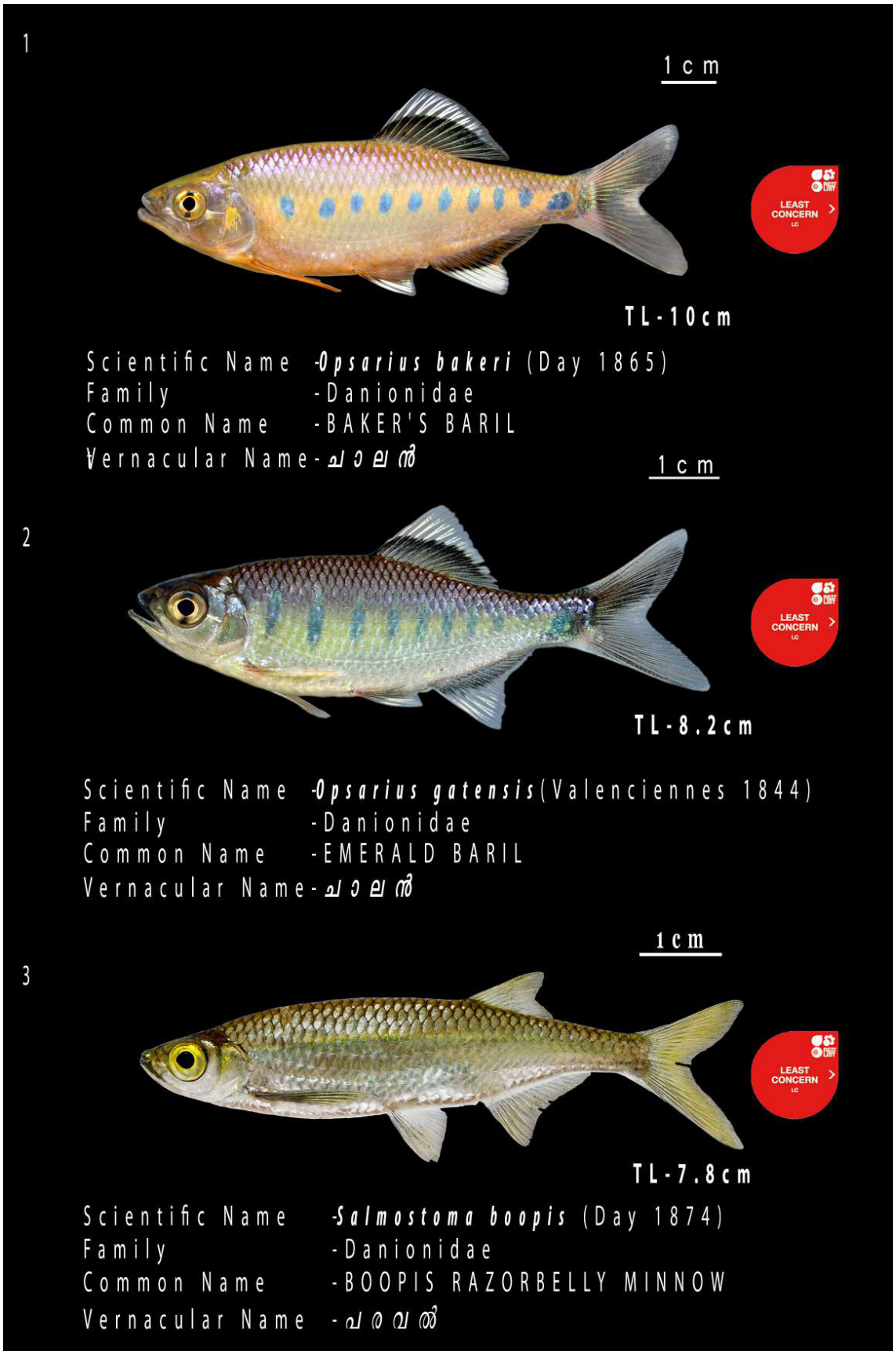
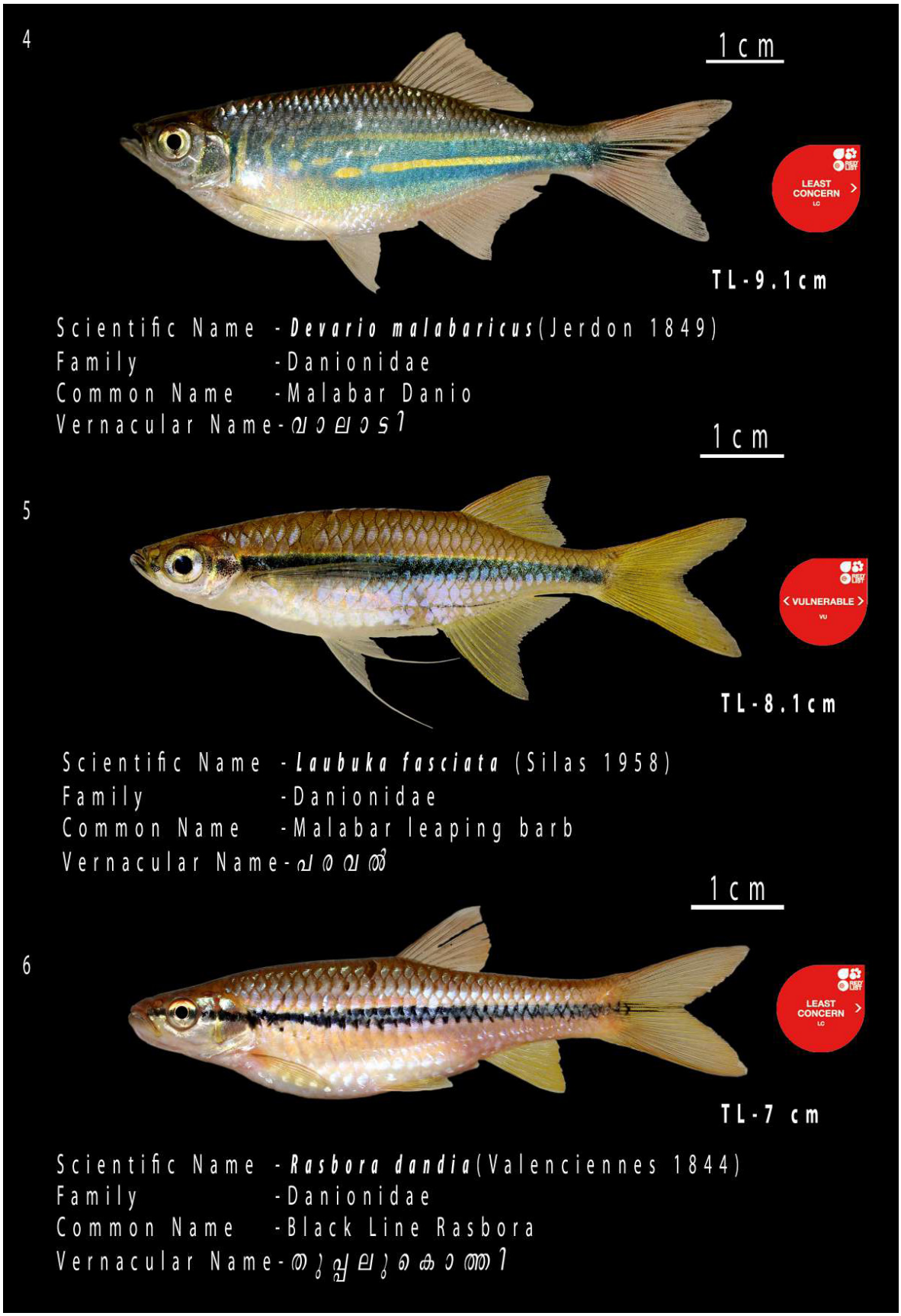


Image 2. Fish specimens from the Kallar Stream. © Melbin Lal.



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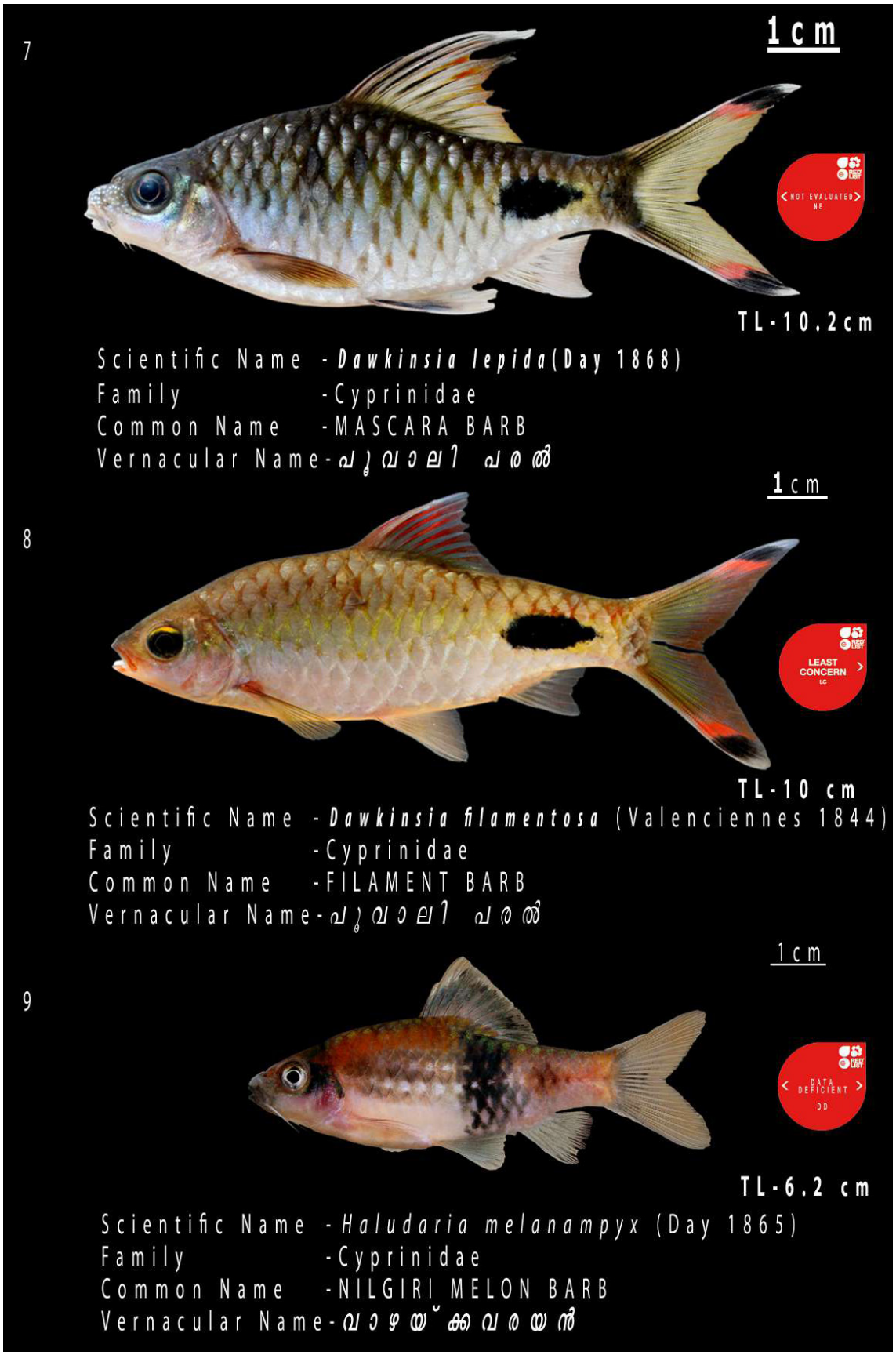

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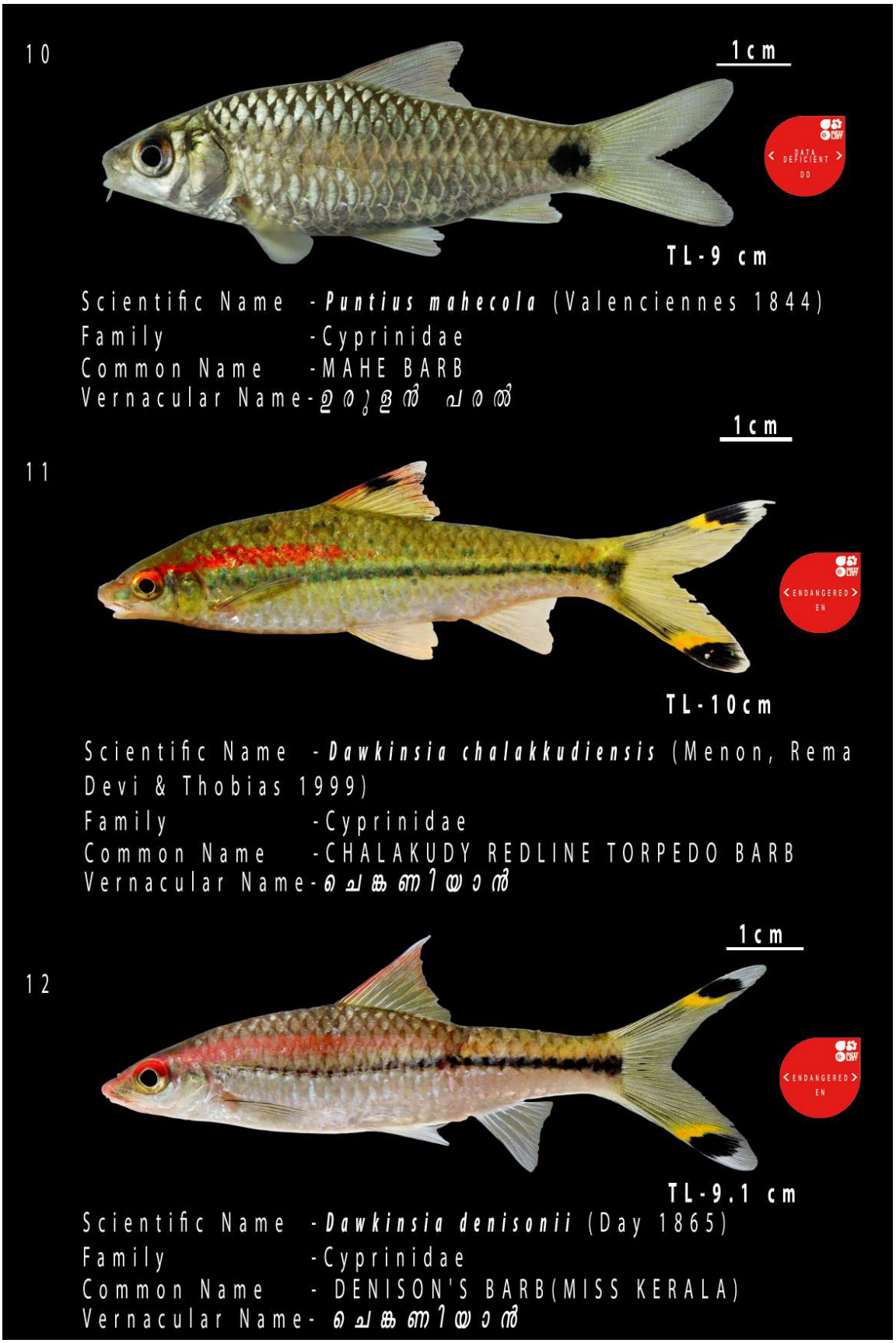

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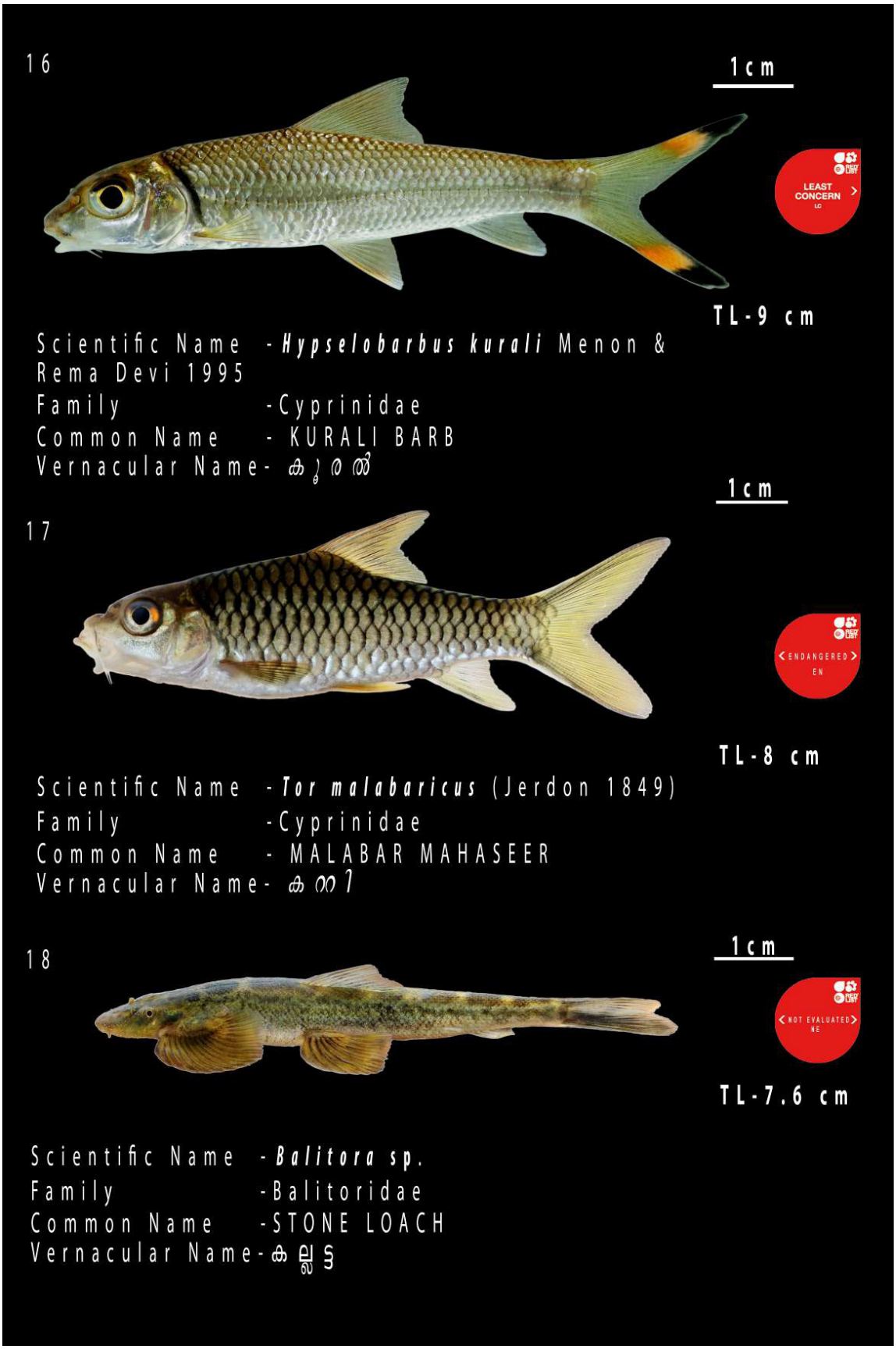
Image 6. Fish specimens from the Kallar Stream. © Josin Tharian.



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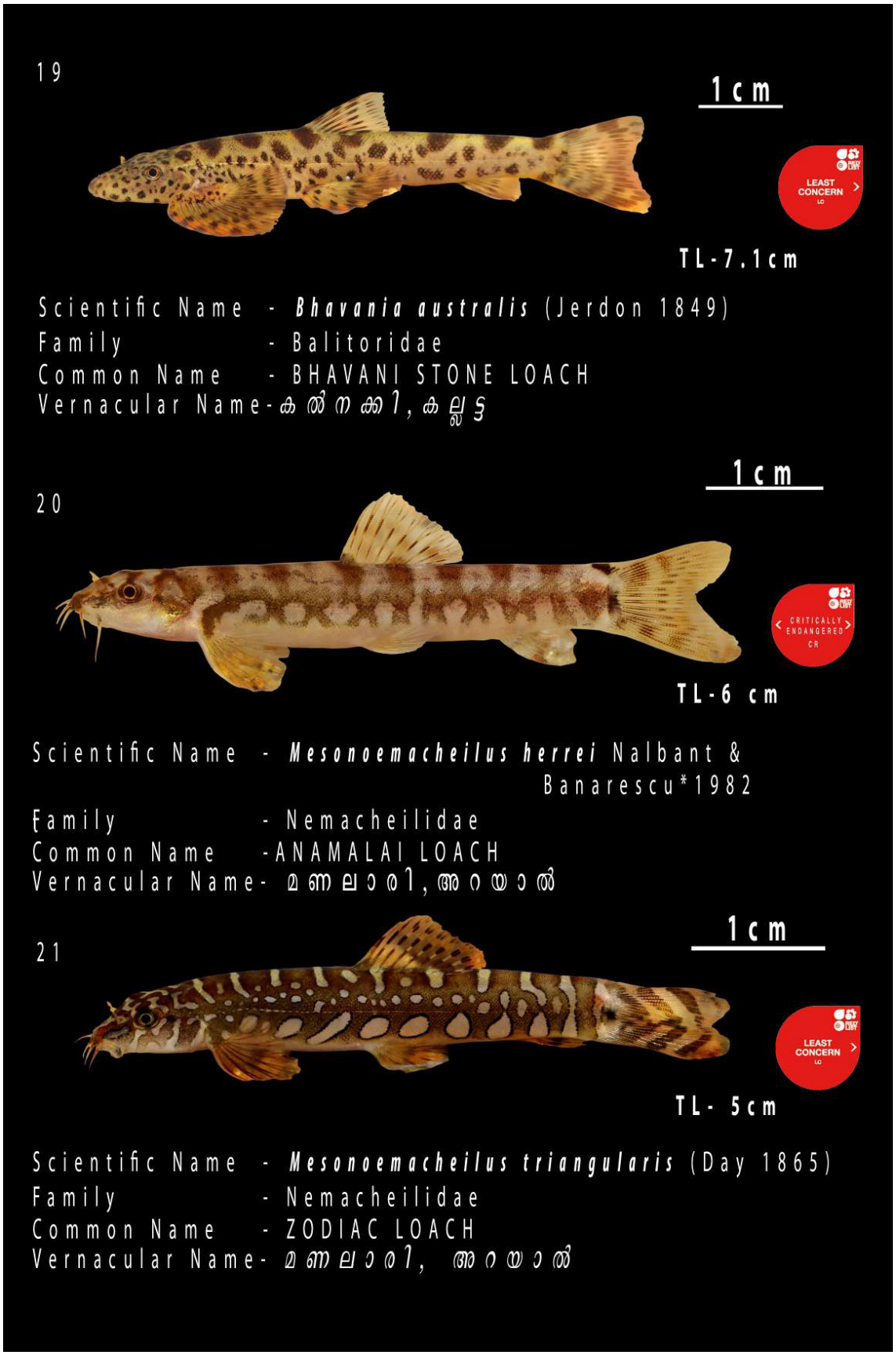

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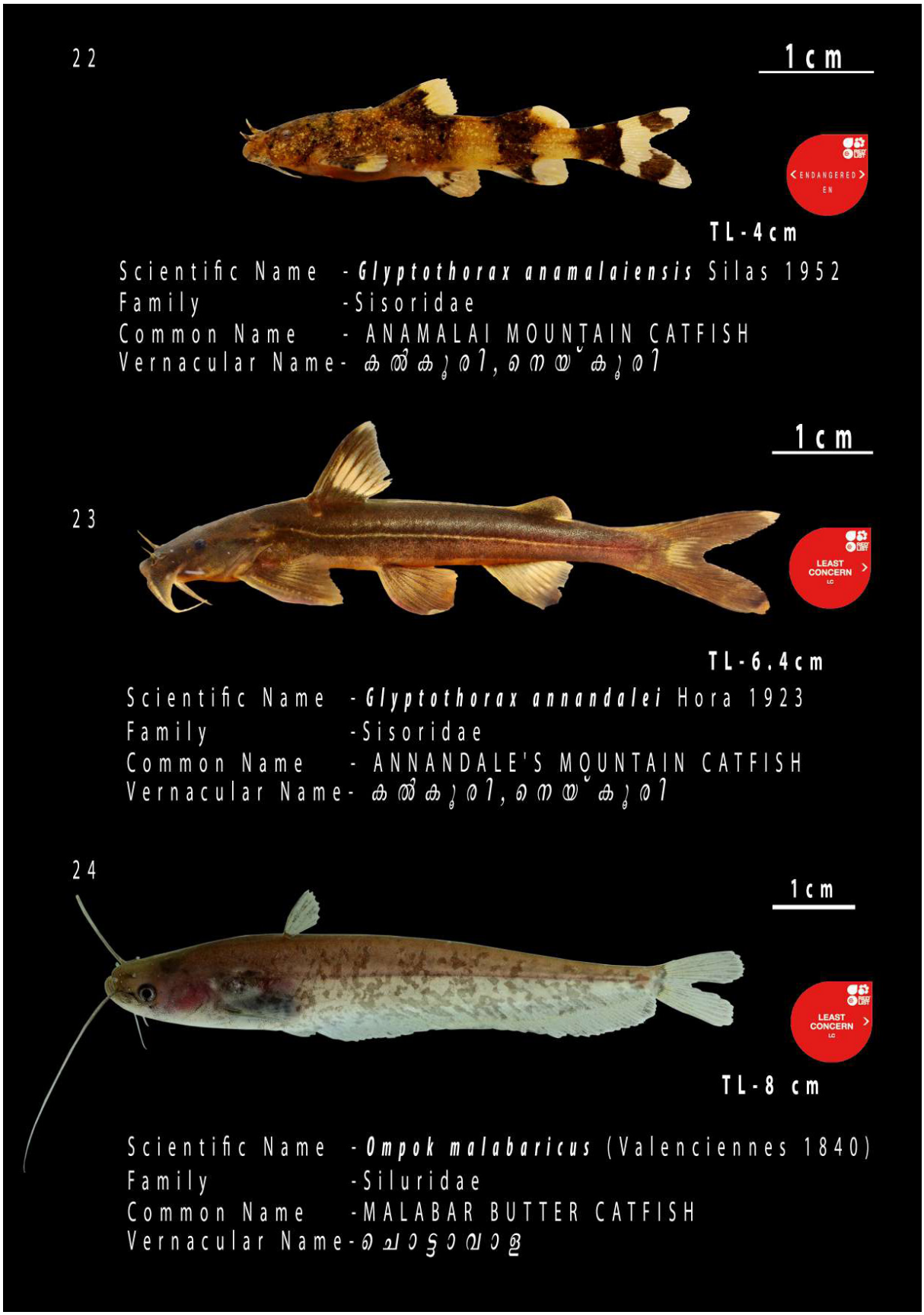

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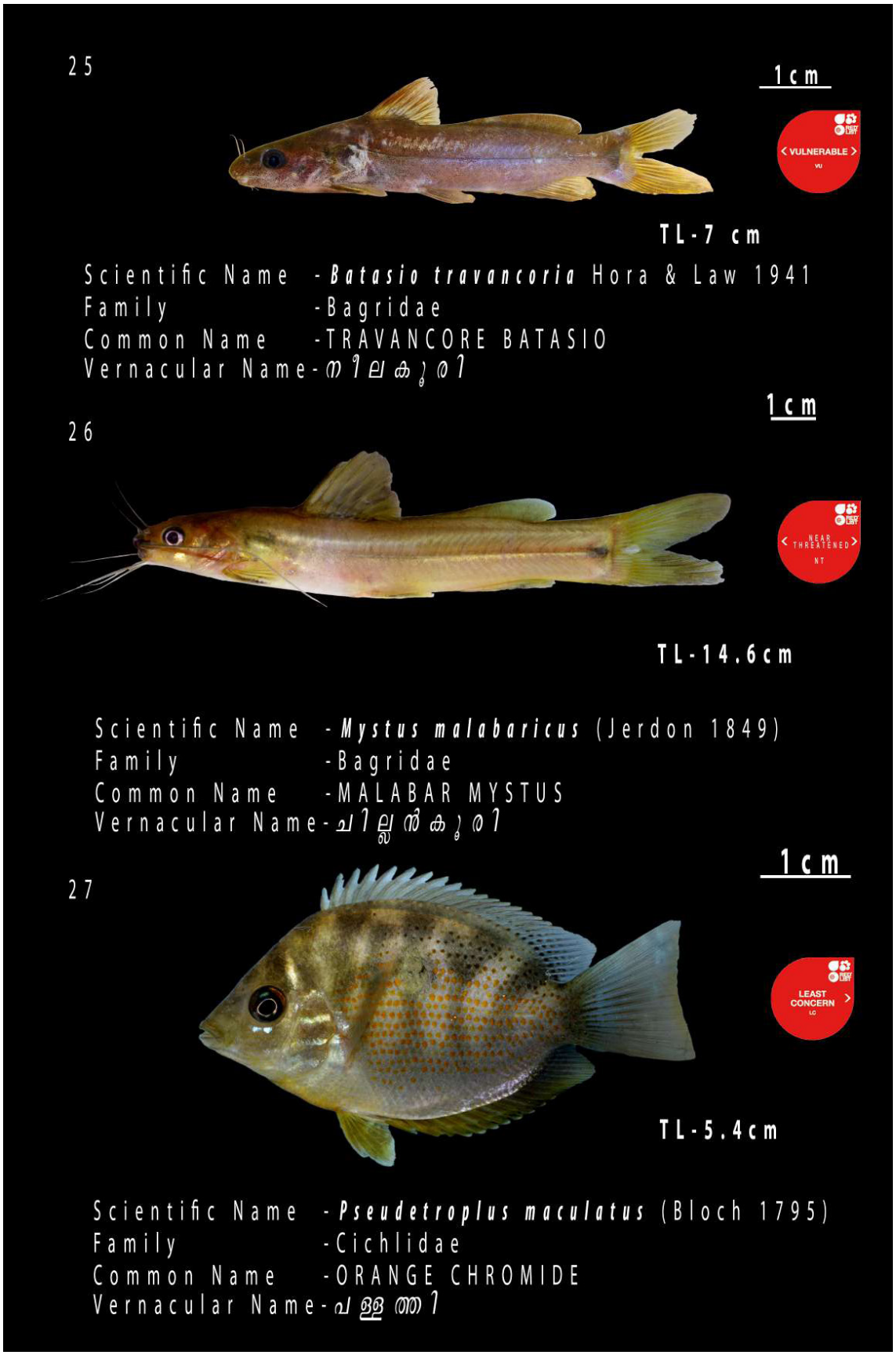

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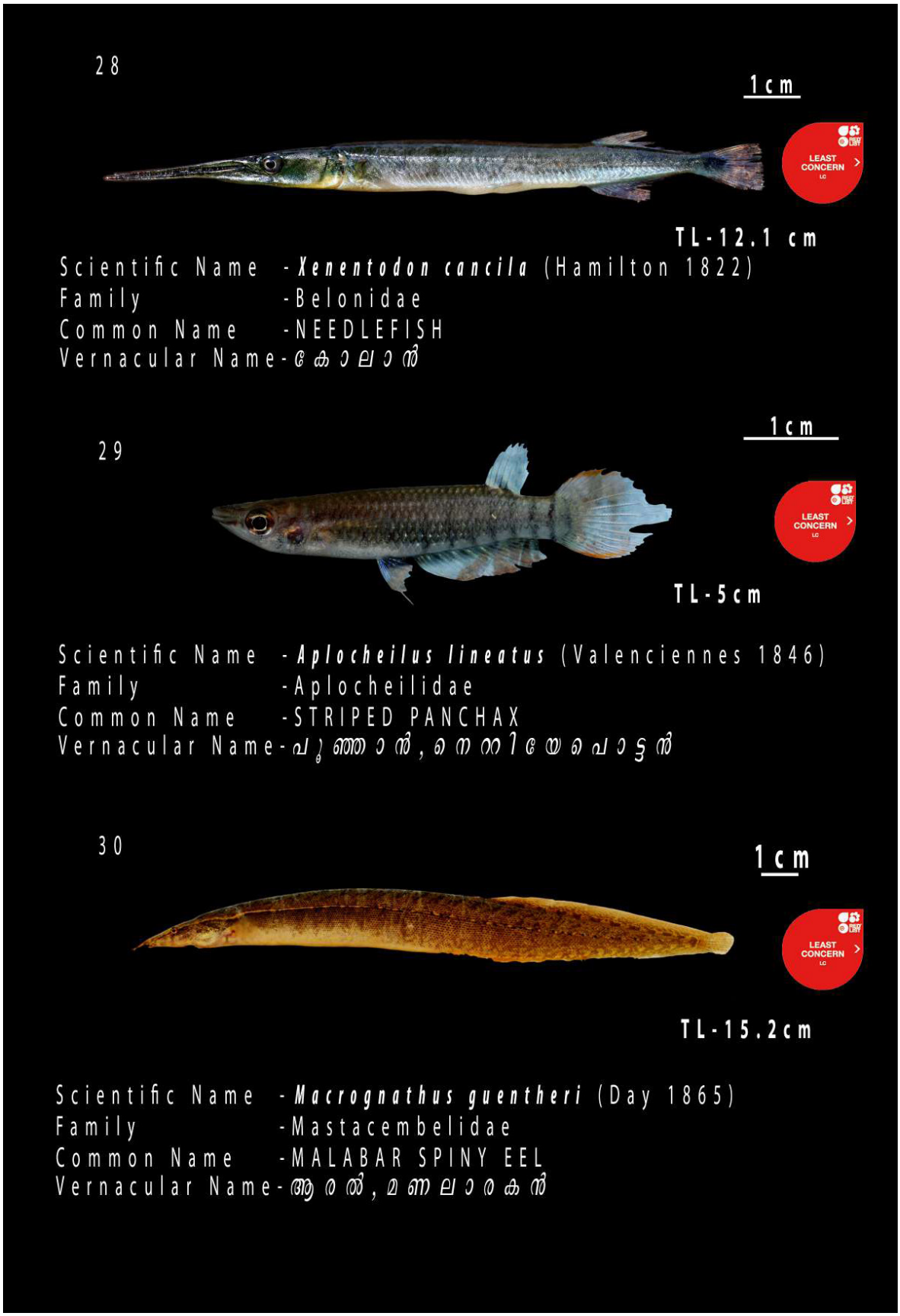

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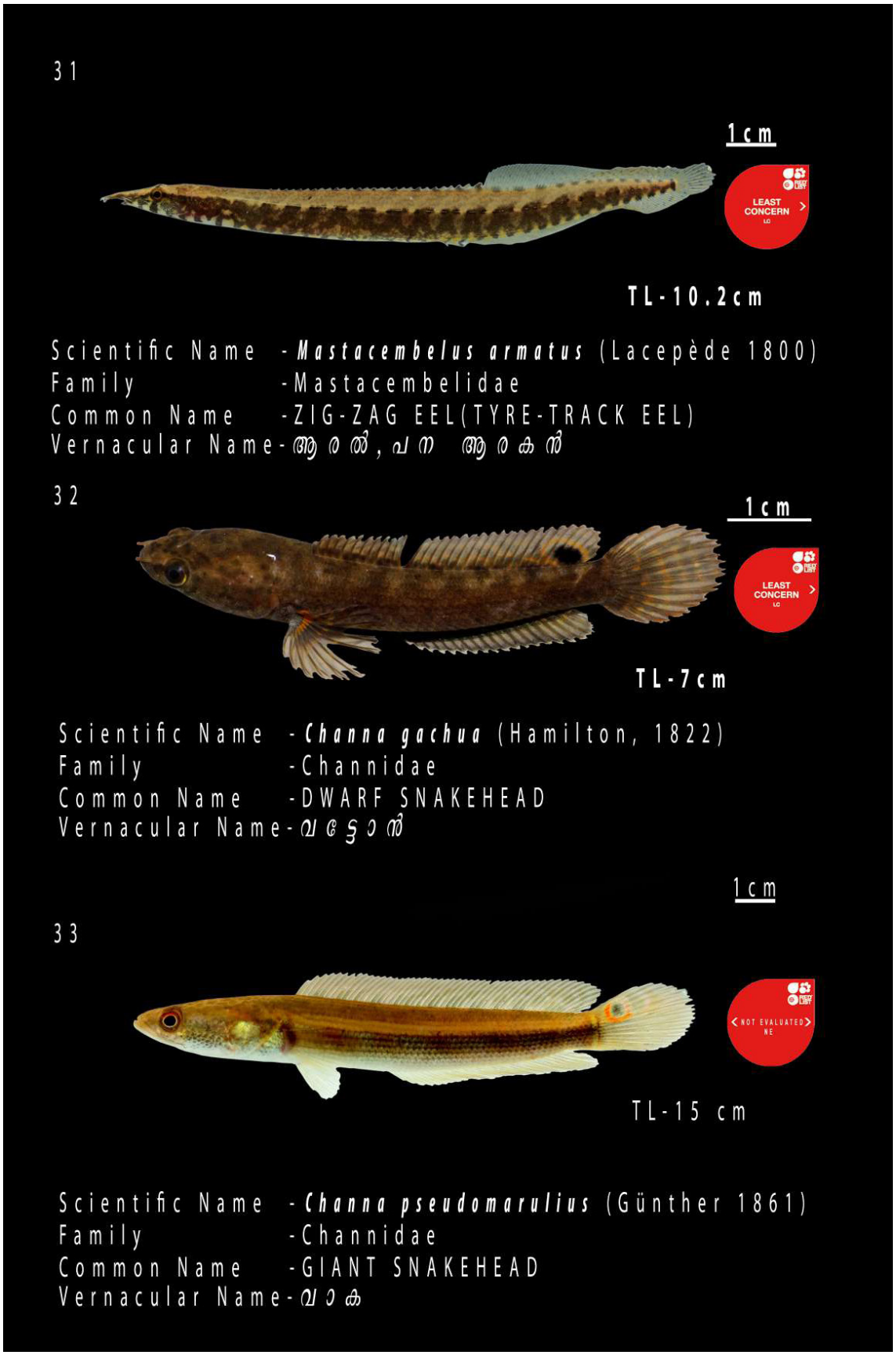

Image 12. Fish specimens from the Kallar Stream. © Melbin Lal.

Image 13. Fish specimens from the Kallar Stream. © Anvar Ali.

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NAAS rating (India) 5.64

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Journal of Threatened Taxa

www.threatenedtaxa.org

ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)

May 2023 | Vol. 15 | No. 5 | Pages: 23139–23282
Date of Publication: 26 May 2023 (Online & Print)
DOI: 10.11609/jott.2023.15.5.23139-23282

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