Feasibility of using sailfin catfish meal as an alternative to commercial fishmeal in the diets of juvenile guppy (*Poecilia reticulata*)

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**Abstract**
A six weeks feeding trial was conducted to elucidate the effect of fishmeal produced from sailfin catfish (SCM) by replacing imported commercial fishmeal (FM) in the diet of *Poecilia reticulata* to reduce the cost of feed. Twenty one days old guppy fry (1.99±0.09 cm; 0.07±0.02 g) were fed four diets using different levels of SCM; control diet (CD; 0% SCM), 10SCM (10% SCM), 20SCM (20% SCM) and 30SCM (30% SCM). SCM contained higher protein content (69.5%) compared to FM (61%). Final body weight, %ADG, %SGR or FCR (1.77±0.16 – 2.21±0.26) and food consumption (9.3±0.1 – 9.45±0.5) did not influence by inclusion of SCM. Survival (>80%) did not influence by the type and quantity of fishmeal inclusion. Moreover, significantly higher profit index for 30SCM (8.94±1.43) and 20SCM (7.88±4.23) was recorded than CD (5.17±4.43) which contained imported, expensive FM. Overall, the present study revealed that commercial fishmeal can be fully replaced by SCM in the diets of juvenile guppy without any adverse effects on their growth. Therefore, producing fishmeal using sailfin catfish, which is an invasive species in reservoirs in Sri Lanka and an underutilized source, will be a feasible method to overcome the invasive problem.

**Keywords:** Alternative protein source; feed formulation; growth metrics; ornamental fish; sailfin catfish meal

1 | INTRODUCTION
The genus *Pterygoplichthys* commonly known as sailfin catfish belong to the family Loricariidae, is one of the exotic fish groups that widely distributed in many tropical and subtropical regions (Orfinger and Goodding 2018). The fish are originally from Amazon River Basin of Brazil and Peru and transferred to other regions including North and Central America to Southern and Eastern Asia, and also to Indo-Pacific and Caribbean islands through aquarium trade (Nico et al. 2012). The intentional and accidental release from aquariums led them dispersed and established in natural environment (Wakida-Kusunoki et al. 2007). The likely factors for sailfin catfish invasion are multiple yet highly influenced by the reproductive success (Gibbs et al. 2008), high fecundity (Hoover et al. 2004), physiological tolerance (Brion et al. 2013) and physical robustness (Ebenstein et al. 2015). Countries including Indonesia (Patoka et al. 2020), India (Raj et al. 2020), Thailand (Panase et al. 2018), Mexico (Tapia-Varela et al. 2021), Bangladesh (Hossain et al. 2018) and Vietnam (Yen 2021) have been declared the invasive threat either as an expansion of existing population or as a new introduction. However, once established it is extremely difficult and costly to remove the fish from the ecosystem (Hill and Sowards 2015).

Sailfin catfishes were initially introduced to Sri Lanka
in 1994 with the intention of promoting the ornamental fish industry (Marambe et al. 2011). The fish is largely used as a janitor fish to feed on the unwanted plant material inside the fish tanks (Wijesinghe et al. 2021). The genus *Pterygoplichthys* contains group of species which are often hybridized for domestication and better varieties. Therefore, this paper will use sailfin catfish to refer the whole group unless otherwise specified. Due to the constant removal of oversized fish from the aquariums, a huge population of invaders established in Sri Lankan water bodies including Polgolla Reservoir, Kala Wewa, Victoria Reservoir, Kandalama Wewa, Balalu Wewa and Ugala Siyambangamuwa Wewa (Kumudinie and Wijeyaratne 2005). The invasion threat has become a serious problem in Sri Lanka and the ecological impact has been vastly described elsewhere (Wijethunga and Epa 2008). Exhibiting an omnivorous feeding behaviour, sailfin catfish preys on eggs of cichlids species cultured on lakes and tanks destroying future potentials of the endemic fishery resources (Amarasinghe et al. 2006). The sharp spines damage the fishing gears and this adds an external effort and cost on fishing (Wijesinghe et al. 2021). Moreover, sailfin catfish have become a regular catch over the indigenous species in many inland reservoirs in Sri Lanka (Sumanasinge and Amarasinghe 2014; Wijesinghe et al. 2021). In Polgolla Reservoir sailfin catfish landings were recorded as 21% out of total landings of food fish (Sumanasinge and Amarasinghe 2014) and for each Kalawewa and Victoria Reservoir, monthly catch was exceeding 100 fish for three consecutive years from 2015 (Wickramaratne et al. 2020a). Therefore, removal of invaders from the natural water bodies is utterly important to overcome this problem. According to the fishermen in Udawalawe Reservoir, the sailfin catfish has a poor demand as a food fish due to its unpleasant appearance, odour, and the hard bony structure (personal communication). Therefore, the fish caught in the nets are extensively discarded at the riverbanks by the fishermen or released back to the water utilised (Sumanasinge and Amarasinghe 2014).

The management of invasive sailfin catfish has become a major concern in inland fisheries and aquaculture in Sri Lanka (Sumanasinge and Amarasinghe 2014). One of the best methods of controlling is to establish a commercial value to encourage intensive fishing. Though, sailfin catfishes are not popularised for direct human consumption, studies have considered other alternatives like producing post-harvest and value-added products such as fish biscuits (Ariyaratne et al. 2016), collagen (Herath et al. 2020), bioactive fish protein hydrolysates (Wijesinghe et al. 2021) and as dried salted fillets (Ariyaratna et al. 2014) to establish a demand. Previous studies on species identification, fish biology and population dynamics have suggested utilising sailfin catfish as a fishmeal alternative to effectively eradicate the invasive threat (Sumanasinge and Amarasinghe 2014; Wickramaratne et al. 2020b; Abesinghe et al. 2020) but not currently practicing in Sri Lanka. There is a study initiated by National Aquatic Resources Research and Development Agency (NARA) Sri Lanka to promote sailfin catfish meal (SCM). In their experiment, SCM was compared with locally produced commercial fishmeal in terms of nutritional profile but did not conduct a feeding trial (Weerasingha and Athukorala 2017). However, in Thailand, SCM has been identified as a successful candidate for fishmeal replacement (Panase et al. 2018).

**Guppy (Poecilia reticulata)** is one of the popular freshwater ornamental fish varieties and, Sri Lanka exports guppies contributing to 4% of the global demand (EDB 2021). Ornamental fish culture practices largely depend on the imported formulated feeds in Sri Lanka, thus, feed attributes to a major cost component (Kumaratunga and Radampola 2019). Hence, developing a feed for guppy using low-cost, locally available ingredients would be a promising means for developing of ornamental fish rearing sector within the country. Further, preparation of fish feed will provide employments for local community facilitating a win-win solution for the country’s economy and the ecology.

Therefore, this study examines the feasibility of using SCM as a novel feed ingredient in fish feed preparation to develop new feed formulations and study the growth and feed performance of juvenile guppy fed with diets with SCM as a replacement for commercial fishmeal component. If this can be used as a low-cost alternative to the expensive imported fishmeal ingredient in the diets for cultured fish in Sri Lanka that would effectively establish a commercial market for unutilised sailfin catfish landings in Sri Lanka.

2 | METHODOLOGY

2.1 Fish collection and processing of sailfin catfish meal (SCM)

Sailfin catfish were caught from Udawalawe Reservoir (6° 26′39.8″N 80°50′07.1″E), Southern Province, Sri Lanka on 4th October 2016. Freshly caught fish were packed in iceboxes, transported to the laboratory of Department of Fisheries and Aquaculture, University of Ruhuna, Sri Lanka and stored at −20°C for 24 hours. Fish were thawed, length and weight of the fish were measured and dissected to remove the visceral organs (Panase et al. 2018). Then fish carcases were cut into small pieces and oven-dried at 60°C for 2 days. Completely dried fish were ground and sieved through 125 μm mesh to produce powdered SCM.

2.2 Experimental diets and proximate analyses

The proximate composition of FM (commercial fishmeal) and SCM are shown in Table 1. Basal ingredients were purchased from local markets in Sri Lanka (Table 2). Ingredients were ground and sifted through 125 μm mesh,
when necessary, to obtain fine powder before use them in feed preparation. In the control diet (CD), commercial fishmeal (FM-30%) was the main protein source whilst the other three diets FM was replaced one-third (10SCM), two-thirds (20SCM) and all of FM (30SCM) using SCM. Feed formulation and the proximate composition of experimental diets are presented in Table 2. All ingredients were mixed thoroughly by adding slightly warm water (60°C) to form a non-stick dough, steamed for 10 minutes and pelleted using a hand-held pellet machine. Feed pellets (4 mm) were air-dried to remove moisture, packed in airtight feed bags and freeze at −20°C until fed.

Proximate analyses were performed following AOAC (1990). Protein was established (N × 6.25) by the Kjeldahl method; crude lipid by the Folch method (Folch 1957); ash by combustion at 600°C in a muffle furnace for 8 hours; moisture by kept under the oven at 100°C to constant weight. Proximate composition of SCM and the commercial FM are given in Table 2.

### TABLE 1 Proximate composition of commercial fishmeal (FM) and sailfin catfish meal (SCM) (g 100g⁻¹ dry matter).

<table>
<thead>
<tr>
<th>Composition</th>
<th>FM (%)</th>
<th>SCM (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>6.1 ± 0.3</td>
<td>6.0 ± 0.2</td>
</tr>
<tr>
<td>Ash</td>
<td>20.9 ± 0.4</td>
<td>10.6 ± 0.2</td>
</tr>
<tr>
<td>Crude protein</td>
<td>61.1 ± 0.06</td>
<td>69.5 ± 0.04</td>
</tr>
<tr>
<td>Crude lipid</td>
<td>4.0 ± 0.02</td>
<td>4.5 ± 0.05</td>
</tr>
</tbody>
</table>

Values are means of triplicate groups ± SD

### 2.3 Experimental fish and feeding

Twenty-one days old male guppy fish (Poecilia reticulata, red-blonde) were purchased from Karandeniya ornamental fish farm, Sri Lanka and packed in aerated polythene bags and transported to the freshwater aquarium, Faculty of Fisheries and Marine Sciences and Technology, University of Ruhuna. Fish fry were kept at 50 L aerated fiberglass tanks for acclimatization for two weeks and fed with commercial Prima diet (43.9% CP and 12.2% L) (Kumaratunga and Radampola 2019). After two weeks, 120 guppy individuals of 1.98 ± 0.03 cm total length and 0.07 ± 0.02 g body weight were randomly assigned to 12 rectangular glass tanks (60 cm × 30 cm × 30cm) at the stocking density of 10 fish tank⁻¹. Fish were exposed to the natural photoperiod (12 h light: 12 h dark) and continuous aeration was supplied to the tanks.

Four diets were randomly assigned to tanks in triplicate and fish were fed manually up to satiation three times daily at 8:00, 12:00 and 16:00 for 42 days period. Feed consumption (g day⁻¹) in each tank was recorded daily. Tanks were cleaned every other day by siphoning out the waste and-refilling (1/5 of tank water) with dechlorinated tap water. Water temperature was monitored daily with a standardized mercury thermometer (°C) while pH was measured once per week using pH meter (EUTECH pH6, UK). Finally, total ammonia nitrogen (TAN) (mg L⁻¹) were measured in every two weeks by using a standard aqua test kit (ZOOLEK, Poland).

### TABLE 2 Feed formulations (g 100g⁻¹ dry matter) and proximate composition of (g 100g⁻¹ dry matter) experimental diets. CD, control with 30% FM; 10SCM, 10% of FM replaced by SCM; 20SCM, 20% of FM replaced by SCM; 30SCM, FM fully replaced by SCM.

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>CD</th>
<th>10SCM</th>
<th>20SCM</th>
<th>30SCM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fish meal</td>
<td>30</td>
<td>20</td>
<td>10</td>
<td>-</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>19</td>
<td>19</td>
<td>19</td>
<td>19</td>
</tr>
<tr>
<td>Coconut meal</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Wheat flour</td>
<td>14</td>
<td>14</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>Rice bran</td>
<td>11</td>
<td>11</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>Vitamin &amp; mineral</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Coconuat oil</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Sailfin catfish meal</td>
<td>-</td>
<td>10</td>
<td>20</td>
<td>30</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Proximate analysis (% dry weight)</th>
<th>Moisture</th>
<th>Ash</th>
<th>Crude protein</th>
<th>Crude lipid</th>
<th>NFE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>7.5</td>
<td>7.3</td>
<td>7.6</td>
<td>7.9</td>
<td></td>
</tr>
<tr>
<td>Ash</td>
<td>11.0</td>
<td>10.9</td>
<td>10.4</td>
<td>10.7</td>
<td></td>
</tr>
<tr>
<td>Crude protein</td>
<td>34.5</td>
<td>34.7</td>
<td>35.0</td>
<td>38.7</td>
<td></td>
</tr>
<tr>
<td>Crude lipid</td>
<td>7.43</td>
<td>7.56</td>
<td>7.78</td>
<td>8.01</td>
<td></td>
</tr>
<tr>
<td>NFE</td>
<td>39.57</td>
<td>39.54</td>
<td>39.22</td>
<td>34.69</td>
<td></td>
</tr>
</tbody>
</table>

^a Danish fishmeal

^b Starter premix B (Nishshanka et al. 2021)

^c NFE = Nitrogen free extracts, calculated as 100 − (%Moisture + %Protein + %Lipid + %Ash + %Fibre). (Thompson et al. 2006).

### 2.4 Growth performance

The total length (cm) and total body weight (g) of individual fish were measured using the measuring board and the analytical balance (OHAUS-Pioneer) at the beginning and in every two weeks. At the end of the study period, fish were sacrificed, and the liver was removed. Liver was taken, and hepatosomatic index (HSI) was computed. Average daily gain (ADG), specific growth rate (SGR), feed conversion ratio (FCR) and HSI were calculated according to the standard equations (Ricker 1979).

\[
\text{Daily food consumption (BW day}^{-1}) = \frac{\text{Daily food consumption (g)}}{\text{Body weight (g)}} \times 100
\]

\[
\%\text{ADG (g day}^{-1}) = \frac{[\text{Final weight} - \text{Initial weight}]}{\text{Time (days)}]} \times 100
\]

\[
\%\text{SGR (g day}^{-1}) = \frac{[\text{In}\finalweight - \text{In}\initialweight]}{\text{Time (days)}]} \times 100
\]

\[
\text{FCR = } \frac{\text{Total feed consumed (g) }}{\text{Body weight gain (g)}}
\]

\[
\text{HSI = } \frac{\text{Liver weight (g)}}{\text{Body weight (g)}} \times 100
\]

\[
\%\text{Survival rate = } \frac{\text{No. of fish at the end of the experiment}}{\text{No. of fish stocked at the beginning}} \times 100
\]
The economic analysis was used to determine the cost-effectiveness of the experimental diets based on the local market price in Sri Lanka (in Sri Lankan rupee, LKR; 1 USD = 199.7 LKR). Profit index and the incidence cost were calculated according to (El-Dakar et al. 2007).

Profit index = \( \frac{\text{Value of fish (Rs)}}{\text{Cost of feed (Rs)}} \)

Incidence cost = \( \frac{\text{Cost of feed (Rs)}}{\text{Weight of fish produced (g)}} \)

**2.5 Data analysis**

All the statistical analyses were performed using the SPSS statistical package (SPSS 16.0) and the data presented as Mean ± SD. For parametric data, Levene’s test was used to test the homogeneity of variance. Final body length and weight data of guppy and HSI were subjected to Randomized block ANOVA model. Daily feed consumption, FCR, %ADG, %SGR and survival data were assessed using one-way analysis of variance (ANOVA). Duncan multiple range test was used to distinguish differences between treatments. For non-parametric data, Kruskal-Wallis test was conducted followed by the Dunn’s multiple comparison test. An α significance level of 0.05 was used to indicate the significant differences.

**TABLE 3 Growth parameters of guppy (Poecilia reticulata, as mean ± SD) fed on different diets over the 42 days of the experimental period. CD, control with 30% FM; 10SCM, 10% of FM replaced by SCM; 20SCM, 20% of FM replaced by SCM; 30SCM, FM fully replaced by SCM.**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Experimental Diet</th>
<th>CD</th>
<th>10SCM</th>
<th>20SCM</th>
<th>30SCM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial total length (cm)</td>
<td>1.99 ± 0.88a</td>
<td>2.01 ± 0.10a</td>
<td>1.97 ± 0.84a</td>
<td>2.01 ± 0.10a</td>
<td></td>
</tr>
<tr>
<td>Initial total body weight (g)</td>
<td>0.07 ± 0.02a</td>
<td>0.07 ± 0.02a</td>
<td>0.07 ± 0.018a</td>
<td>0.07 ± 0.02a</td>
<td></td>
</tr>
<tr>
<td>Final total length (cm)</td>
<td>2.80 ± 0.18a</td>
<td>2.83 ± 0.19ab</td>
<td>2.82 ± 0.18ab</td>
<td>2.91 ± 0.25ab</td>
<td></td>
</tr>
<tr>
<td>Final total body weight (g)</td>
<td>0.29 ± 0.08a</td>
<td>0.28 ± 0.06a</td>
<td>0.29 ± 0.06a</td>
<td>0.29 ± 0.08a</td>
<td></td>
</tr>
<tr>
<td>% ADG</td>
<td>7.54 ± 0.69a</td>
<td>6.75 ± 0.69a</td>
<td>8.20 ± 0.88a</td>
<td>7.13 ± 1.92a</td>
<td></td>
</tr>
<tr>
<td>% SGR</td>
<td>3.39 ± 0.16a</td>
<td>3.19 ± 0.18a</td>
<td>3.55 ± 0.19a</td>
<td>3.26 ± 0.48a</td>
<td></td>
</tr>
<tr>
<td>FCR</td>
<td>2.21 ± 0.26a</td>
<td>2.0 ± 0.20a</td>
<td>1.84 ± 0.43a</td>
<td>1.77 ± 0.16a</td>
<td></td>
</tr>
<tr>
<td>Food consumption (%BW day⁻¹)</td>
<td>9.30 ± 0.10a</td>
<td>9.33 ± 0.21a</td>
<td>9.45 ± 0.50a</td>
<td>9.36 ± 0.71a</td>
<td></td>
</tr>
<tr>
<td>%HSI</td>
<td>0.5 ± 0.008a</td>
<td>0.6 ± 0.002a</td>
<td>0.5 ± 0.006a</td>
<td>0.5 ± 0.003a</td>
<td></td>
</tr>
<tr>
<td>% Survival</td>
<td>90.0 ± 10.0a</td>
<td>90.0 ± 10.0a</td>
<td>86.67 ± 15.27a</td>
<td>80.0 ± 20.0a</td>
<td></td>
</tr>
</tbody>
</table>

Different lowercase letters indicate the significant difference among treatments (p < 0.05).

**3.2 Water quality analysis**

During the experimental period water temperature, pH, and TAN did not change significantly among the treatments (all p > 0.05). Water temperature ranged from 26.9 to 27.0°C while pH varied from 7.0 to 7.1. In addition, at all-time points, TAN levels were closer to zero (Table 4).

**3.3 Cost analysis**

The cost of per kg experimental diets varied from 109 to 181 LKR. The CD diet which consisted of 30% of FM had the highest cost compared to the diets including SCM (Table 5). Significant profit index was recorded for the diets containing SCM when compared to the CD (Table 5). The opposite trend was observed for the incidence cost where 30SCM yielded the lowest value (Table 5). However, profit index and incidence cost did not significantly differ between 20SCM and 30SCM (Table 5).

**4 DISCUSSION**

Invasion of sailfin catfish has been recognised as a serious threat to reservoir ecosystem functioning and the local capture fishery in Sri Lanka (Wickramaratne et al. 2017a). As this fish group is not utilised in a productive way, it becomes an unwanted fishery resource as well as an envi-
Sailfin catfish meal as ingredient in guppy feed

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Environmental pollutant near the inland freshwater reservoirs within the country (Wijesinghe et al. 2021). In the present study an attempt was taken to utilise this under-utilised fishery resource into a valuable commodity in aquaculture industry which may give a practical solution to the problem of invasion. The experiment assessed the potential of SCM as a commercial expensive FM replacement in the diets of juvenile guppy fish, a popular ornamental fish in Sri Lanka. As hypothesised, there was no significant difference observed in growth responses between the levels of fishmeal protein replacement by the SCM.

The results clearly showed that, no significant difference was observed in terms of daily feed consumption, %SGR, %ADG, FCR and final body weight of fish fed experimental diets with SCM. Low FCR indicates the better conversion of protein into the body tissues. The results give positive insights of utilising this novel ingredient of SCM to fully replace the fishmeal in the diets of juvenile guppy fish without any adverse effect on fish growth.

Panase et al. (2018) reported that Pterygoplichthys pardalis meal contains 54% protein and 6% fat. Present study also represents a close percentage of protein and lipid contents, 69.5% and 4.5% respectively. However, Asnawi et al. (2015) stated the protein and lipid contents

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Experimental diets</th>
<th>CD</th>
<th>10SCM</th>
<th>20SCM</th>
<th>30SCM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature (°C)</td>
<td>26.97 ± 0.28</td>
<td>26.97 ± 0.01</td>
<td>27.0 ± 0.01</td>
<td>27.0 ± 0.01</td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td>7.12 ± 0.01</td>
<td>7.12 ± 0.06</td>
<td>7.12 ± 0.01</td>
<td>7.12 ± 0.01</td>
<td></td>
</tr>
<tr>
<td>TAN</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

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<td>27.0 ± 0.01</td>
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</tr>
<tr>
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<td>7.12 ± 0.01</td>
<td></td>
</tr>
<tr>
<td>TAN</td>
<td>0</td>
<td>0</td>
<td>0</td>
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of sucker mouth armoured catfish as 37% and 16.9% respectively.

TABLE 5 Cost of producing one kg of feed in Sri Lankan Rupees (LKR), profit index and Incidence cost for different experimental diets (n = 3, mean ± SD). CD, control with 30% FM; 10SCM, 10% of FM replaced by SCM; 20SCM, 20% of FM replaced by SCM; 30SCM, FM fully replaced by SCM.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Experimental diets</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CD</td>
</tr>
<tr>
<td>Total cost (LKR kg⁻¹)</td>
<td>180.5</td>
</tr>
<tr>
<td>Profit index</td>
<td>5.17 ± 4.43⁷</td>
</tr>
<tr>
<td>Incidence cost</td>
<td>0.55 ± 0.01⁵</td>
</tr>
</tbody>
</table>

Total cost was calculated in Sri Lankan Rupees (LKR), where 199.7 LKR = 1 USD. Total cost = Ingredient cost + Preparation cost (LKR20 kg⁻¹).

Market prices (LKR kg⁻¹): fish meal: LKR.300, soybean meal: LKR.113, coconut meal: LKR.40, rice bran: LKR.30, wheat flour: LKR.97, vitamin-mineral mixture: LKR.1800, Coconut oil: LKR.680. It was assumed that preparation costs (electricity, labour) were same for all and the preparation cost for feed was assumed LKR 20 kg⁻¹.

The differences in composition could be due to the species difference or based on the different laboratory procedures practices in the experiments. It was established that sailfin catfish is a rich source of essential amino acids, calcium and phosphorus (Asnawi et al. 2015). The diets used in the present study had 34 – 39% protein and 7 – 8% lipids which is in accordance with the requirements of protein 30 – 40% and lipid 4 – 9% levels for growth of guppy (National Research Council 1993). Comparing our results with similar study, Panase et al. (2018) have shown that P. pardalis meal can be used to fully replace the FM for Mekong catfish (Pangasiadodon gigas) besides its decreasing trend in the growth performance after the replacement of 75% fishmeal. As such, fishmeal replacement level is largely depended on nutritional requirement and the physiology of the fish feeding on the test diet. Therefore, future studies for extended period of feeding trials followed by blood parameters to measure the nutritional and health status (Madibana et al. 2017) are recommended for guppy fish. Serum biochemical parameters like serum protein, cholesterol, and triglycerides vary with the dietary protein in fish diets and play a key role in defining the health status of fish (Hrubec et al. 2001).

Nevertheless, water quality parameters measured were within the range for normal growth of guppy. These are usually known as hardy fish which can survive in harsh environmental conditions (Fernando and Phang 1994). However, the present study experienced drastic weather condition and sudden changes from long sunny days to cold rainy days although fish were reared inside the aquarium. During the first two weeks fish had to undergo with stressful events such as moving from acclimatization tanks to experimental setup, length weight measurements followed by severe weather conditions that can negatively affect the fish health. The caused for the mortalities has been recognised as the post-stress after the initial length weight measurements and experiencing cooler temperature after a heavy rain during the initial phase of the experiment. However, after the first two weeks of the experiment, no death or lethargic behaviour was observed.

Cost analysis revealed that on-farm preparation of SCM can be profitable than buying expensive commercial fishmeal to produce diets for guppy fish. Sailfin catfish are freely available at local fish landing sites near freshwater reservoirs and the drying and grinding of fish to produce SCM can be done with very low cost. On-farm feed preparation is very common practice among most of small-scale ornamental fish farmers in Sri Lanka (Athukorala 2017). Also, powder or dough are found to be effective than feed pellets for guppies (Harpaz et al. 2005). On the other hand, if community based SCM processing places can be established around local reservoirs e.g. Udawalawe, the surrounding ornamental fish breeders can get the benefit over it.

Replacement of commercial fishmeal with locally prepared fishmeal is not uncommon in nutrition studies. It was identified as one of the most effective protein sources based on the nutrition profile compared to plant-based foodstuffs. For instance, dried fish powder of minor cyprinids (Dawkinsia singhala and Puntius chola), which is not a traditional source of preparing fishmeal, has been described as a very promising source for koi carp Cyprinus carpio diets (Weerasingha et al. 2017). The use of invasive species in fishmeal preparation has been discussed in the literature in terms of mitigating their negative impacts and intensifying the aquaculture practices. For instance, knife fish meal (Abarra et al. 2017), Asian carp (Bowzer et al. 2014), sucker mouth catfish (Panase et al. 2018) and apple snail (Jintasataporn et al. 2004) have provided excellent fishmeal substitutes in the diets of food fish species. Literature on the use of SCM as a fishmeal substitute in ornamental fish species in Sri Lanka is scarce. Therefore, future studies are required to explore the current limitations such as revealing the fatty acid and amino acid profile of SCM and importantly, colour additives to enhance the body colouration of ornamental fishes, a lucrative business in Sri Lanka.

5 CONCLUSIONS

In summary, invasive sailfin catfish meal can be utilised as an alternative to commercial fishmeal in the diets of ju-
venile guppy fish without any adverse effect on their growth. Therefore, this is a practical solution to encourage the local ornamental fish farmers and simultaneously, eradicating the invasive threat from local reservoirs in Sri Lanka.

ETHICAL APPROVAL
The scientific and ethical responsibility of the animal experiment belongs to the author(s). No committee established on the ethics in the institution at when the experiment was performed. However, fish were killed using MS222 anaesthesia for HSI index, and all efforts were made to minimise suffering.

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CONFLICT OF INTEREST
The authors declare no conflict of interest.

AUTHORS’ CONTRIBUTION
Conceptualization, RdF & KR; data curation, RdF & KR; formal analysis, KR; investigation, RdF; methodology, RdF & KR; project administration, KR; resources, KR; supervision, KR; visualisation, RdF & KR; writing - original draft, RdF; reviewing and editing RdF & KR.

DATA AVAILABILITY STATEMENT
The data that support the findings of this study are available on request from the corresponding author.

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Sailfin catfish meal as ingredient in guppy feed

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