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43/2 Varadarajulu Nagar, 5th Street West, Ganapathy, Coimbatore, Tamil Nadu 641006, India
Registered Office: 3A2 Varadarajulu Nagar, FCI Road, Ganapathy, Coimbatore, Tamil Nadu 641006, India
Ph: +91 9385339863 | www.threatenedtaxa.org
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Cover: Mixed media illustration of a Blue bird and Sunbird. © Lakshmi Niranjana.



The opportunistic feeding behaviour of *Schistura notostigma* (Teleostei: Nemacheilidae) in tropical mountain streams in Sri Lanka

J. Bandara¹ , M.P. Gunawardena² & R.T.P. Jayasuriya³

^{1,2,3} Faculty of Science, Horizon Campus, Knowledge City Malabe, KCM Drive, Off Millennium Road, Malabe, 10115, Sri Lanka.

² Biodiversity Educational Research Initiative (BERI), LE CUBE, No. 130, High Level Road, Colombo 06, 00600, Sri Lanka

² Thema Collection, LE CUBE, No. 130, High Level Road, Colombo 06, 00600, Sri Lanka.

¹janaminabandara@gmail.com (corresponding author), ²medhisha@gmail.com, ³ravishkajayasuriya@gmail.com

Abstract: *Schistura notostigma* is a bottom-dwelling freshwater fish endemic to Sri Lanka. In this study, we document an opportunistic feeding behavior exhibited by this loach species in close association with *Garra ceylonensis* and *Plesiopuntius bimaculatus* in the streams of high-elevation headwater regions of the Knuckles Mountain Range and Piduruthalagala Mountain Range in Sri Lanka.

Keywords: Feeding ecology, behavioural ecology, coexistence, commensalism

Schistura notostigma (Bleeker, 1863) is a small, bottom-dwelling freshwater fish endemic to Sri Lanka. It features an elongated, moderately cylindrical body that is ventrally flattened and slender, and possesses three pairs of small barbels, which characteristics are shared by many benthic freshwater fishes (Pethiyagoda 1991; Sundarabarathy et al. 2001; Herath 2009; Shirantha 2021). In this study, we document instances of opportunistic feeding behavior exhibited by this loach. These behaviors were observed frequently in the close association with two species of the family Cyprinidae,

Garra ceylonensis (Bleeker, 1863) and *Plesiopuntius bimaculatus* (Bleeker, 1863), in streams situated in high elevation headwater regions of the Knuckles Mountain Range (KMR) and Piduruthalagala Mountain Range (PMR).

Schistura notostigma (Image 1A) is one of the few freshwater fishes found at elevations exceeding 1,000 m in Sri Lanka, along with *Garra ceylonensis* (Image 01B), *Plesiopuntius bimaculatus* (Image 01C) and *Devario* spp. (Pethiyagoda & Sudasinghe 2021). Although *S. notostigma* can sometimes be found at elevations above 1,300 m, the other species mentioned generally inhabit elevations up to 1,000 m, albeit with rare exceptions (Pethiyagoda & Sudasinghe 2021; Sudasinghe et al. 2021, 2023). Despite our observations indicating that *S. notostigma* could occasionally be the sole freshwater fish in high-elevation habitats, however, it exhibits a notable inclination to associate closely with *G. ceylonensis* when present in the ichthyo-community as associates.

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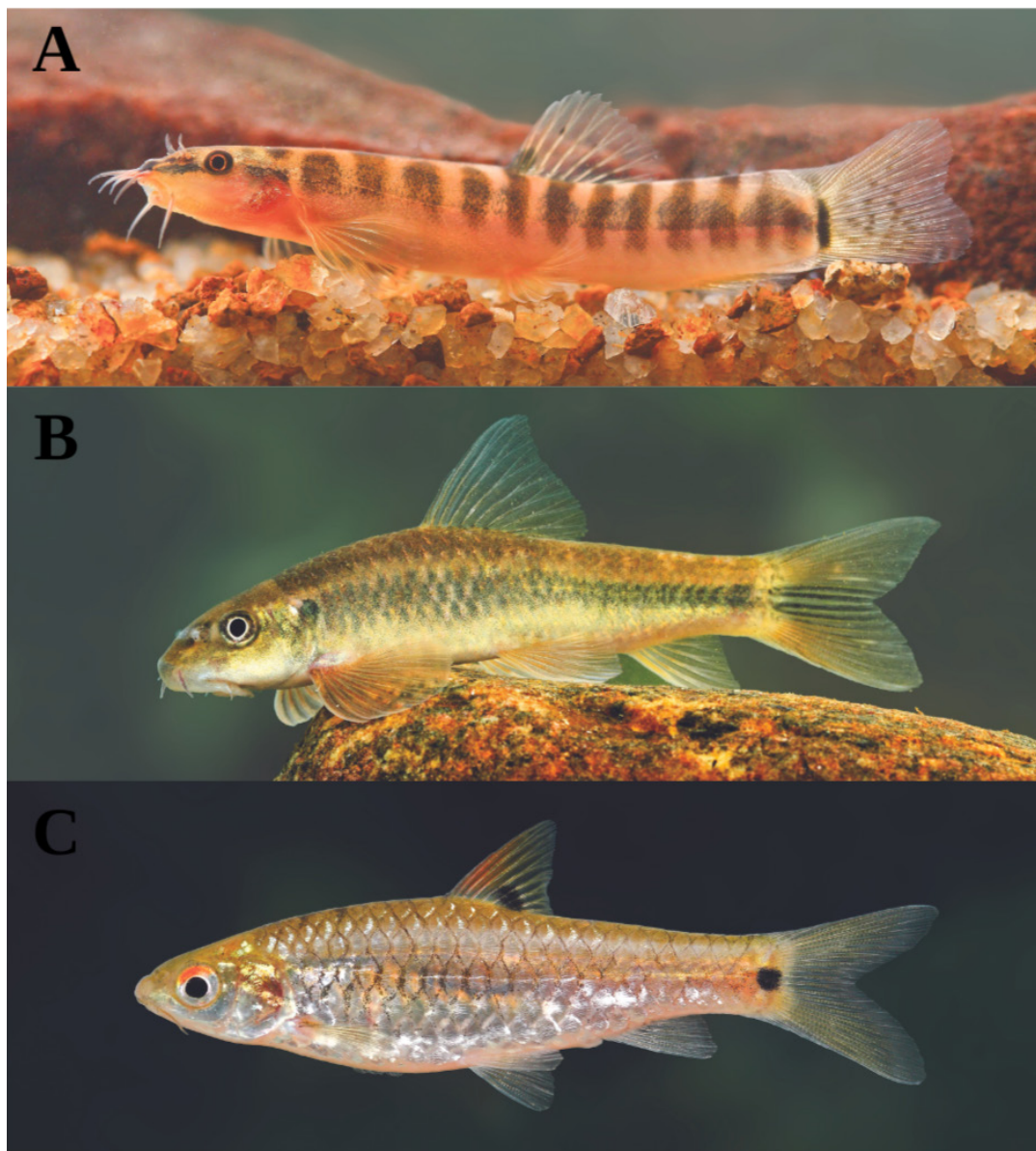


Image 1. Three benthic co-existing species from tropical mountain streams of Sri Lanka: A—Banded Mountain Loach *Schistura notostigma* | B—Ceylon Stonesucker *Garra ceylonensis* | C—Red-side Barb *Plesiopuntius bimaculatus*. © Madura De Silva & Wildlife Conservation Society, Galle (WCSG).

MATERIALS AND METHODS

The present study was conducted as part of an ongoing research project on Sri Lankan freshwater fishes. The study was carried out in Mandaramnuwara, situated on the eastern slopes of PMR at an elevation of 1,000 m. PMR study site is a circular area with a 5-km radius centered on coordinates 7.0638°N, 80.7652°E, situated in the Belihul Oya (river) headwaters, near Kalu Palama Ella, and in Medadumbara, on the southern flank of KMR at 590 m. KMR study site is a circular area of 5-km radius, centered at 7.3475°N, 80.8202°E in the Heel Oya and Galmal Oya headwater regions (Figure 1).

Five points were arbitrarily selected for observation from each site within the specified range. These observations spanned a 12-month period from November 2022 to October 2023. Observations were made monthly (five days per month from 0700–1800 h) using remote underwater video footage (GoPro Hero 9 action camera) and snorkelling. Fish identification was performed in the field using the latest field guides (De Silva et al. 2015; Shirantha 2021) and later confirmed by reference to recent publications (Sudasinghe 2017, 2018). During the species identification process, fishes were captured using a scoop-net and immediately released to their

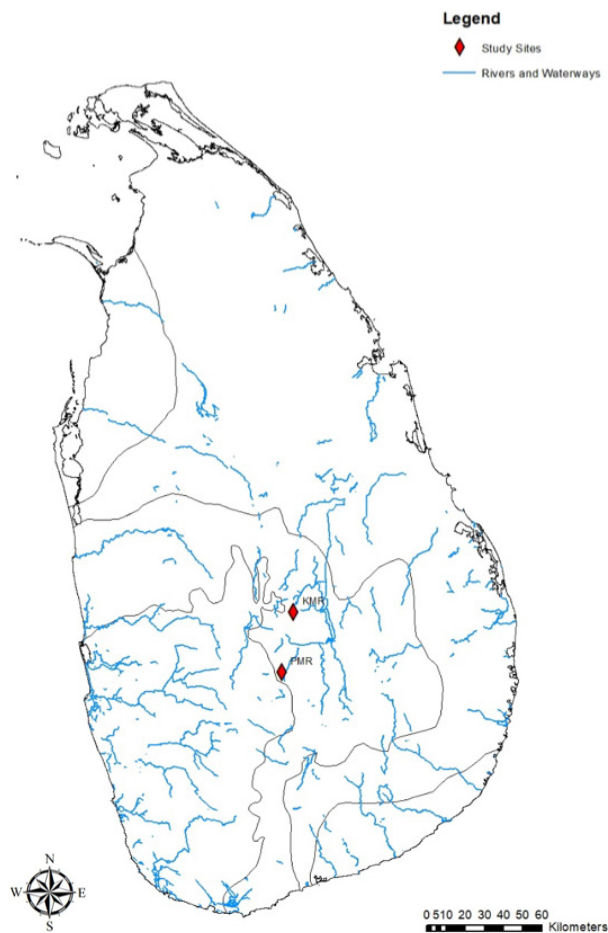


Figure 1. The locations of the study sites in Sri Lanka. KMR—Knuckles Mountain Range | PMR—Pidurutalagala Mountain Range.

original habitats.

OBSERVATIONS AND DISCUSSION

Garra ceylonensis and *Schistura notostigma* (at an elevation range of 590–1,350 m in KMR and PMR) exhibit a close association and a commensalism relationship as follows: *G. ceylonensis* was observed grazing on algae on the rocky substrate, using its sucker mouth (Sudasinghe et al. 2021), causing small invertebrates and other food particles to be detached. The opportunistic species *S. notostigma* then exploits this disturbance by browsing on the dislodged food particles (see Image 2A,B).

Analysis of diets, notwithstanding different degrees of selectivity for various food categories, showed both species to be omnivorous (confirmed through gut content analysis in prior studies and references in: Moyle & Senanayake 1984; Wikramanayake & Moyle 1989; Sundarabarathy et al. 2001, 2005; Shirantha 2004; Pethiyagoda & Sudasinghe 2021). However, *S. notostigma* was found to primarily feed on a variety

of small invertebrates, especially caddisfly larvae (Trichoptera: Hydropsychidae and Rhyacophilidae) and small mayfly larvae (Ephemeroptera: Leptophlebeidae) (Moyle & Senanayake 1984). Furthermore, Moyle & Senanayake (1984) suggest carnivory as the dominant mode of feeding for this loach, highlighting the short intestine (less than $1 \times$ body length) and the observed willingness of *S. notostigma* to attack small benthic prey. On the other hand, *G. ceylonensis* is mentioned as a benthic algae feeder in Sudasinghe (2021) by referring to Lujan & Conway (2015) and Kottelat (2020). Moreover, Moyle & Senanayake (1984) also showed *G. ceylonensis* to be primarily a detritus and diatom feeder, based on a gut content analysis in Costa & Fernando (1967). Furthermore, studies conducted by Wikramanayake & Moyle (1989) and Moyle & Senanayake (1984) in rainforest streams and lowland wet zone streams show that there is no statistically significant dietary overlap among *G. ceylonensis* and *S. notostigma*. Therefore, based on the diet and behaviour, we hypothesize this association as a commensal relationship, in which *S. notostigma* benefits substantially more, rather than a mutualism in which both species benefit.

A similar set of observations were also recorded with schools of *Plesiopuntius bimaculatus* in the KMR during the study period (recorded in five occasions specifically during March 2023 and April 2023), which also confirmed the opportunistic feeding behaviour of *S. notostigma*. Here, *S. notostigma* followed the schools of foraging *Pl. bimaculatus*, feeding on food particles sinking to the substrate.

In this case of *S. notostigma*, given the absence of any recorded negative interactions up to date, whether of a predatory or competitive nature between these species (*G. ceylonensis* and *S. notostigma* or *Pl. bimaculatus* and *S. notostigma*), we suggest that opportunistic feeding behaviours and close associations may enable these species to access food sources more easily and with less competition. This becomes especially pertinent in high-elevation tropical mountain regions, where co-evolved fishes and other vertebrate species are recognized to have a high degree of adaptation to their environments, as described in Abell et al. (2008).

In addition to *S. notostigma*, similar opportunistic feeding behaviours have been observed in other benthic loach species, including *Misgurnus anguillicaudatus* (Cantor, 1842) as documented by VanHaitsma (2020) and McNair et al. (2023), *Misgurnus fossilis* (Linnaeus, 1758) as reported by Pyrzanowski et al. (2019), and *Barbatula barbatula* (Linnaeus, 1758) as noted by Andrei et al. (2015) and Worischka et al. (2015). Furthermore,

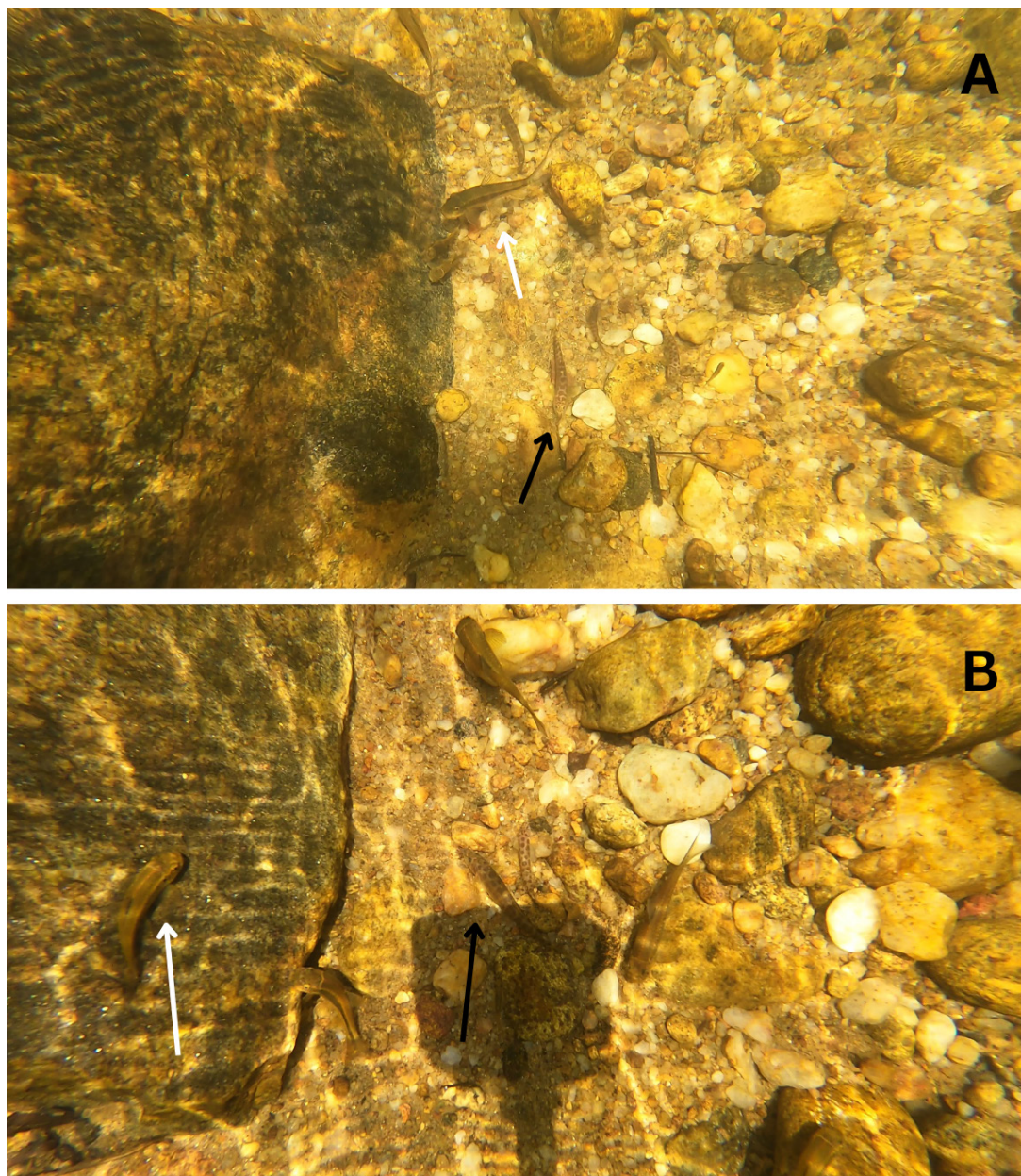


Image 2A,B. Close association of *Garra ceylonensis* (GC) and *Schistura notostigma* (SN) recorded frequently in Heel Oya, southern flank of Knuckles Mountain Range, Sri Lanka. GC pointed by the white arrowheads and SN by the black arrowheads. © Janamina Bandara.

Rice et al. (2019) too, make reference to several unique benthic feeding behaviours of fishes.

Pethiyagoda & Sudasinghe (2021) also make reference to a similar set of ecological interactions among Sri Lankan freshwater fishes, originally documented by Schut et al. (1984). These interactions involve *Rohanella titteya* (Deraniyagala, 1929) and *Pl. bimaculatus*, as well as juvenile *Dawkinsia fillementosa* (Valenciennes, 1844) and adult *Pethia cuningii* (Günther, 1868). These associations can be succinctly summarized as optimizations of dietary habits and the avoidance of

shared predators.

Apart from *G. ceylonensis*, *S. notostigma*, and *Pl. bimaculatus*, only *Devario malabaricus* (Jerdon, 1849) and *Poecilia reticulata* (Peters, 1859) were found inhabiting the high-elevation regions in KMR (600 m) (Pethiyagoda & Sudasinghe 2021; Bandara & Gunawardena 2023a,b). No other freshwater fishes were recorded in headwaters of the PMR study site, except for *G. ceylonensis* and *S. notostigma*. Generally, it shows a lower fish diversity in high-elevation tropical freshwater fish assemblages recorded above 1,000 m elevation, when compared to

lowland assemblages in the island's south west wet zone (Sumith et al. 2011; Pethiyagoda & Sudasinghe 2021; Sudasinghe et al. 2023). In this case we believe that the opportunistic feeding of *S. notostigma* reported here could be a common behaviour with the co-occurring benthic species *G. ceylonensis* and *Pl. bimaculatus*.

CONCLUSION

In conclusion, frequent occurrences of the aforementioned ecological associations and interactions provide insight into the feeding behaviours of this benthic loach species. Moreover, these records also offer vital information that can be used to understand the ecological structure of tropical freshwater fish assemblages in high-elevation mountain streams (1,000 m) in Sri Lanka.

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Prof. Karan Bahadur Shah, Budhanilakantha Municipality, Kathmandu, Nepal
Dr. Susan Cheyne, Borneo Nature Foundation International, Palangkaraja, Indonesia
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Dr. Mandar S. Paingankar, University of Pune, Pune, Maharashtra, India (Molecular)
Dr. Jack Tordoff, Critical Ecosystem Partnership Fund, Arlington, USA (Communities)
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Tamil Nadu 641006, India
ravi@threatenedtaxa.org

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