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Unveiling Fish Community Response to Anthropogenic Stressors in Tributary Streams of Pamba River in the Western Ghats

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ABSTRACT

The anthropic impact on stream environments is increasing uncontrollably and affecting rich biodiversity. The intensity of anthropogenic stressors and their influence on the fish community was studied from the tributary streams of the Pamba river in the Western Ghats from January to December 2019. We quantified the anthropogenic stressors using a metric scale, which combines the severity and proximity of the stressor to the stream environment. Agricultural practices, riparian cover removal, hydrologic modifications, tourism, and pilgrimage were recorded as major stressors in the investigated streams. In this study, human pressure significantly affected the ichthyofaunal community in the streams. Generalists were found to be more tolerant of environmental stress in their respective sites, whereas specialists were adversely affected. The stream with a high intensity of stressors supported greater ichthyofaunal diversity, especially those of generalist fishes. Streams with an intermediate level of disturbances were noted to support high species richness. In the Western Ghats streams in Kerala, the ichthyofaunal response to human pressure is not well documented. This study is the first of its kind to concentrate on how ichthyofauna reacts to stressors caused by humans. The variety of stream fish assemblages in the Western Ghats must be preserved, which calls for regular monitoring of stressors.

Key words: *Stressors, Stream fishes, Eco-degradation, Specialists, Generalists*

Introduction

The interactions that living things have with one another and their surroundings are incredibly intricate. As a result of rising human activity, biodiversity loss is accelerating on a regional or global level across a variety of ecosystems. The sustainability of ecological processes and the provision of ecosystem services are both threatened by biodiversity erosion. The growing population poses serious threats to the aquatic resources of the Western Ghats in Kerala. The main causes of hydrological perturbations in the lower-order streams are development projects, agricultural practices, damming activities in headwaters, significant changes in riparian vegetation, and traditional fishing techniques. The alteration of the river flow regime caused habitat loss, fragmentation, and related biodiversity loss. Freshwater fish are more sensitive to changes in the aquatic environment; they are therefore regarded as the taxonomic groups that are most in danger (Darwall and Vie, 2005). An aquatic ecosystem may experience long-term effects from implications on a species or a non-living component. Among the aquatic inhabitants, fishes are more vulnerable to changes in water chemistry and river network connectivity.

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The Pamba river, popularly known as 'Southern Ganga' is investigated for manifold human activities and associated pollution in its whole catchment area due to pilgrimage, agricultural practices, and land-use patterns (Bhaskaran and Prateesh, 2008; Sajudeen *et al*. 2012; Shilly *et al*. 2016; Maya, 2017; John, 2020). Varghese (2012) asserts that unregulated tourism operations, especially religious tourism, have significantly harmed the Pamba river and caused it to be highly contaminated and polluted. Hydrologic changes in river basins are significantly influenced by the climate changes brought on by the human-centric environment. According to Sudheer *et al*. (2019), in addition to physical and topographical characteristics, the spatio-temporal distribution of rainfall is essential for determining the river basin's hydrologic response. The temporal and environmental factors that influence the structure of fish communities in two Indian streams were examined by Mondal and Bhat (2020). In the Indian context, the ichthyofaunal response to human pressure is not well documented.

The objectives of the present study were to (1) quantify the intensity of human disturbances in the stream ecosystems (2) evaluate the consequences of stressors on aquatic ecosystems and ichthyofauna (3) predict the effect of disturbances on ichthyofaunal diversity to guide conservational efforts and the management of riverine resources. This paper is the first of its kind to focus on the response of ichthyofauna to anthropogenic stressors, occurring in tributary streams of the Pamba river in the Western Ghats. The implications for both generalist and specialist species were also well covered in this paper.

Materials and Methods

Study Area

The quantification of stressors and their effect on the ichthyofauna was investigated from five tributary streams of the Pamba river in the Western Ghats (Fig. 1). Four stream systems: Nilackal-Kaduvappara (S1), Karimthookku (S2), Veluthodu (S3), and Chorakakki (S4) are located in the plateaus of Goodrical reserve forests. While, the fifth stream, Chekuthanthodu (S5) flows through the domestic areas of the Ranni Forest Range. The stream systems lie between 76° 55' and 77° 17' E longitude and between 9° 10' and 9° 30' N latitude, at an altitudinal range of 100 to 1400 m.

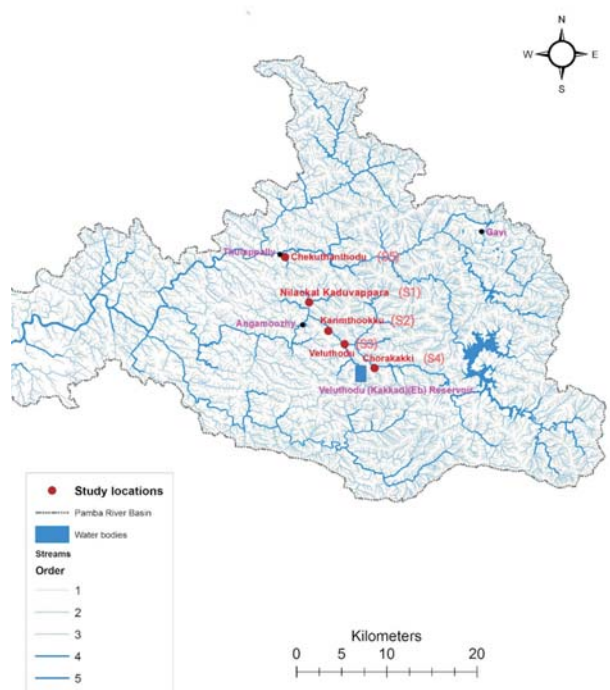


Fig. 1. Location of analysed streams in the Pamba river basin

Quantification of anthropogenic stressors in the stream environment

The degree of human interference with the stream environment was determined by creating a scoring system. The Minnesota Pollution Control Agency's human disturbance scoring system-2006 version (MPCA, 2016) was used as a foundation for the creation of the new scheme. The anthropogenic stressors found in the examined stream segments were categorised into the "human disturbance activity class" with six components (Agricultural activities, Hydrologic modification, Riparian zone change, Tourism, Pilgrimage, and Miscellaneous activities). Each component is given a severity rating on a metric scale from 0 to 10. A five-metric scale is used to measure the stressor's proximity to the stream environment. Combining the severity of the stressor and the proximity of the stressor to the stream environment, the degree of anthropogenic stress (D_{AS}) in every single stream is assessed. The Most Probable Number (MPN) method was used to assess the amount of Coliform in the water (Bartram and Ballance, 1996). The sample for this was taken from the stream that flows through the domestic areas and with pilgrim activity; other streams are avoided.

Ichthyofaunal assessment

Ichthyofaunal specimens were collected on a monthly basis from January to December 2019, using cast nets and scoop nets. The collected fishes from the streams were preserved in a 10% formalin solution. Species-level identification was done using the standard keys developed by Talwar and Jhingran (1991), Jayaram (1999), and Froese and Pauly (2021). Using the number of distinct species discovered during the sampling process, the ichthyofaunal abundance was calculated.

Statistical analysis

A correspondence Analysis (CA) was used to visualise the influence of stressors on the fish community in the investigated streams. Kendall's tau correlation was performed to analyse the impact of stressors specifically on the individual fish species and the result is depicted visually as a corrplot. The relationship is considered strong when the Tau correlation coefficient (τ) is equal to 0.786. The corrplot uses circles to show the strength and direction of correlation; blue circles indicate a positive correlation, and red circles indicate a negative correlation. The name of the fish species was entered as species codes (Appendix) for the correspondence and correlation analysis.

Species richness and diversity patterns at each site were assessed with individual-based rarefaction curves, constructed using the algorithm of Krebs (1989).

All calculations were performed using the PAST software of version 4.03.

Results and Discussion

Anthropogenic stressors in the investigated streams

The degree of human intervention in the area is largely determined by the land use pattern along the stream continuum; and the surveyed streams experienced significant heterogeneity in the type and intensity of anthropogenic stressors (Table 1, Fig. 2).

Developmental activities in the headwater streams lead to hydrologic modification in the form of stream bank erosion, destabilisation of the pool-riffle pattern, instability of the stream bed, and flow regulation or modification.The assessment of anthropogenic stressors in the tributary streams of the Pamba river revealed that the S5 experiences a high degree of anthropogenic stress (D_{AS}=175) as it flows through the domestic areas with agricultural and pilgrimage activities. During the Sabarimala pilgrimage season, the MPN count (most probable number count) of this stream was noted at 1100/100 ml, while it dropped to 250/100 ml in the off-season of 2019. However, the corresponding stream shows a consistent level of coliform bacterial presence in both seasons. The year-round bathing, washing, and domestic use of stream water by the locals are found to be the cause of the coliform presence. In the Pamba basal area, Soorya (2021) measured a total coliform count ranging from 4000 to 78000 MPN per 100 ml. And demonstrated that, over time, coliform

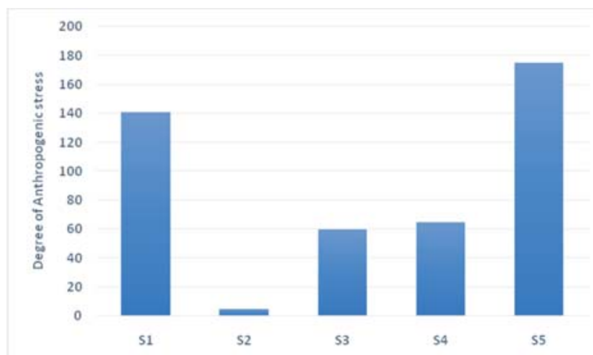


Fig. 2. Degree of human intervention recorded from tributary streams of the Pamba river in the Western Ghats

Table 1. Anthropogenic stress evaluated in tributary streams of Pamba river

Human Disturbance Activity Class	S1		S2		S3		S4		S5	
	1^0 Metric	Proximity Score	1^0 Metric	Proximity Score	1^0 Metric	Proximity Score	1^0 Metric	Proximity Score	1^0 Metric	Proximity Score
Agriculture	0	0	0	0	0	0	0	0	10	5
Hydrologic Modification	10	5	0	0	9	5	0	0	4	5
Riparian Zone Change	7	3	0	0	3	5	10	5	1	5
Tourism	2	5	0	0	0	0	1	5	0	0
Pilgrimage	2	5	0	0	0	0	0	0	10	5
Miscellaneous	10	5	1	5	0	0	2	5	10	5

Appendix

Species codes assigned to fishes listed from tributary streams of the Pamba river in the Western Ghats

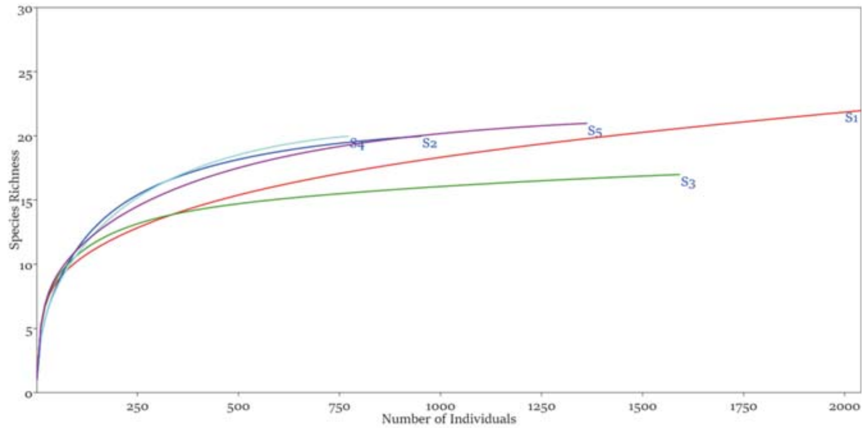
Species code	Species
1	*Haludaria fasciata*
2	*Hypselobarbus kurali*
3	*Barilius bakeri*
4	*B. barna*
5	*B. bendelisis*
6	*B. canarensis*
7	*Devario aequipinnatus*
8	*D. malabaricus*
9	*Rasbora daniconius*
10	*Garra mullya*
11	*Nemacheilus pulchellus*
12	*Schistura denisonii*
13	*Batasio travancoria*
14	*Mystus keletius*
15	*M. malabaricus*
16	*Puntius chola*
17	*Puntius* sp.
18	*Xenentodon cancila*
19	*Macrognathus guentheri*
20	*Dawkinsia filamentosa*
21	*Mesonoemacheilus triangularis*
22	*Mastacembelus* sp.
23	*Channa marulius*
24	*Bhavania australis*
25	*Travancoria jonesi*
26	*Longischistura striatus*
27	*Mesonoemacheilus guentheri*
28	*Mystus armatus*
29	*Hypselobarbus curmuca*
30	*Mastacembelus alboguttatus*
31	*Pethia ticto*
32	*Salmophasia boopis*
33	*Salmophasia acinaces*
34	*Mastacembelus armatus*
35	*Nemacheilus* sp.
36	*Barilius gatensis*
37	*Amblypharyngodon* sp.
38	*Channa gachua*
39	*Garra menoni*
40	*Homaloptera montana*
41	*Glyptothorax trilineatus*
42	*Mystus montanus*
43	*Devario neilgherriensis*
44	*Garra mcclellandi*
45	*Garra hughi*
46	*Lepidocephalichthys thermalis*
47	*Pterocryptis berdmorei*

counts increase more quickly during the pilgrimage season. S1 ranked second position (D_{AS}= 141) followed by S4 (D_{AS}= 65) and S3 (D_{AS}= 60). The hydrologic modification was found maximum in S1 and also this stream is heavily utilized for leisure activities, vehicle washing, and bathing by residents of the nearby town of Angamoozhy. S2 was found to be a pristine stream with little anthropogenic interference (D_{AS}= 5). According to Muller *et al*. (2019), fish community composition was simultaneously affected by multiple stressors acting on the aquatic environment.

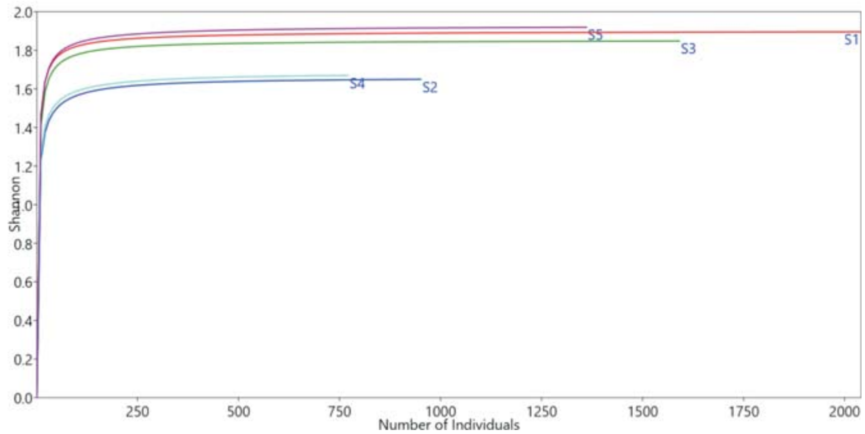
The ichthyofaunal community and their response to anthropogenic stressors

A total of 47 species and 6,775 fish were sampled from five tributary streams of the Pamba river in the Western Ghats. The rarefaction curves for the fish community in the investigated streams suggest that differences in species richness and Shannon diversity were independent of capture rates (Fig. 3 a and b). The individual-based rarefaction curves for species richness revealed that the taxonomic richness was lowest in S3 and highest in S1. But the Shannon diversity index (H) rarefaction curves showed the highest diversity in S5 and the lowest in S2. Hence the current study shows that stressors support the ichthyofaunal diversity in the surveyed streams, ie., stream with a high intensity of human intervention harbours diverse ichthyofaunal community. Meanwhile, the stream with an intermediate level of stress supports high species richness. Kunes *et al*. (2019) reported a similar observation from temperate ecosystems.

The response of the fish community to the identified stressors in their stream environment was explained by correspondence analysis (CA) (Fig. 4). The riparian zone change was seen to affect *Schistura denisonii* and *Mystus malabaricus*. The hydrologic modification of the streams was closely associated with the cyprinid *Rasbora daniconius* and the Mastacembelidae family members especially the *Mastacembelus* sp. and *Macrognathus guentheri*. Tourism-related stress was linked to *Garra mullya*, *Bhavania australis*, and *Mesonoemacheilus triangularis* in their natural environments. Additionally, despite not falling within the confidence interval, agricultural practices and pilgrimage were in the same dispersion plane, demonstrating the proximity of these two stressors. The freshwater catfish *Pterocryptis berdmorei* and the loach *Lepidocephalichthys thermalis* displayed a stronger positive association with the stress brought on by local agricultural practices. Consequently, in S5, agricultural effluents may re-



(a)



(b)

Fig. 3. (a) Species richness and (b) Shannon diversity index (H) rarefaction curves for fish community in the investigated streams

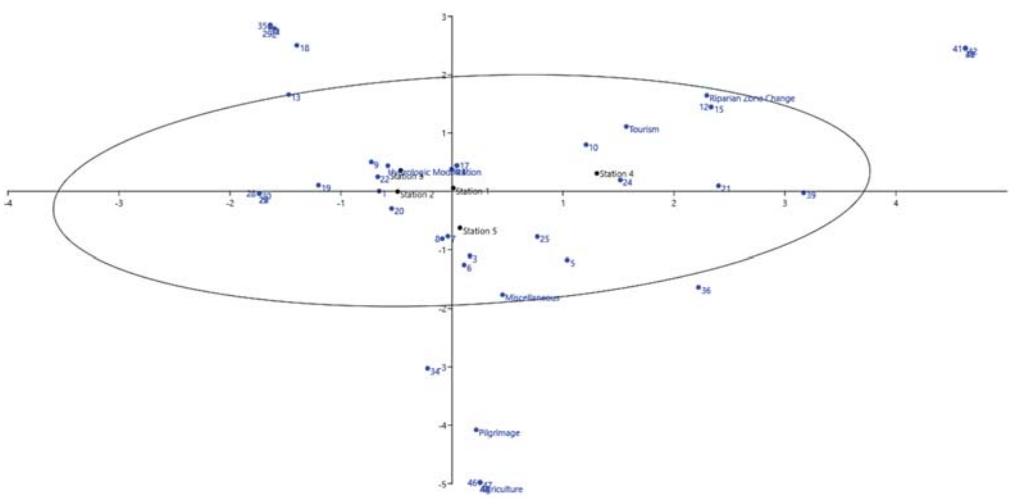


Fig. 4. Correspondence Analysis (CA) displaying the influence of anthropogenic stressors on the ichthyofaunal abundance in selected streams of the Pamba river (Species names were represented as codes). Axis 1 explained 53.9% of the variation in ichthyofaunal abundance with an eigenvalue of 0.2822, axis 2 explained 23.98% of the variation with an eigenvalue of 0.1256.

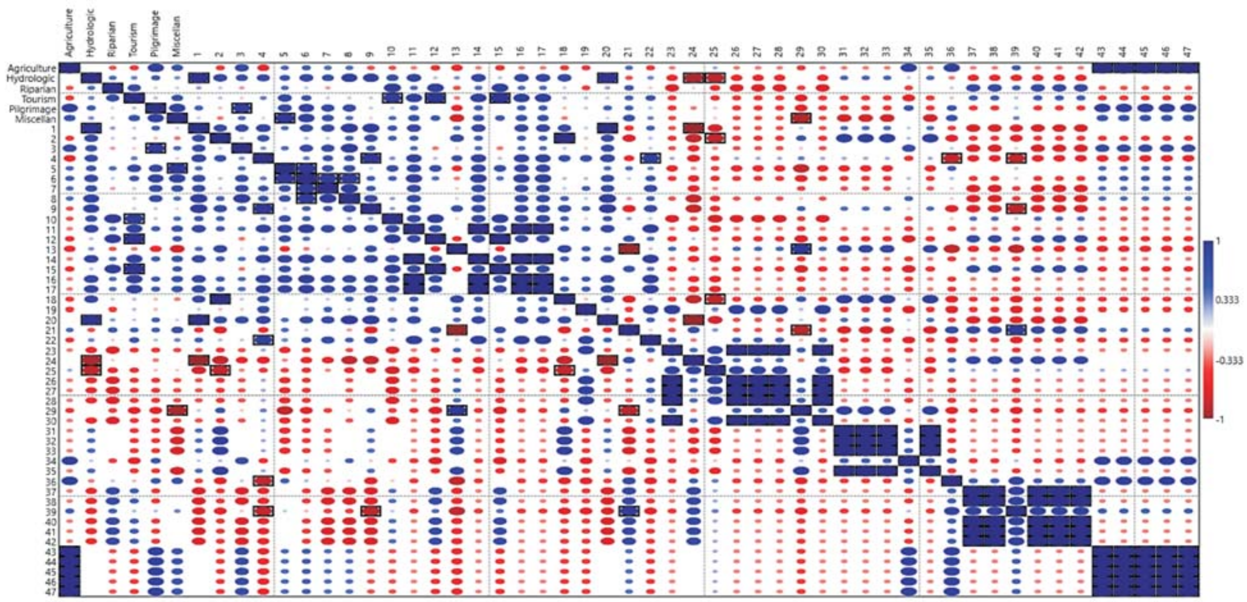


Fig. 5. Corrplot depicting the influence of anthropogenic stressors on the ichthyofaunal abundance in tributary streams of the Pamba river; Species names were represented by the species codes

sult in an infestation of aquatic weeds and algae, which may act as fish-foraging habitats. According to Bristow *et al*. (1992), livestock excretions and fertilisers are both potential sources of DON (Dissolved Organic Nitrogen), which can lead to eutrophic conditions in aquatic environments. According to David and Jennerjahn (2013), the holy river Pamba had the highest global maximum DON concentration (29302 μM), which was brought on by pilgrimage activities, agricultural and livestock farming, and a lack of sanitary infrastructure.

Kendall's tau correlation analysis (Fig. 5) was used to further confirm that the anthropogenic stressors had an impact on the local fish fauna. As per the analysis, the cyprinid generalists *H. fasciata*, *D. filamentosa*, and *R. daniconius* benefited from the hydrologic modification that took place in the sampled stations (τ =0.94). The specialists *Bhavania australis* and *Travancoria jonesi* exhibited a strong negative correlation to hydrologic changes, with correlation coefficients of -0.88 and -0.82, respectively. The lack of available pool-riffle sequences brought on by stream channelization may be the cause. Balitorids typically live in torrential streams that follow a pool-riffle-run pattern. It was found that the generalists were more resilient to the environmental stress in their respective stream habitats. According to Scott (2006), increased environmental degradation is associated with an abundance of tolerant species. Numerous studies have shown that due to environmental degradation, some species that are typical of unaltered environments are being replaced by more generalist species with adaptations that allow them to survive in streamlined environments (Walters *et al*. 2003; Casatti *et al*. 2006; Smart *et al*. 2006).

The tributary streams of the Pamba river in the Western Ghats face eco-degradation due to agricultural activities, hydrologic changes, pilgrimage, tourism, and development projects occurring in the catchment area. These disruptions have an impact on a number of biological functions as well as the distribution of aquatic life, particularly resident fishes. The current investigation highlighted that human interventions had a positive impact on the generalist species and a negative impact on specialists. It is important to implement effective planning, management, and monitoring programs in order to preserve abundant biodiversity and riverine resources. To lessen the impact of agriculture on water resources, the appropriate authority can promote sustainable agricultural practices.

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Conflict of interest: There is no conflict of interest.

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