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Spatio-Temporal Diversity and Abundance of Fish in the Little Ruaha River Catchments, Iringa Tanzania

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ABSTRACT

Fish are an important component of Tanzania's aquatic biodiversity and contribute to the national economy. However, there has not been a sufficient evaluation of the spatial-temporal distribution of fish in the Little Ruaha River catchments. This study determined the spatiotemporal diversity and abundance of fish and generated information on the spatial distribution of fish across the catchments. Fish samples were collected during the dry and rainy seasons at three sampling sites (upper reach, middle reach, and lower reach) using gillnets of 76.2 mm mesh size. Using the Shannon diversity index, we computed the diversity of fish in different habitats and seasons. We used the Kruskal-Wallis and Mann-Whitney tests to determine the differences in fish diversity and abundance between habitats and seasons. We captured a total of 250 fish individuals from five different species. The fish species diversity and relative abundance were higher in the lower reach compared to the upper reach. The relative abundance of fish was statistically different ($p = 0.01$) between habitat and seasons. However, there was no significant ($p = 0.3$) difference in fish diversity between habitats and seasons. Oreochromis and Clarias were the most common species across all habitats. Management of river basins should integrate fisheries activities for integrated river basin management.

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1.0 Introduction

Understanding the spatial and temporal patterns and processes that influence the functional organisation of species assemblages is an essential step in understanding ecosystem structure and function (Boersma et al., 2016). Both spatial and temporal factors highly influence the patterns in species diversity and abundance (Konan et al., 2006; Suvarnaraksha et al., 2012; Felix et al., 2013). In freshwater fish, both biological and physical factors cause differences within and among communities (Myers et al., 2000). Local-scale biological factors such as competition, predation, and high food availability during the rainy season interact with physical factors such as habitat diversity, flow regime, temperature, and channel morphology to influence species diversity and abundance (Vieira et al., 2013; Worischka et al., 2014). The latitudinal gradient of the upper part can also inhibit temperature variability, which is necessary for fish growth and production, and make fish diversity and abundance low in the particular habitat (Knouft and Anthony, 2016). The catchments can experience large variations in water level during a short time period and extreme low water during the dry season, which can reduce fish abundance (Winemiller and Leslie, 1992). The little Ruaha River is among the water sources in Tanzania with both ecological and economic value (Sobo, 2012). Aquatic resources, including the Little Ruaha River, are under high degradation pressure due to increasing demand for aquatic resources for income generation and community livelihood improvement (MNRT, 2005). Loss of biodiversity is associated with declining levels of water due to the expansion of human activities like fishing and agriculture (Sosoveleet al., 2002). Clarifying fish distributions can aid in monitoring and managing biodiversity, as well as informing fish-related policies for river catchment management and biodiversity conservation (Shechongeet al., 2019). Considerations such as species richness and biomass are crucial when examining spatio-temporal changes in species diversity and abundance (Loiseau and Gaertner, 2015). When implementing an ecosystem-based management approach, diversity in the ecological roles of fish communities may be a more important indicator of change for monitoring programs to track (Micheli et al., 2014). This study investigated the spatial and temporal patterns of fish in the Little Ruaha River catchments. Questions addressed include: (i) How does the fish assemblage change along the longitudinal and temporal gradient of the river catchments? (ii) How does fish distribution vary spatially across the Little Ruaha River Catchments?

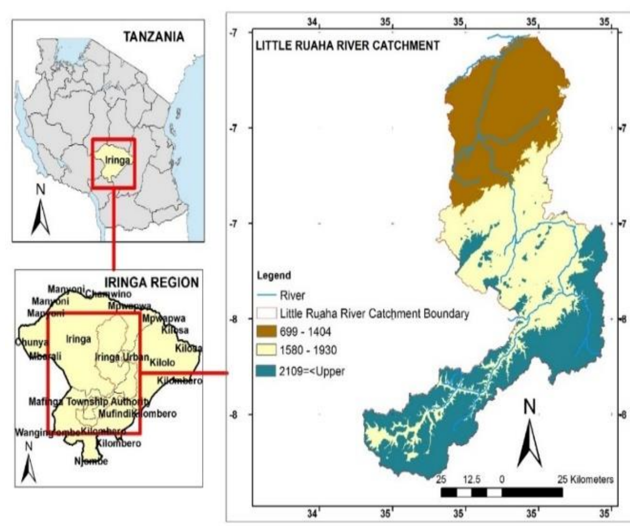
2.0 Materials and Methods

2.1 Description of the Study Site

The Little Ruaha River is one of the three tributaries forming the Great Ruaha River Catchment (GRRC). Geographically, the watershed lies within longitudes 35˚2'E and 35˚36'E and latitudes 7˚11'S and 8˚36'S. Estimates place the Little Ruaha River watershed at 6210 km^2, draining parts of Iringa Municipality, Iringa, Kilolo, and Mufindi Districts in the Iringa Region. The average annual rainfall ranges from 500 mm in the lowlands (e.g. rainfall measured at Mtera Met station) to 700 mm in the highlands at Iringa based on average rainfall from 1979 to 2012. The mean annual temperature varies from about 18˚C at higher altitudes to about 28˚C. Elevation ranges from 698 to over 2300 m above sea level (m.s.l.) (Mbungu and Kashaigili, 2017). The dominance of agriculture and fishing is due to geographic factors and the region's position. Iringa has favourable geographic and climatic conditions for a range of food and cash crops (Andrew *et al.,* 2018).

Figure 1

Map of the Little Ruaha Catchments Showing the Different Reaches of the River (Down 699–1304 m; Middle 1580–1930m; and Upper >2109m)



2.2 Sampling Procedures and Data Collection

We conducted the study between March and May 2019 to encompass both the dry and rainy seasons. We purposefully stratified the area into three gradients: upstream, midstream, and lower stream catchments, which encompass Mufindi and Iringa District in the Iringa Region. We categorised the gradients into specific elevation bands: 1546-2293 m.s.l. for upstream, 946-1545 m.s.l. for midstream, and 699-945 m.s.l. for downstream. We purposefully selected the Band One catchment because of its importance in fisheries activities. We selected Lake Ngwasi in Mufindi District and Igowole Village for upstream catchments; Kibebe Catchment in Iringa District and Kibebe Village for midstream catchments; and Mtera Reservoir in Iringa District and Migoli Village for downstream catchments. In the early morning and evening, we sampled fish at all three locations. Fishermen used legal fishing gear, specifically a gillnet with a mesh size of 76.2 mm, to capture fish. We counted and identified the captured fish using a field guide book. We recorded species' distribution by noting their presence or absence in a specific habitat. We used the Global Positioning System (GPS) to document the coordinates of the sites where we recorded the fish samples. We developed a spatial map using a GIS tool, illustrating the spatial distribution of fish species at the study sites.

2.3 Data Analysis

We used Shannon's diversity index (Shannon and Weaver, 1963) and the equitability index (Piélou, 1969) to conduct a comparative study of the spatial and temporal variations in fish diversity along the Little Ruaha River Catchments. $H' = -\sum (P_i \ln P_i)$, where H' is the index of species diversity, P*i* is the proportion of individuals in the species, and ln is the natural logarithm; $E = H'/\text{Log2}(Rs)$, where H' is the Shannon's diversity index and Rs is the total number of species. We used the Kruskal-Wallis test, a non-parametric analysis of variance, and then the Mann-Whitney test to look at how species richness (number of species, Shannon diversity, and equitability) changed in different habitats and times of the year. The software Paleotological Statistic (PAST) version 2.17 (Hammer et al., 2001) carried out Shannon's diversity index, equitability index, and all statistical analyses. We calculated the relative abundance of fish species in various habitats by dividing the number of species found in each habitat by the total number of species recorded in all study habitats. We used a GIS-based spatial analysis technique to establish the spatial distribution of fish in the different catchments of the Little Ruaha River.

3.0 Results and Discussion

3.1 Fish Species Richness by Habitats and Seasons

We captured 250 individuals from five fish species, five genera, and five families in the Little Ruaha River Catchments during both the dry and rainy seasons (Table 1). We recorded the highest species richness in downstream (lower reach) catchments (n = 4), followed by upstream (upper reach) catchments (n = 3), and the lowest richness in midstream (middle reach) catchments (n = 2). All five identified families, genera, and species were present in both dry and rainy seasons. The Ruaha basin has recorded more than 38 species, 40% of which are endemic and unique to the world. This catch result supports the enormous fishery that has developed in the Mtera reservoir and the Great and Little Ruaha rivers (Payne, 1995).

Table 1
Families, Fish Species Composition and Richness in the Little Ruaha Catchments

			Number of Individuals				
Family	**Genera**	**Species**	**USC**	**MSC**	**DSC**	**RS**	**DS**
Cichlidae	*Oreochromis*	*Oreochromisurolepis*	20	32	12	110	63
Clariidae	*Clarias*	*Clariasgariepinus*	2	3	11	12	4
Mochokidae	*Synodonts*	*Synodontsspp*	0	0	18	12	6
Alastidae	*Hydrocynus*	*Hydroynusvittatus*	0	0	29	21	8
Cyprinidae	*Labeobarbus*	*Barbusmacrolepis*	14	0	0	6	8

Note: USC=Upper stream Catchment, MSC=Midstream Catchment, DSC=Downstream Catchment, RS=Rain season, DS=Dry season

3.2 Fish Species Diversity by Habitats and Seasons

Fish diversity varied across spatial gradients (Table 2). The highest species diversity was recorded in the downstream (lower reach) catchments (*H'* = 0.962), followed by the upstream (upper reach) catchment (*H'* = 0.8544), and the lowest species diversity was recorded at the midstream (middle reach) catchment

(*H'*= 0.2925). The Kruskal-Wallis test shows no significant difference (DF = 2; P > 0.05) in species diversity between habitats. Fish species diversity was higher during the rainy season (*H'*= 1.036) compared to the dry season (*H'* = 0.9989). The Mann-Whitney test also suggests no significant difference (P >0.05) in species diversity between seasons. Flinders et al. (2009) suggested in other tropical regions that average or persistent differences in environmental conditions among sites determine the assemblage structure more than seasonal variation in environmental conditions. The homogeneity in fish species composition among the habitats may result from connectivity between one catchment and another by the Little Ruaha River because fish migrate more easily between them.

3.3 Relative Abundance of Fish Species by Habitats and Seasons

The study recorded a total of 250 individual fish (Table 3). 69% of the species were Orechromisurolepis, 11.6% were Hydrocynusvittatus, 7.2% were Synodontsspp, 6.4% were Clariasgariepinus, and 5.6% were Barbusmacrolepis (Table 3). Oreochromisurolepis was the most abundant species due to their high reproduction rate (a very common fish species) and their feeding behaviour in a variety of food; they feed on aquatic plants, worms, and insects (Johansson, 1997; Chale, 2004). Oreochromisurolepis and Clariasgariepinu, on the other hand, were found in all three habitats, but the species were most common in the downstream habitat because the environment there is more stable and changes less often.

Fish species were more abundant in the lower-reach habitat than in other habitats. Additionally, the abundance of the species was higher during the rainy season compared to the dry season (Table 4). Statistical tests show that there is a significant difference (p<0.05) in fish abundance between habitats and seasons. Fish abundance was lowest at the upper and middle catchments because of the altitudinal gradient of the upper part, which inhibits temperature variability and is necessary for fish growth and production (Knouft and Anthony, 2016). Also, the catchments may experience large variations in water level during a short time period and extreme low water during the dry season, which reduces fish abundance (Winemiller and Leslie, 1992). The abundance of fish was seasonal, with a high abundance in the rainy season compared to the dry season, because during the wet season there is water input into the catchments, which results in fish migrations from the river to the catchments, which makes it easier to catch fish into migration pathways (Sosoveleat et al., 2002). The cycles of the moon and tides, seasonal changes in the climate, and the breeding patterns of fish and other species closely influence the activities of the fisheries. Therefore, there is a close relationship between weather and fishing operations (Vieira et al., 2013).

Table 2
Fish Species Richness, Abundance and Diversity in the Little Ruaha River Catchment by Habitat and Season

	USC	MSC	DSC	RS	DS
Species Richness	3	2	4	5	5
Individual	36	35	179	161	89
Shannon-Weiner diversity (H')	0.8544	0.2925	0.962	1.036	0.9989
Evenness	0.7833	0.6699	0.6542	0.5634	0.5431

Note: USC=Upper stream Catchment, MSC-=Midstream Catchment, DSC=Downstream Catchment, RS=Rain season, DS=Dry season

Table 3

Relative Abundance of Fish Species in the Little Ruaha River Catchment Southern Tanzania

Species	N	USC	Habitat MSC	DSC	Total %
Oreochromisurolepis	173	20	32	121	69.2
Hydrocynusvittatus	29	0	0	29	11.6
Synodontsspp	18	0	0	18	7.2
Clariasgariepinus	16	2	3	11	6.4
Barbusmacrolepis	14	14	0	0	5.6
Total	250	36	35	179	100

Note: N= Number of individuals, USC= Uppstream Catchment, DSC= Midstream Catchment, DSC= Downstream Catchment

Table 4

Relative Abundance of Fish by Habitats and Seasons in the Little Ruaha River Catchments Sothern Tanzania

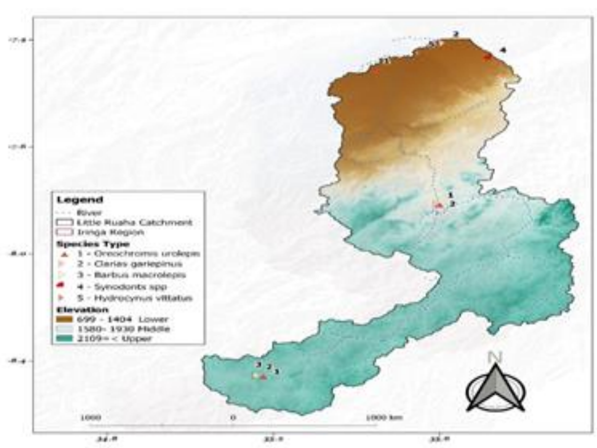
	Total number	Percentage
Downstream Catchment	179	71.6
Upstream Catchment	36	14.4
Midstream Catchment	35	14.0
Rain season	161	64.4
Dry season	89	35.6

3.4 Spatial Distribution of Fish in the Little Ruaha River Catchments

Compared to other species, Oreochromisurolepis was the most abundant. However, spatially, *Oreochromisurolepis* and *Clariasgariepinus were* present in all catchments, though there was considerable variation in their abundances among the different river catchments (Figure 3). We only collected *Hydrocynus vittatus* and *Synodonts* species from the downstream catchments, and their abundances varied. We only found Barbusmacrolepis in the upper catchment.

Figure 2

Spatial Distribution of Fish Species along the Little Ruaha River Catchments



4.0 Conclusion and Recommendation

Understanding the dynamic nature of spatial variation and fish distribution patterns is necessary to inform fisheries monitoring, management, and conservation programmes. Seasonal rainfall changes modulate the longitudinal gradient of the Little Ruaha River system, altering the fish assemblage structure. The seasonal flow of the river influences fish assemblage structure, with greater abundance and biomass of fish in the river catchments, although there are no differences in species richness and diversity between habitats and seasons. Based on these findings, we recommend integrating fisheries activities into river basin management as a viable option, and urge the authorities to consider these catchments to safeguard biodiversity, including fish in the Little Ruaha River catchments. Future studies should incorporate alternative sampling techniques that encompass the entire range of fish sizes.

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