# SURVEY OF FRESHWATER FISH FAUNA IN MARAI PARAI AREA, KINABALU PARK, SABAH

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## ABSTRACT

Continuous surveys of freshwater fish species along altitudinal gradients in Kinabalu Park are crucial for developing effective conservation strategies, but the park's challenging topography has hindered this effort. The Marai Parai-Gurkha Hut Kota Belud Scientific Expedition 2023 provides an excellent opportunity to explore this understudied plateau on the north-western side of Mount Kinabalu. The present study aims to document fish species occurrences up to the peak of Marai Parai and analyse their relationship with selected environmental variables. Concurrently, fish samples and selected environmental parameters were collected from seven sampling stations, ranging from 619 meters to 1645 meters above sea level (m asl). A total of 11 species belonging to three families and seven genera were recorded in the forest streams of Marai Parai. Gastromyzontidae emerges as the dominant family in this high-altitude zone. The number of fish species is significantly correlated with elevation and water temperature (p-value $< 0.05$), where it decreased as elevation increased and water temperature dropped. *Glaniopsis hanitchi*, *Protomyzon griswoldi*, and *Barbodes sealei* were found at a higher elevation than previously recorded in Kinabalu Park. Water quality including dissolved oxygen, total dissolved solids, conductivity, and temperature were associated with fish species occurrences along the altitudinal gradient of forest streams. It is crucial to conduct regular surveys on freshwater fish in Kinabalu Park as regular and long-term baseline data could be useful for future research and conservation efforts in the area.

**Keywords:** *Altitudinal range, Gastromyzontidae, Glaniopsis, Protomyzon, Kinabalu Park.*

## INTRODUCTION

Kinabalu Park is a protected area and a UNESCO World Heritage Site managed by the Sabah Parks. Mount Kinabalu (4,095 meters), the highest mountain in Malaysia, and Mount Tambuyukon (2,579 meters) are located within the park. A wide range of flora and fauna species, including freshwater fish, can be found across the mountains' large altitudinal gradient (Samat, 1990; Kikuta et al., 1997; Aiba & Kitayama, 1999; Harris et al., 2012; Geml et al., 2017). Previous studies have shown that the park and its surrounding areas are home to more than 40 species of freshwater fish, with Cyprinidae being the most dominant family (Samat, 1990; Chin, 1996; Soo et al., 2022).

Similar to other freshwater fish inhabiting mountainous forest streams, fish assemblages in Kinabalu Park undergo dramatic changes along the large altitudinal gradient in the park. Each fish species in Kinabalu Park has its unique altitudinal range, which is determined by a combination of factors including historical process, habitat availability, physiological tolerances, and ecological preferences of fish species (Jaramillo-Villa et al., 2010; Carvajal-Quintero et al., 2015; Soo et al., 2021). For instance, fish from the Cyprinidae family can only be found in lowland areas, whereas species such as *Glaniopsis denunata* from the Gastromyzontidae family are commonly found in high altitudes. Nonetheless, a few species from the Gastromyzontidae family, including *Glaniopsis hanitchi*, *Protomyzon aphelocheilus*, and *Protomyzon whiteheadi* are found inhabiting a wide altitudinal range in Kinabalu Park (Samat 1990; Chin, 1996).

Continuous exploration of fish species across altitudinal gradients and documentation of their altitudinal range in Kinabalu Park is important to develop effective conservation strategies. Regular and long-term baseline data would allow us to analyse the health of freshwater ecosystems in Kinabalu Park and detect potential threats or changes in biodiversity over time. However, conducting fish surveys in the highland region of Kinabalu Park can be a challenging task. This is mainly due to the difficult terrain that makes it challenging to access streams at high altitudes for fish sampling (Nyanti et al., 2019).

Marai Parai (a type of grass in the Dusun language) is a plateau on the north-western side of Mount Kinabalu. The Marai Parai-Gurkha Hut Kota Belud Scientific Expedition 2023, organised by Sabah Parks, provides an excellent opportunity for researchers to explore and document the diversity of fish fauna in this highland area of Kinabalu Park, which has never been studied before. The main objectives of this research are to document changes in the freshwater fish fauna as elevation ascends toward the peak of Marai Parai and to analyse the relationship between fish species occurrences and selected environmental variables at high altitudinal sites.

## METHODOLOGY

A five-day survey of freshwater fish fauna was conducted in Marai Parai during the Marai Parai-Gurkha Hut Kota Belud Scientific Expedition 2023 (Figure 1). Freshwater fish samples were collected from seven sampling stations ranging from 619 to 1645 meters above sea level (m asl). Station 1 was located in Kinabalu Park near the Marai Parai Camp, whereas the last station was near the Kiau Village. GPS coordinates and elevations were obtained at each station using a Portable Global Positioning System (Garmin GPSMAP® 64S). Stream width was

measured using a measuring tape. Table 1 summarises the sampling regime and location for the present study.

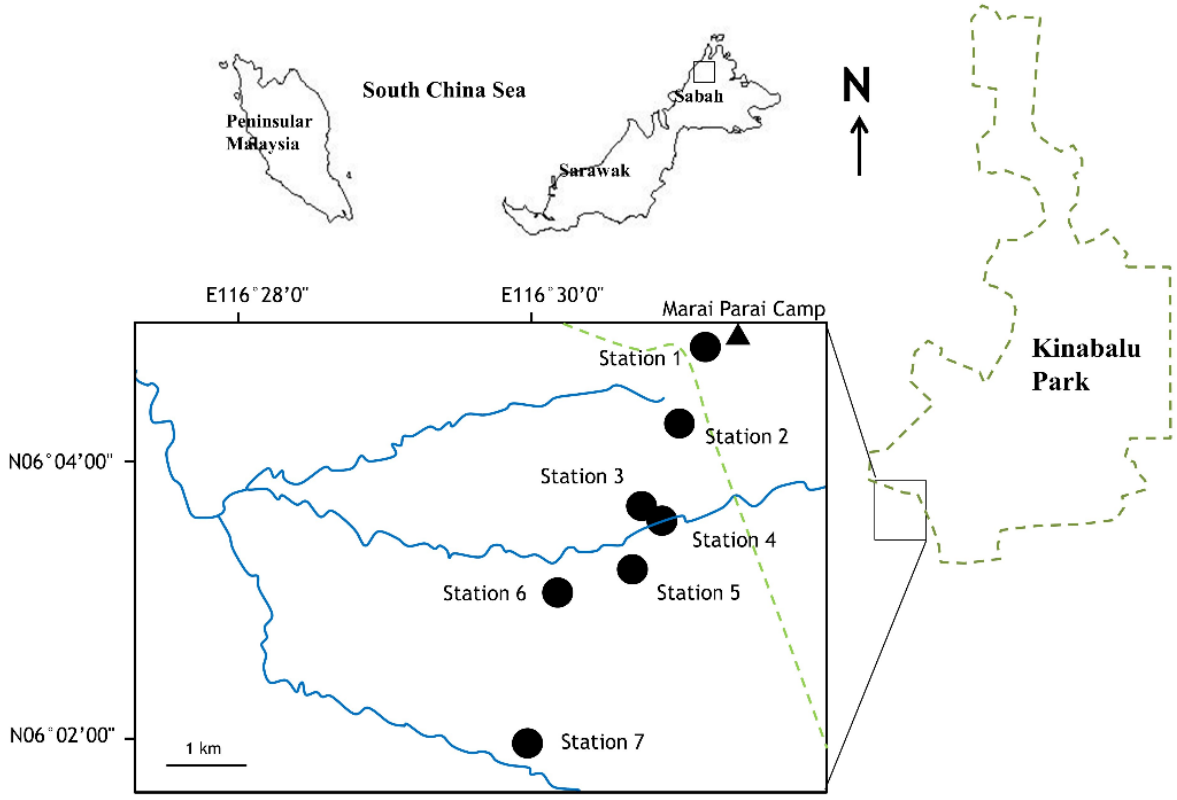


**Figure 1. Study area and the seven sampling stations in Marai Parai, Kinabalu Park, Sabah**

**Table 1. The details of the sampling regime and sampling locations in the present study**

| Sampling station (St) | GPS Coordinates | Sampling Date | Elevation (m asl) | Stream width (m) |
|---|---|---|---|---|
| St 1: Sg. Marai-parai | N06°04'55.1" E116°31'11.4" | 12/10/2023 | 1645 | 1.3 |
| St 2: Sg. Kinotoki | N06°04'24.0" E116°31'02.0" | 12/10/2023 | 1518 | 2.5 |
| St 3: Sg. Mahalui | N06°03'45.8" E116°30'49.4" | 12/10/2023 | 1057 | 2.4 |
| St 4: Sg. Tahubang | N06°03'45.0" E116°30'50.0" | 9/10/2023 | 1053 | 7.8 |
| St 5: Sg. Muhan-tuhan | N06°03'23.4" E116°30'42.9" | 12/10/2023 | 1015 | 2.6 |
| St 6: Sg. Tinokok | N06°03'14.9" E116°30'12.9" | 9/10/2023 | 922 | 3.4 |
| St 7: Sg. Dalampai | N06°02'01.6" E116°29'60.0" | 13/10/2023 | 619 | 2.0 |

The fish sampling was conducted using an electrofishing device powered by a 600-watt power inverter (SUSAN-735MP) with a 12V battery (NIKO YTZ5S-BS). At each station, a 20 m

stretch was delimited with one sampling conducted along each stretch in the downstream–upstream direction. The electroshocking process was carried out for approximately 20 to 30 minutes at each station. The stunned fish were taken with scoop nets (2 mm mesh). Fish samples were identified at the species level using known taxonomic keys (Inger & Chin, 2002; Tan, 2006). Unidentifiable samples from the field were fixed in 10% formalin and preserved in 70% ethanol for further identification in the laboratory. Finally, the taxonomic status was confirmed using the FishBase (Froese & Pauly, 2019) and Eschmeyer's Catalog of Fishes (Fricke et al., 2024). *In-situ* water quality parameters were measured simultaneously with fish sampling. Water temperature, pH, total dissolved solids (TDS), and conductivity were measured using a multi-parameter pen-type water quality tester (Gain Express M0199720). Dissolved oxygen (DO) was measured using a DO meter (SMART SENSOR AR8406).

Non-metric Multidimensional Scaling (NMDS) based on the Bray-Curtis similarity matrix was applied to compare fish assemblage along the altitudinal gradients of forest streams. Seven environmental variables (elevation, width, temperature, pH, DO, TDS, and conductivity) were incorporated into the NMDS. The analysis was carried out using the Paleontological Statistics software package (PAST, Palaeontological Association, 2001). A stress value of less than 0.2 was considered a good fit for NMDS. The Spearman's Rank-Order Correlation was performed to elucidate the significant relationship between environmental parameters and fish species number at a p-value $< 0.05$ by using the Statistical Software for Social Sciences (SPSS Version 24, SPSS Inc., 1995).

## RESULTS AND DISCUSSION

A total of three families, seven genera, and 11 species of freshwater fish were recorded in the forest streams in Marai Parai (Table 2). The low number of fish species recorded in the present study is not uncommon given that this study was conducted within a high altitudinal site. Seven of the 11 species were recorded at the lowest elevation station (619 m asl), while only one species was recorded at the highest elevation station (1645 m asl). Spearman's Rank-Order Correlation analysis revealed that the number of species negatively correlated with elevation (Table 3, Spearman's rho = -0.815, p-value $< 0.05$) and positively correlated with water temperature (Table 3, Spearman's rho = -0.964, p-value $< 0.01$). Water temperature decreased from 24 ºC at 619 m asl to 16 ºC at 1645 m asl (Table 4). Harsh environmental conditions including decreased water temperature in highlands have been shown to decrease fish diversity (Jaramillo-Villa et al., 2010; Carvajal-Quintero et al., 2015). Metabolic constraints and thermal tolerances of fish can limit the number of species that can thrive in highland areas with low water temperatures (Buisson et al., 2008).

Figure 2 shows that in high altitudinal sites, the most dominant family was Gastromyzontidae with seven species (64%), followed by Cyprinidae (three species; 27%), and Nemacheilidae (one species; 9%). The results are not unexpected given that loaches of the Gastromyzontidae family are known to thrive in highland forest streams. The present finding is contrary to Samat (1990) who reported Cyprinidae being the most dominant family in Kinabalu Park, which encompasses an elevation range of 200 to 1580 m asl. When focusing solely on high elevations, as in the present study, Gastromyzontidae emerges as the most dominant family. This finding is in line with a similar study conducted by Ishak et al. (2007), where Gastromyzontidae was the most prevalent family at high elevations of the Kinabalu Park substation. The dominance of the Gastromyzontidae family highlights the importance of these loaches in the Marai Parai area, which appears to be a key component of the high-altitude fish fauna.

**Table 2. Occurrence of freshwater fish fauna in forest streams in Marai Parai, Sabah**

| Family | Species | Sg. Marai-Parai | Sg. Kinotoki | Sg. Mahalui | Sg. Tahubang | Sg. Muhan-Tuhan | Sg. Tinokok | Sg. Dalampai |
|---|---|---|---|---|---|---|---|---|
| Cyprinidae | *Barbodes sealei* | - | - | - | - | - | - | + |
| | *Garra borneensis* | - | - | - | - | - | - | + |
| | *Tor tambra* | - | - | - | - | - | - | + |
| Gastromyzontidae | *Gastromyzon monticola* | - | - | - | - | - | - | + |
| | *Glaniopsis denudata* | - | + | - | + | - | - | - |
| | *Glaniopsis hanitchi* | + | + | + | + | + | + | - |
| | *Protomyzon* cf. *aphelocheilus* | - | - | + | + | + | + | - |
| | *Protomyzon borneensis* | - | - | + | - | + | - | + |
| | *Protomyzon griswoldi* | - | - | - | - | - | + | + |
| | *Protomyzon whiteheadi* | - | - | - | + | - | - | - |
| Nemacheilidae | *Nemacheilus olivaceus* | - | - | - | - | - | - | + |

+ indicates present; - indicates absent

**Table 3. The correlation between environmental and fish fauna factors in forest streams in Marai Parai, Sabah**

| | Species number | Elevation | Width | Temperature | pH | TDS | Conductivity | DO |
|---|---|---|---|---|---|---|---|---|
| Species number | 1.000 | -0.815* | 0.334 | 0.964** | -0.037 | 0.148 | 0.148 | -0.037 |
| Elevation | -0.815* | 1.000 | -0.321 | -0.893** | 0.393 | -0.107 | -0.107 | 0.143 |
| Width | 0.334 | -0.321 | 1.000 | 0.429 | -0.643 | -0.714 | -0.714 | 0.857* |
| Temperature | 0.964** | -0.893** | 0.429 | 1.000 | -0.214 | 0.071 | 0.071 | 0.036 |
| pH | -0.037 | 0.393 | -0.643 | -0.214 | 1.000 | 0.750 | 0.750 | -0.500 |
| TDS | 0.148 | -0.107 | -0.714 | 0.071 | 0.750 | 1.000 | 1.000** | -0.750 |
| Conductivity | 0.148 | -0.107 | -0.714 | 0.071 | 0.750 | 1.000** | 1.000 | -0.750 |
| DO | -0.037 | 0.143 | 0.857* | 0.036 | -0.500 | -0.750 | -0.750 | 1.000 |

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

**Table 4. *In-situ* water quality parameters of forest streams in Marai Parai, Sabah**

| Sampling station (St) | Temperature (ºC) | pH | TDS (mg/L) | Conductivity (µS/cm) | DO (mg/L) |
|---|---|---|---|---|---|
| St 1: Sg. Marai-parai | 16.3 | 7.8 | 39.0 | 60.0 | 7.3 |
| St 2: Sg. Kinotoki | 16.4 | 7.4 | 16.0 | 23.0 | 7.9 |
| St 3: Sg. Mahalui | 20.4 | 8.3 | 68.5 | 103.0 | 7.5 |
| St 4: Sg. Tahubang | 20.9 | 7.4 | 10.0 | 15.0 | 8.0 |
| St 5: Sg. Muhan-tuhan | 20.5 | 7.0 | 6.0 | 11.0 | 7.6 |
| St 6: Sg. Tinokok | 20.8 | 7.1 | 18.3 | 28.0 | 7.6 |
| St 7: Sg. Dalampai | 24.3 | 7.8 | 92.0 | 138.5 | 6.7 |

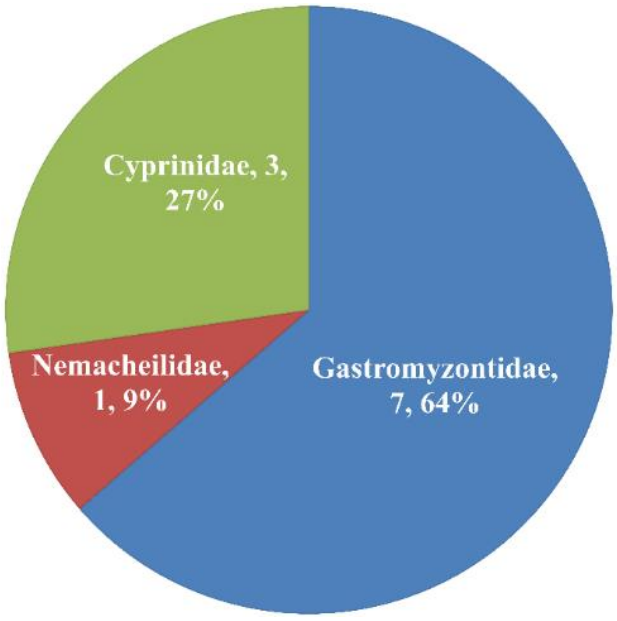


**Figure 2. The number of fish species and percentage of the fish family from seven sampling stations in the study area**

All fish species documented in the present study align with previous records in Kinabalu Park. Figure 3 illustrates the altitudinal range of fish found in the present study. While most fish were found within the previously reported altitudinal range, this study discovered that *Glaniopsis hanitchi* and *Protomyzon griswoldi* from Gastromyzontidae were present at a higher elevation than previously recorded in Kinabalu Park. Furthermore, *Glaniopsis hanitchi* demonstrated a narrower altitudinal range than what was previously reported. A recent comprehensive fish survey conducted at Kinabalu Park showed that *Glaniopsis hanitchi* was not found at elevations lower than 874 m asl (unpublished data). In addition, *Barbodes sealei* from the Cyprinidae family was found at higher elevations than previously recorded. The documentation of altitudinal range extensions for several species suggests that the park's fish biodiversity may be broader than previously understood. More studies should be conducted to verify the possible shift in the species' altitudinal range and to identify factors contributing to the shift, such as habitat degradation and climate change (Comte & Grenouillet 2013; Carosi et al., 2019).

The NMDS plot demonstrates the relationship between selected environmental parameters and fish occurrences in the forest streams in Marai Parai. Axis 1 of the plot illustrates that DO, TDS, and conductivity are strongly associated with fish occurrences. The occurrence of *Protomyzon whiteheadi* is associated with the high DO value in Sg. Tahubang. Occurrences of fishes in the Cyprinidae family are associated with high TDS and conductivity recorded in Sg Dalampai near Kiau Village. *Glaniopsis denudata* is negatively associated with water temperature indicating that the species prefer cold water as highlighted by Samat (1990). Axis 2 of the plot highlights the associations of elevation and water temperature with *Protomyzon* cf. *aphelocheilus* where the species was found in elevations around 1000 m asl with a water temperature of 21 ºC. This broader understanding of the park's freshwater fish species and their associations with environmental variables can help shape conservation strategies. By maintaining the crucial habitats and ecological conditions required by high-altitude fish species, park management can ensure their long-term resilience in the face of emerging threats.

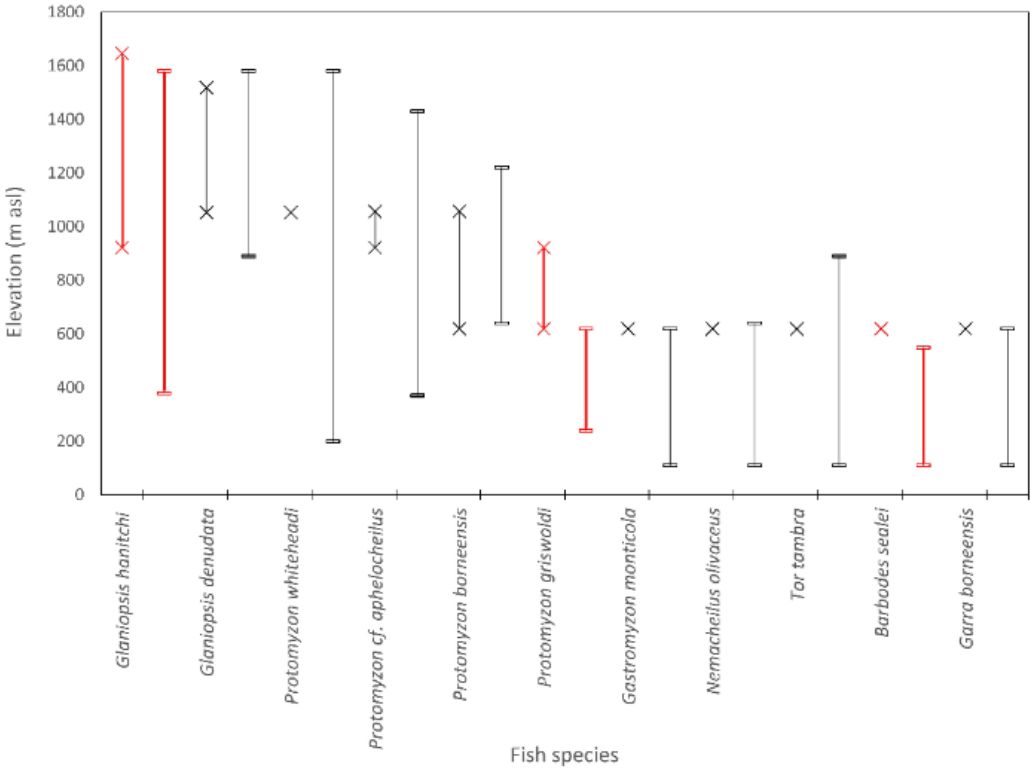


**Figure 3. Comparison of the altitudinal range of fish species found in the present study with previous records documented by Samat (1990), Chin (1996), Ishak et al., (2007), and Soo et al., (2022). Symbol (x) indicates fish caught in the present study; (-) indicates the previous records. Species that have their range outside the previous record are indicated in red colour**

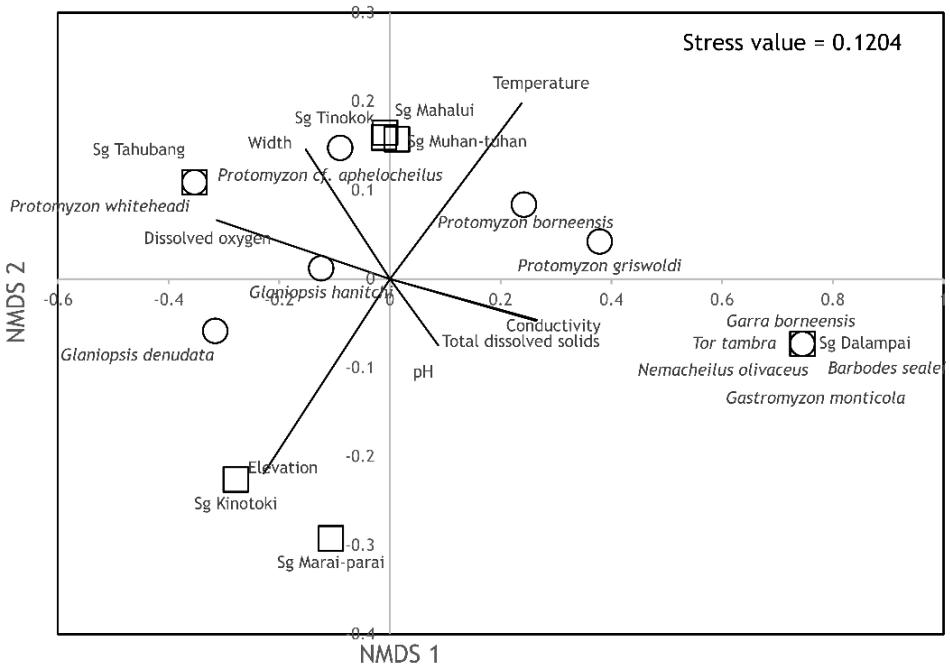


**Figure 4. Ordinations of sampling stations by Nonmetric Multidimensional Scaling (NMDS) based on the Bray-Curtis Similarity Matrix using fish presence/absence data. A Second Matrix of Environmental Variables was incorporated into the NMDS. The stress value Is a Goodness-of-Fit Metric**

## CONCLUSION

Although the scope of this study was restricted to the Marai Parai area for a short period of survey, which might limit the applicability of the findings to the entire park, the current study helped establish an ongoing baseline for monitoring fish populations and their responses to any potential future changes in the park. A total of three families, seven genera, and 11 species were recorded in a high elevation forest streams in Marai Parai of Kinabalu Park. The three families are Gastromyzontidae, Cyprinidae, and Nemacheilidae, with the most dominant family being Gastromyzontidae. The number of fish species decreased with higher elevations and lower water temperatures. *Glaniopsis hanitchi*, *Protomyzon griswoldi*, and *Barbodes sealei* were found at a higher elevation than previously reported in Kinabalu Park. Fish occurrences are associated with water quality parameters including DO, TDS, conductivity, and temperature along altitudinal gradients in forest streams.

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