

Effect of mercury on the growth of *Micralestes eburneensis* (Daget, 1965), a fish endemic to the Cavally River (southwest Ivory Coast).

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Abstract

Original Research Article

The assessment of the effect of mercury on the growth of *Micralestes eburneensis* in the Cavally River, specifically in the Zouan-hounien department, involved determining the length-weight relationship and the average mercury content in the specimen's tail. The length-weight relationship was calculated using the formula $P = a \times L^{sb}$. The mercury content in the tail was determined using atomic absorption spectrometry. A total of 320 specimens were collected from four sampling stations: three (Bakatouo (SB), Daapleu (SD), and Floleu (SF)) subject to gold panning, and one (Niampleu (SN)) not subject to it. Sampling was conducted monthly from February to May 2024. The results showed negative allometric growth of *M. eburneensis* in the Cavally River for the studied stations (SD: $b=1.96$; SN: $b=1.25$; SF: $b=2$; and SB: $b=2.9$). The highest median value (3.8) of the condition factor was obtained at the Niampleu station, which was not subject to gold panning, and the lowest median values (0.96 to 2.76) were recorded at the stations subject to gold panning. Analysis of the mercury content of the sampled individuals showed that all samples analyzed had total mercury levels below the World Health Organization (WHO) standard of 0.5 mg kg^{-1} wet weight. The results of the Spearman correlation analysis between the condition factor, standard length, fish weight, and mercury level showed a negative correlation between these parameters and the mercury level. Thus, the pressures of illegal gold mining lead to a biological weakening of populations and highlight the need for rigorous ecological management to preserve the health of the Cavally River and this endemic species.

Keywords: *Micralestes eburneensis*, mercury effect, growth, morphometrics, Cavally River.

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INTRODUCTION

In Côte d'Ivoire, fish remains the most accessible food for many households, including the poorest [1], and constitutes a primary source of animal protein, providing nearly 70% of the population's protein intake [2]. However, fish diversity in the various aquatic ecosystems of Côte d'Ivoire is seriously threatened by human pressures [3]. Numerous studies report a serious threat to fish in the Ivorian river system, particularly the Cavally River, which has been suffering from increasing pollution in recent years due to the intensification of illegal gold mining near the Ity gold mine [4]. This intensive mining activity in the main channel of this river has led to habitat destruction and an increase in mercury emissions into the aquatic environment [5]. Indeed, small-scale artisanal gold mining in this river uses mercury to form an amalgam [6, 7]. This mixture is heated, which causes the mercury to evaporate, allowing the gold to be collected. This gold extraction method is responsible for approximately 37% of mercury emissions

and represents a significant source of mercury pollution in the air. Furthermore, after evaporation, the mercury eventually settles in the soil, sediments of lakes, rivers, bays, and oceans, where aerobic microorganisms transform it into methylmercury. This methylmercury is then absorbed by phytoplankton, ingested by zooplankton and fish, thus contaminating the food chain. The bioaccumulation of these metals in the food chain poses a risk not only to fish and piscivorous organisms but also to the people who consume them. In humans, the consumption of contaminated fish leads to adverse health effects such as kidney problems, autoimmune disorders, and neurological symptoms.

This river is an important source of protein for local populations and is home to endemic species with limited distributions, threatened by mining activities in its main channel [8]. Among these endemic species is *Micralestes eburneensis*, classified as a threatened species by the International Union for Conservation of Nature [9]. Currently, there is almost no information

available for the Cavally River regarding the effects of mercury on the growth of *Micralestes eburneensis*. The aim of this study is to assess the impact of mercury on the growth of *Micralestes eburneensis* in the Cavally River.

MATERIALS AND METHODS

Study setting:

The Cavally River stretches for 700 km and is divided between three countries:

Côte d'Ivoire, Guinea, and Liberia. The Cavally has numerous meanders, and its riverbed is disturbed by gold panning activities [10]. Furthermore, its watershed is characterized by dense forest and a very narrow hydrographic network [11]. According to [12], the main activity in the region is agriculture, while illegal gold panning is also one of the region's main economic activities. Samples were collected at four stations, three (Bakatouo, Daapleu, and Floleu) affected by illegal gold panning and one (Niampleu) not affected (Figure 1).

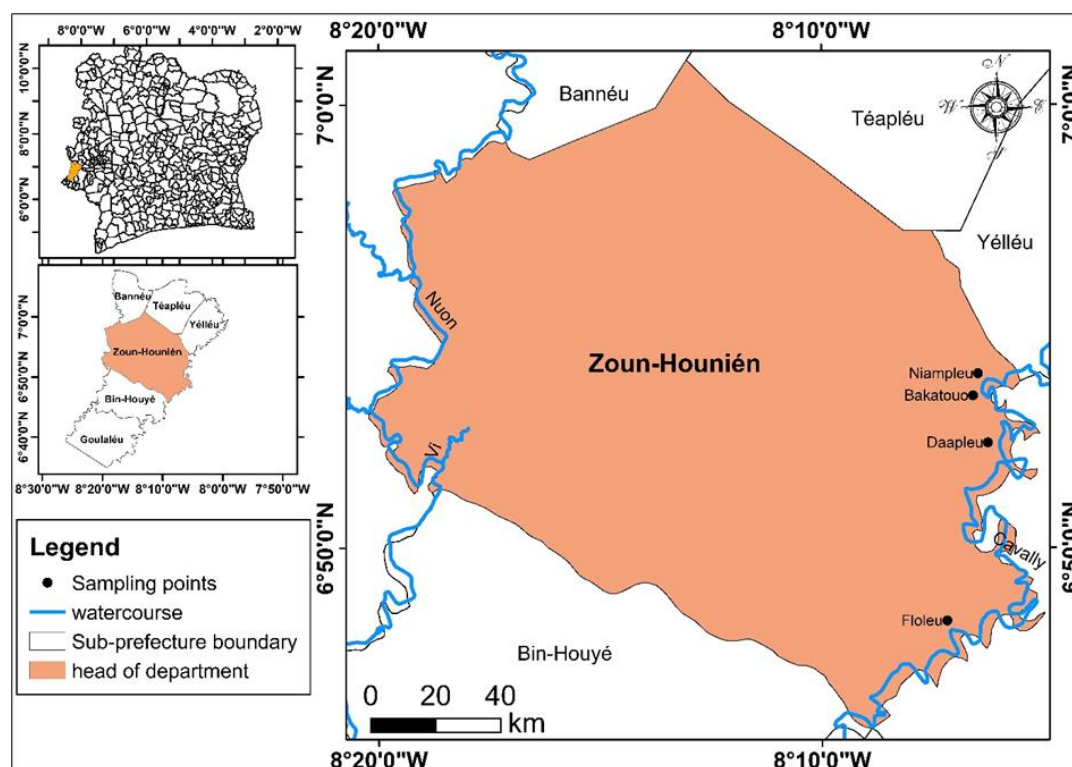


Figure 1: Location of the study area

Fish sampling:

A total of 220 *Micralestes eburneensis* individuals were captured from February to May 2024. A battery of four monofilament nets with mesh sizes of 8, 10, 12, and 15 mm was used for experimental fishing. Each net was 30 meters long with a drop height of 1.5 meters. The top rope was equipped with floats, and the bottom rope with lead weights. Thanks to the combination of the two ropes, the net remained vertical, thus forming a filtering barrier that retained the fish. The gillnets were set around 5:00 PM and retrieved the following day around 8:00 AM.

Characterization of Mercury Content in Fish Flesh:

Mercury content in fish flesh was determined by atomic absorption spectrometry, according to standard NF EN 13805. Fish flesh samples weighing 0.3 to 0.5 g were placed in an oven at 110°C for approximately 3 hours. After drying, the samples were placed in a muffle furnace for 15 minutes at 450°C and then removed to be moistened with nitric acid. They were

then placed back in the furnace at 350°C for 1 hour and 30 minutes. The resulting ash was filtered using 0.45 µm pore size filter paper and then diluted with 20 ml of nitric acid solution (2 ml of acid in 1 L of distilled water). The resulting filtrate was kept cool in labeled containers until analysis by atomic absorption spectrophotometry.

Multiple regressions were performed on the correlation matrix between weight, total length, and mercury concentration to assess mercury flux in the Cavally River fish *Micralestes eburneensis*.

STATISTICAL ANALYSIS OF DATA

The non-parametric Krustall-Wallis test was used to compare the values of spatial variation in size, weight, and condition factors. Differences were considered significant at $p < 0.05$. Spearman's rank correlation coefficient was used to study the correlation between mercury levels in the fish flesh and growth

parameters. These analyses were performed using PAST 4 software.

RESULTS

Size Class Determination

The size class distribution of *Micralestes eburneensis* specimens sampled in the Cavally River

basin is shown in Figure 2. This allowed the captured individuals to be divided into 8 size classes. However, due to the very small size values, the number of classes was reduced to 5. Individuals *Micralestes eburneensis* exhibit a unimodal size distribution that varies between 45 and 55 mm. This distribution shows that the largest individuals are those whose size falls within this range.

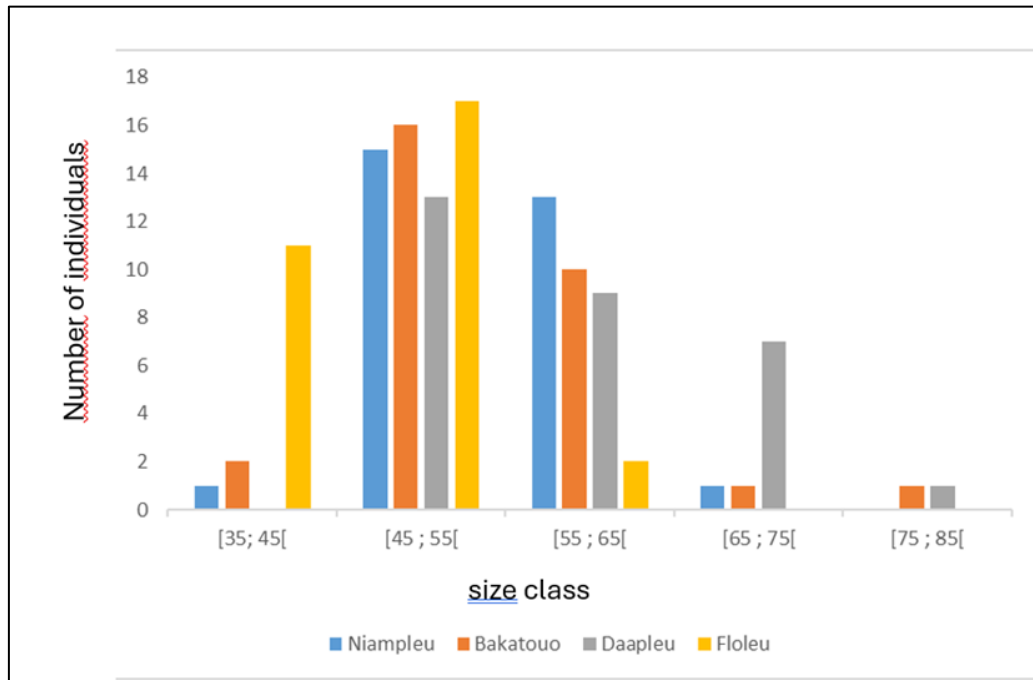


Figure 2: Size class distribution of *Micralestes eburneensis* specimens in the Cavally River

Spatial variation in *Micralestes eburneensis* sizes:

A total of 220 *Micralestes eburneensis* individuals were captured. Standard fish lengths ranged from 35 to 80 mm. The Daapleu station recorded the largest sizes, ranging from 45 to 80 mm with a median of 55 mm, followed by the Bakatouo station with a size ranging from 42 to 75 mm and a median of 52 mm.

At the Niampleu station, the size of *Micralestes eburneensis* ranged from 45 to 70 mm with a median of 52 mm, while the Floleu station recorded the smallest sizes (35 to 55 mm) for this species, with a median of 46.5 mm (Figure 8). Analysis of size variation between stations reveals a significant difference between *Micralestes eburneensis* specimens sampled in the Floleu station and the three other stations (Kruskal-Wallis test, $p < 0.005$).

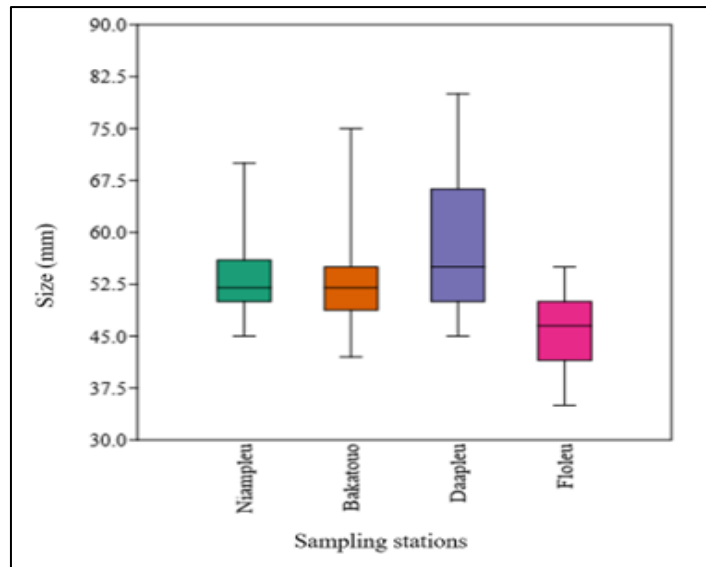


Figure 3: Spatial variation of the standard length of *Micralestes eburneensis* collected at different stations.

Length-weight relationship of *Micralestes eburneensis*

The population length-weight relationships between the standard length and weight of *Micralestes eburneensis* individuals sampled in the Cavally River are illustrated in Figure 10. The coefficients of determination (r^2) are 0.46, 0.92, 0.85, and 0.90 for the Niampleu, Bakatouo, Daapleu, and Floleu sectors, respectively.

Except for the Niampleu sector, all these correlations are highly significant.

The estimated values of the allometric coefficient b range from 2.30 (Niampleu) to 2.87 (Bakatouo). These values appeared significantly lower than threshold 3 (Student's t-test; $p < 0.05$), which reflects negative allometric growth in *Micralestes eburneensis*.

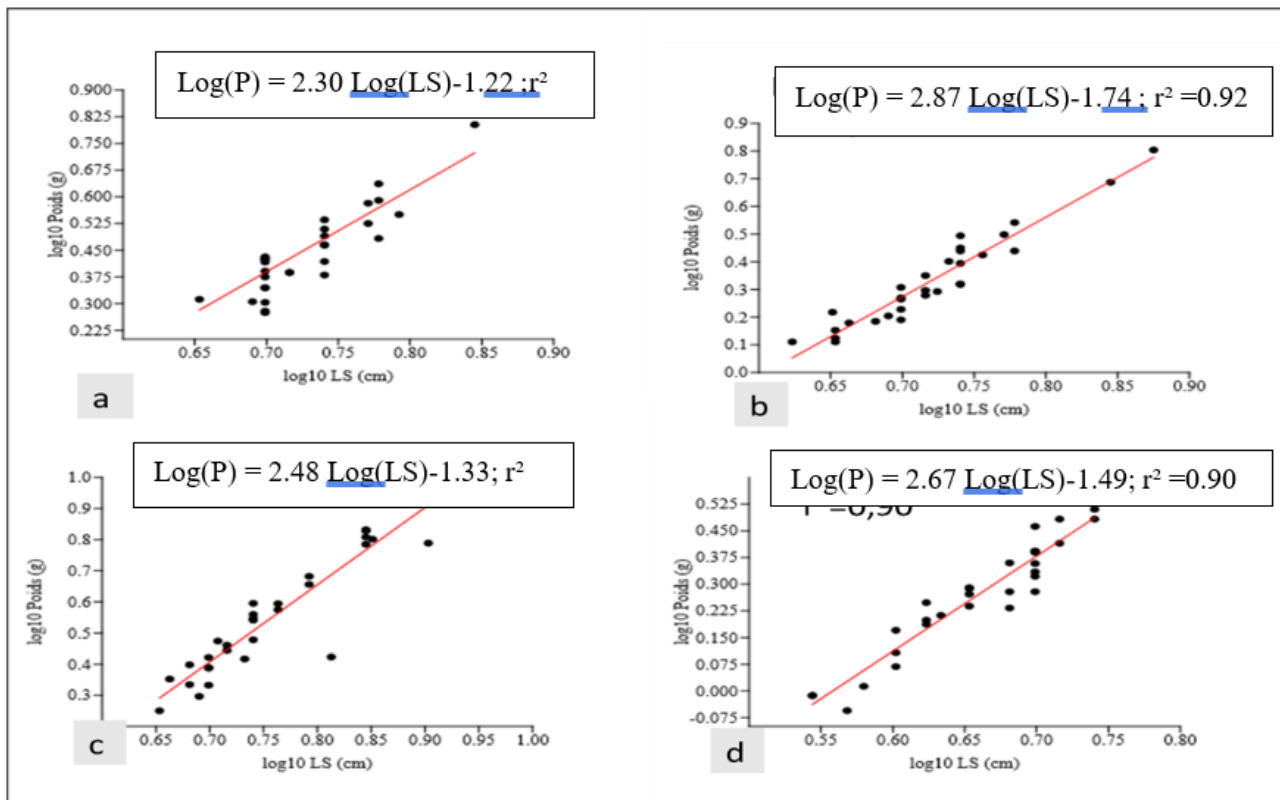


Figure 4: Regression curve of total weight (TW) as a function of standard length (SL) of *Micralestes eburneensis* captured from February to May 2024 in the Cavally River (Côte d'Ivoire). a: Niampleu station; b: Bakatouo station; c: Daapleu station; d: Niampleu station

Condition factor (K) of *Micralestes eburneensis* species

The condition factor of *Micralestes eburneensis* sampled in the Cavally River fluctuated from 0.8 to 9.15. The highest median value (3.8) of this parameter was obtained at the Niampleu station, and the lowest median

values (0.96 to 2.76) were recorded at the other stations (Figure 11). Comparison of variables between stations showed a significant difference in the condition factor between the Niampleu station and the other three stations (Kruskal-Wallis test, $p < 0.005$).

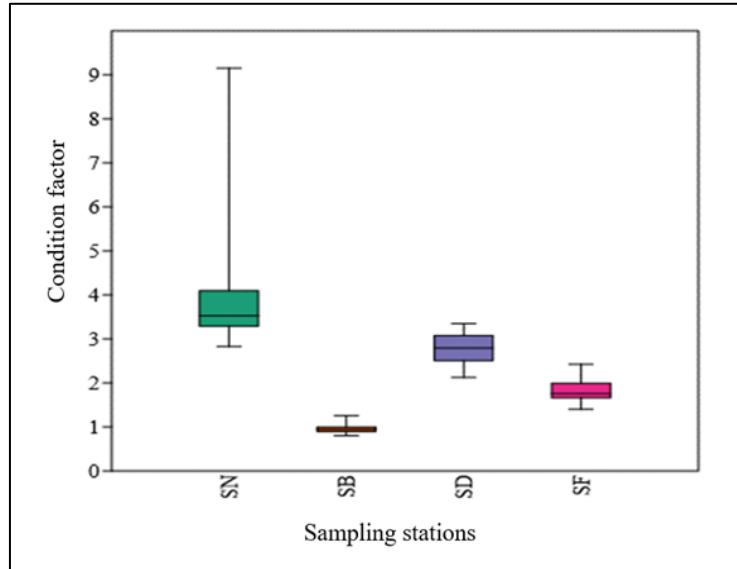


Figure 5: Variation in the condition factor of *Micralestes eburneensis* according to stations from February to May 2024 in the Cavally River

Spatial variation of mercury levels in the flesh of *Micralestes eburneensis*:

Mercury levels in the flesh of *Micralestes eburneensis* individuals from the Cavally River ranged from 0.005 to 0.018 mg/kg. Mercury levels in the fish flesh were highest at the Bakatouo station (0.018 mg/kg)

and lowest at the other stations (0.005 to 0.007 mg/kg) (Table I). Analysis of mercury levels in the flesh of fish caught in the different sampled areas showed no significant difference between stations (Kruskal-Wallis, $p > 0.05$).

TABLE I. Mercury content in the flesh of *Micralestes eburneensis* fished in the Cavally River

Stations	Moyenne	Ecart-type
SB	0.018	0.013
SD	0.007	0.007
SF	0.005	0.005
SN	0.007	0.007

Influence of mercury on the growth of the fish *Micralestes eburneensis*:

The results of Spearman's rank correlation analysis applied to the growth parameter/mercury rate

matrix revealed that condition factor, standard length, and weight are negatively correlated with mercury.

Table II: Results of the comparison of Spearman rank correlation analysis between growth factors and mercury.

	K	Ls	Poids
r	-0.71	-0.68	-0.54

DISCUSSION

The size structure of the fish samples exhibited a unimodal distribution, with individuals measuring between 45 mm and 54 mm being the most abundant. This group could correspond to juveniles of *Micralestes eburneensis*. Indeed, the presence of juveniles in this sampling environment could be explained by the fact that this environment is a spawning and feeding area for the

species *Micralestes eburneensis*. Indicators that characterize a fish spawning area include the presence of eggs, fry, juveniles, and mature individuals [13, 14,15].

The predominance of length growth rate relative to weight, or weight relative to length, in fish is assessed using the coefficient b, whose value varies between 2 and 4 according to [16]. In this study, the values of the

allometric coefficient b for the length-weight relationship in *Micralestes eburneensis* (2-2.95) fall within this range. Analysis of the coefficient b revealed negative allometric growth for *Micralestes eburneensis*. Thus, weight gain is slower than length growth for this species in our study area. Furthermore, the high values of the coefficient of determination (0.74 to 0.92) in the mining stations (Bakatouo, Daapleu, and Floleu) indicate a strong correlation between fish mass and length in these study areas.

The condition coefficient allows us to monitor changes in the fish's body condition. It is considered a good tool for comparing the overall physiological state of populations between stations with different ecological conditions [17]. In the present study, the spatial analysis of the condition factor reveals significant disparities between sampling stations (Kruskal-Wallis test, $p < 0.05$). Specifically, the condition coefficient of *Micralestes eburneensis* was higher at the Niampleu station, which is not subject to mining activity, and lower at the other stations. These differences are likely related to differing environmental conditions. Indeed, the Niampleu station is free of any gold panning activity, while the three other stations on this river are subject to intense gold panning activity that takes place without respect for environmental and social standards, even though the surrounding populations use the river water for their food, personal hygiene, and agricultural needs [18]. Furthermore, several studies have shown that the condition coefficient is strongly influenced by stress and water quality [19,20,21]. These observations are confirmed by the fact that the Bakatoua station located at The periphery of the Ity mine is the only mining site to have a condition factor below 1, while the other two have a higher condition factor (1.82 to 2.76). These results suggest that the physiological state of *M. eburneensis* populations is spatially variable and that the Niampleu site may constitute a more favorable habitat compared to the other areas studied.

The results of this study clearly indicate the presence of mercury in the flesh of *Micralestes eburneensis* individuals. This presence confirms that the sampling stations in the study area are polluted by this metal, although the degree of pollution varies from one station to another. Previous studies have demonstrated the presence of several heavy metals, including mercury, lead, and arsenic, in the flesh of fish from Ivorian waters, notably the work of [22] in the Ebrié Lagoon and of [23] in the Jacqueline Lagoon. The average mercury level measured in the flesh of *Micralestes eburneensis* ranged from 0.005 to 0.018 mg/l, although there was no significant difference in this level between the four sampling stations (Kruskal-Wallis, $p > 0.05$). Compared to WHO standards (0.5 mg/kg for human consumption), the levels observed remain well below critical thresholds, indicating low environmental contamination at this stage. However, the very presence of traces of mercury in the flesh of the fish indicates an emerging risk linked

to mining activities, which could increase over time if discharges continue. Thus, the spatial distribution of mercury in the flesh of *Micralestes eburneensis* reflects a diffusé but still moderate anthropogenic influence. Regular monitoring is necessary to assess the evolution of this contamination and prevent potential risks of bioaccumulation in the food chain.

Furthermore, the results of the Spearman correlation analysis between growth parameters and mercury levels show a negative correlation between condition factor, standard length, fish weight, and mercury levels. This means that the higher the mercury level in the fish flesh, the lower the fish's condition and growth. This inverse relationship indicates that the higher the mercury content, the lower the physiological condition and growth of the individuals. Mercury, by interfering with energy metabolism, reduces the capacity for nutrient assimilation and disrupts tissue growth [24]. Such results should not be disregarded in the long term, given the cumulative nature of this metal.

CONCLUSION

This work contributes to our understanding of the living conditions of *Micralestes eburneensis* in the Cavally River in Côte d'Ivoire (West Africa) within a mining environment. The effects of mercury on the growth and morphology of this endemic species in the Cavally River were also investigated. Analysis of spatial variations in size and weight revealed that specimens from Bakatouo (6.79g and 75mm), Daapleu (6.37g and 85mm), and Niampleu (6.78g and 70mm) were significantly larger than those from Floleu (3.24g and 55mm). The highest median value (3.8) of the condition factor was obtained in the Niampleu station (not subject to illegal gold mining) and the lowest median values (0.96 to 2.76) were recorded in the stations subject to illegal gold mining. The mercury content in the flesh of this species is below the WHO standard. Furthermore, the results of the Spearman correlation analysis between growth parameters and mercury levels show a negative correlation between condition factor, standard length, fish weight, and mercury levels.

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