

Cadmium Exposure Effects on Lateral Line, Above-Lateral Line, and Predorsal Scales of *Trichopodus pectoralis*

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Abstract

In this research, the exposure of cadmium was done to assess the impacts of exposure on the external meristic characteristics of *Trichopodus pectoralis*, a freshwater fish species with a biological usage in measuring aquatic pollution. The concentration levels of cadmium were 4 levels of 0.000, 0.005, 0.010 and 0.015 mg/L and each lasted 16 weeks. Three external meristic parameters were studied, such as lateral line scales, scales above a lateral line, and predorsal scales. The findings indicated that all three meristic traits were greatly influenced by the cadmium exposure, and the reduction changed more at a higher level. An adaptive response was observed in some of the traits and was observed in earlier stages of exposure before the toxic effects started becoming chronic. In general, the results show that the concentration of cadmium and the duration of exposure to the cadmium element are essential factors that can affect morphological alterations in fish and the results suggest the possibility of using *Trichopodus pectoralis* external meristic characteristics as biomarkers of cadmium pollution in aquatic environments.

Keywords

Cadmium Exposure, External Meristics Traits, Aquatic Pollution, *Trichopodus pectoralis*

1. Introduction

The toxicity, persistence and accumulation of heavy metal pollution in the ecosystems have made it a critical environmental problem. The elements that are found naturally and with a high atomic weight and density more than 5 g/cm³ can

be recognized as heavy metals and are differentiated by the rest of the metallic elements in their chemical and biological behavior [1]. These chemicals are more likely to create stable compounds, which are not easily degraded, and which can continue to exist in both the aquatic and the terrestrial environment. Urban sprawl, rapid industrialization, and the use of more chemicals have been a major contributor to the heavy metal contamination in recent decades [2].

Heavy metals emitted by industrial operations find their way into the aquatic environments by waste discharged into the sewage system, through atmospheric deposition and solid wastes improperly discarded. They may be deposited in the environment as contaminants in sediments and organisms and cause bioaccumulation and biomagnification of the food chain [3]. Consequently, chronic exposure to heavy metals is of significant threat to aquatic life and human health.

Cadmium is one of the heavy metals that is of great concern because it is very toxic even at low levels. The anthropogenic processes like the use of phosphate fertilizer, burning fossil fuels, smelting metals, and battery production have augmented the level of cadmium in water [4]. Exposure to cadmium may be in the form of contaminated water and food and once it is absorbed it accumulates in the main body organs leading to oxidative stress and biological harm in the long term.

The fish are extensively utilized in determining the extent of aquatic pollution using biological indicators since they inhabit different trophic positions and accumulate heavy metals in their tissues easily. Cadmium transfer via aquatic food webs can have unfavorable ecological impacts and may have ill effects on human beings eating contaminated fish [5]. Hence, sensitive and reliable methods are required to detect sublethal effects of cadmium exposure in fish.

Trichopodus pectoralis is a species of freshwater fish species that is prevalent in rivers, lakes and swampy water bodies of Southeast Asia as shown in **Figure 1**. It is an ecologically and economically significant species because it is an omnivorous species that tolerates low-oxygen conditions and is commonly utilized as both food and aquaculture [6]. They are some of the traits that make *T. pectoralis* an appropriate bio-indicator species in determining the effects of aquatic heavy metal pollution.

Meristic analysis offers a feasible and valid method of morphology evaluation to see sublethal impacts of cadmium exposure in fish. Meristic traits refer to countable external characteristics such as fin rays, gill rakers, and scale numbers, which are sensitive to environmental stress during development [7]. The changes in these characteristics can be used as precursors of morphological disturbances due to toxic exposure. Consequently, the proposed study will evaluate the impacts of cadmium exposure on the external meristic characters of *T. pectoralis*, with the idea that the morphological characteristics can be exploited as sensitive biological measures of cadmium occurrence in the aquatic environments.



Figure 1. Snakeskin gourami (*Trichopodus pectoralis*).

2. Materials and Methods

This was an experimental laboratory research that was carried out to assess the impacts of cadmium exposure on the external meristic characteristics of *Trichopodus pectoralis*. Fish were randomly assigned into four treatment groups exposed to different concentrations of cadmium (0.000 mg/L, 0.005 mg/L, 0.010 mg/L and 0.015 mg/L) for 16 weeks. Each treatment was maintained in three separate aquariums and sampling was performed at four-week intervals (weeks 0, 4, 8, 12, and 16). At each interval, 30 fish per group (10 individuals from each aquarium) were randomly selected for morphometric analysis. Fish density for each aquarium were adjusted and equalized after each sampling.

The medium used in the aquarium was dechlorinated tap water, which was prepared by leaving the water overnight to eliminate chlorine. The acclimatization was done on the fish using large containers before it could be transferred to the aquarium. Each aquarium was filled with 10 liters of dechlorinated water, with control aquarium containing only dechlorinated water and treatment aquarium containing the respective cadmium concentrations. Replacement of water was done monthly in order to ensure quality of water and fish were fed commercial pellets at 1% - 8% of their body weight, as recommended previously [6]. The health condition and survival were monitored throughout the experiment.

Fish at every sampling point were taken randomly using nets and euthanized by cold shock technique to maintain external structures. The fish was dried using tissue before being measured. Measurements of external meristic traits were lateral line scales, transverse scales above the lateral line and predorsal scales. The traits were rated thrice on each fish and the mean was taken to be analyzed. The analysis of data was done in IBM SPSS Statistics version 27. Mean and standard deviation were used as descriptive statistics of each meristic character. The Kruskal-Wallis test was used to determine differences in external meristic characteristics among treatment groups, with a statistical significance level of $p < 0.05$.

3. Results and Discussion

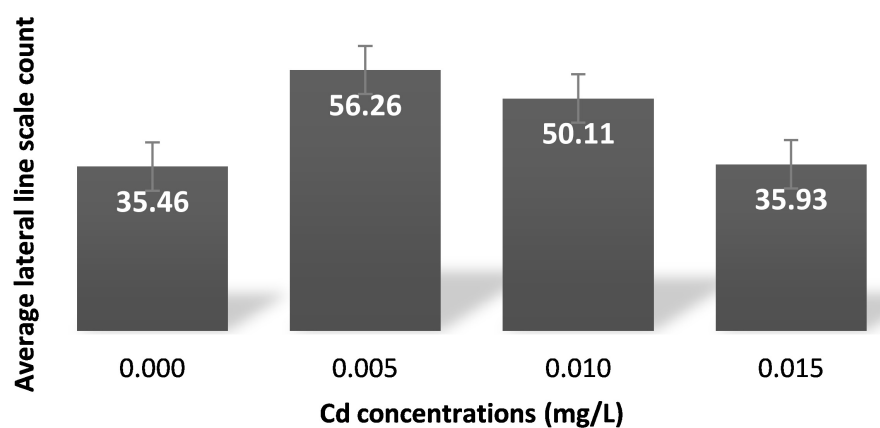


Figure 2. Average lateral line scales across cadmium concentration.

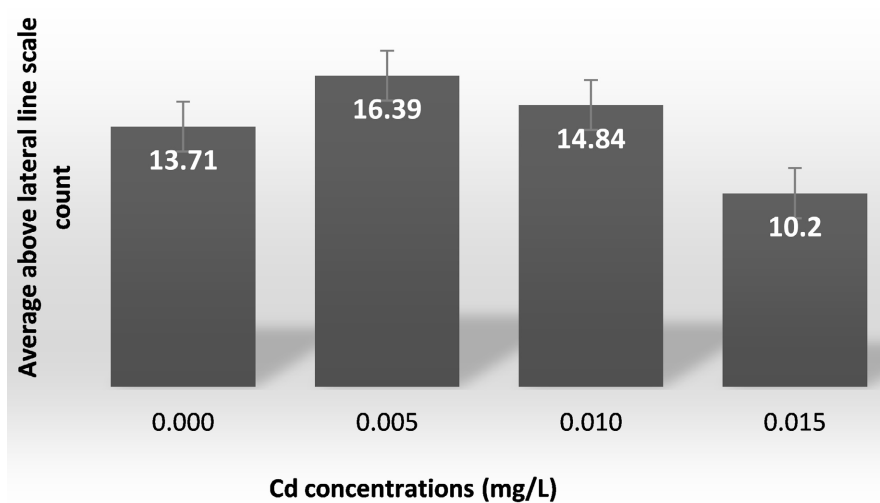


Figure 3. Average above lateral line scales across cadmium concentration.

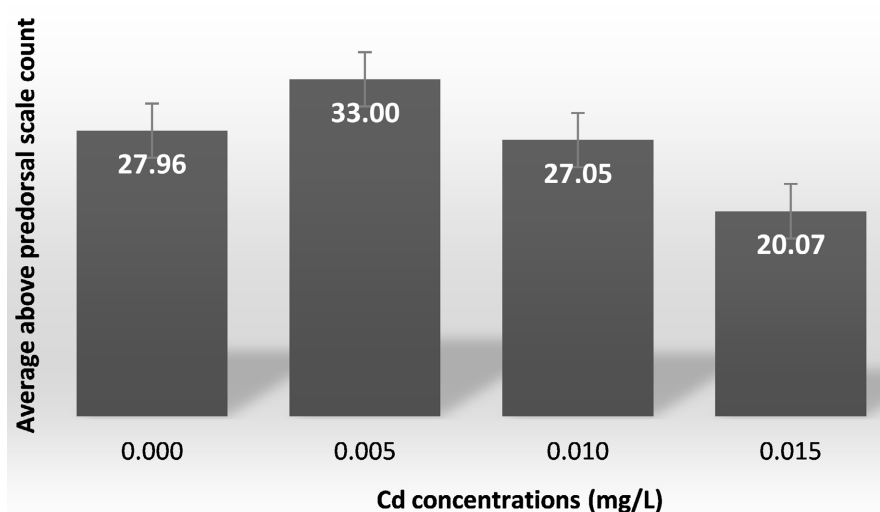


Figure 4. Average predorsal scales across cadmium concentration.

In this experiment, meristic quality of fish that was subjected to different levels of cadmium was measured. In the case of the lateral line scales, the greatest mean was measured as 0.005 mg/L of cadmium with a value of 56.26. This was then followed by exposure at 0.010 mg/L with a mean value of 50.11. **Figure 2** indicates the lowest mean scale counts of the lateral lines in the control group of 35.46 and the highest concentration of 0.015 mg/L of 35.93.

According to **Figure 3**, the mean of scales above the lateral line was also highest at 0.005 mg/L where the value was 16.39. It went down at 0.010 mg/L to 14.84 and a value of 10.20 was the lowest level. The mean in the control group was an intermediate of 13.71.

The same case was observed with predorsal scales. The greatest average predorsal scale count was found at 0.005 mg/L and was 33.00. This value was found to decrease at 0.010 mg/L to 27.05 and the lowest mean value was recorded at 0.015 mg/L with the value of 20.07. **Figure 4** illustrates that the control group had a mean predorsal scale count of 27.96. Kruskal-Wallis test showed that there were significant differences in the lateral line scale, scales above the lateral line and predorsal scale between the various cadmium concentrations ($p < 0.05$).

The toxicity of cadmium in fish has been well recorded to interfere with physiological processes and morphogenesis. Cd is deposited in a number of tissues and disturbs the normal ion balance, especially in calcium metabolism, which is vital in the development of the integument and skeletal structure, such as scale formation and patterning. The research has indicated that heavy metal exposure may change the scale structure and lead to circular and radii defects and the fragility of the scale edge, with a result that scales are amenable indicators of adverse environmental toxins like cadmium. Besides, exposure to Cd is linked to oxidative stress and cellular dysfunction, which may suppress cell proliferation and differentiation in meristic trait development [8].

The given reduction in the lateral line scales and predorsal scales with increasing cadmium levels may be explained by the interference with the signalling pathways involved in the lateral and skeletal patterning. Mechanosensory structures that are said to be especially affected by cadmium toxicity include the lateral line systems that are the ones that are built into the skin and scale matrix and that in fact change the morphological and functional aspects of the related sensory tissues in cadmium exposed fish [9]. This disturbance might have indirect impact on the scale counts across the axis of lateral line. Also, cadmium induces oxidative stress that prompts more reactive oxygen species and lipid peroxidation to cause tissue damage and prevent normal morphological development [8].

The variability in reactions between the latter scales and scales above the lateral line may indicate that functional roles have an impact on cadmium exposure sensitivity. Lateral line system which is crucial in monitoring movement and pressure of water is developed at an earlier age and is hence more vulnerable to any toxic exposure in the course of development. Consequently, this may make cadmium influences the formation of lateral line scales. On the contrary, those scales above

the lateral line may have external protection purpose and seem to be less directly affected at lower exposure levels. This is an increased sensitivity of the lateral line system to heavy metal contamination in line with former results, noted by Hernandez *et al.* (2006) [10].

T. pectoralis may show a concentration dependent reaction of predorsal scale counts to cadmium exposure. Predorsal scales are found on the exposed dorsal side and they hence serve as a primary defense against environmental stressors hence are some of the morphological characters that respond to water quality changes the most [11]. Besides playing a protective purpose, the predorsal scales also affect the hydrodynamic performance in terms of the water flow, drag, and locomotor efficiency. Therefore, predators may suffer negative effects on swimming effects because of cadmium-induced changes in the number of scales on the predorsal side [12].

These findings are consistent with the general evidence that heavy metal pollution has adverse effects on fish morphology and physiology. The bioaccumulation of cadmium in gill and liver, among others, leads to structural and functional damage, which may be reflected in the lower growth and change in morphological properties of the study population of fish [13]. The dose dependent decrease in meristic characters in the given study justifies the use of lateral line scales, scales beyond the lateral line and predorsal scales as sensitive morphological biomarkers of lower cadmium levels in aquatic ecotoxicology.

4. Conclusions

This study proves that the effect of cadmium exposure on the external meristic characteristics of *Trichopodus pectoralis* is of a great concentration-dependent nature. The highest counts were recorded on the lateral line scales, scales above the lateral line and the predorsal scales at low cadmium level, at the level of 0.005 mg/L and thereafter the number declined progressively upon increasing the level. These results suggest that accumulation of cadmium levels interferes with normal morphogenesis, probably by interfering with calcium metabolism, oxidative stress and perturbation of signaling pathways regulating scale and skeletal patterning. The variation in the sensitivity of the traits indicates their behavioral functions with the lateral line scales and the predorsal scales being the most vulnerable since they develop first and are the ones that are exposed to stress factors in the environment.

The dose-related reduction in meristic features indicates the possibility of using the hypothesized external traits as sensitive and non-invasive biomarkers of sub-lethal cadmium exposure in freshwater fish. The above-lateral, predorsal scales, and lateral line counts have the potential to offer considerable data to ecological surveillance and risk evaluation of the heavy metal pollution in water bodies. In general, the meristic analysis can serve as an effective instrument of early-stage identification of morphological and physiological disturbances due to cadmium that can be used to develop the set of efficient measures to address and reduce the

impact of heavy metal pollution of fresh water sources.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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