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Seasonal Bioaccumulation of Heavy Metals in the Gills of *Lepturacanthus savala*

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Abstract

This study investigated the seasonal bioaccumulation of seven heavy metals—lead (Pb), manganese (Mn), zinc (Zn), nickel (Ni), cadmium (Cd), chromium (Cr), and copper (Cu)—in the gills of *Lepturacanthus savala* at Station 1 from June 2022 to July 2023. The data were analyzed using one-way ANOVA to assess seasonal variations in metal concentrations during pre-monsoon, monsoon, and post-monsoon periods. The results revealed significant seasonal fluctuations, with Pb and Mn concentrations peaking during the monsoon season, reaching 2.1 µg/g and 1.41 µg/g, respectively, with p-values of 0.00 for both. Other metals such as Zn, Ni, Cd, Cr, and Cu showed minimal variation across seasons. These findings suggest that Pb and Mn bioaccumulate significantly during the monsoon, likely due to increased runoff, while other metals remain stable. This study emphasizes the importance of continuous monitoring of heavy metal bioaccumulation in marine species to assess potential environmental and public health risks.

Keywords: Heavy Metals, Bioaccumulation, Lepturacanthus Savala, Seasonal Variation, Pb, Mn, Environmental Monitoring.

1. Introduction

In Indian waters, there are 10 species of ribbon fish from the *Trichiuridae* family spread across three genera. *Trichiurus lepturus* and *Lepturacanthus savala* are the two most common species along the Gujarat coast. Ribbon fish landings in India were estimated to be 1.41 lakh tons in 2021 (CMFRI). However, because of the COVID-19 epidemic, landings fell to 75,664 tons in 2020, a 24% decline over 2019. In 2021, pelagic fish landings in Gujarat were 2.18 lakh tons, with ribbon fish accounting for 38% of the total marine fish landings in the region. Ribbonfish accounted for 10.49% of all marine fish landings and 27.71% of pelagic fish landings. Ribbon fish made up 4.46% of all marine fish landings, with 4.20% at the landing price and 4.4% at the retail price (2021).

The most common method for catching ribbon fish is with mechanical multiday trawl nets (82%), followed by set bag nets (11%), purse seines (5%), and gillnets (2%). *Trichiurus lepturus* is the most common species, ranging in size from 235 to 1150 mm. Mature and pregnant females are seen from January to March and October to December. Ribbon fish are predatory and carnivorous, with cannibalistic and selective feeding behaviors. They primarily consume species such as Acetes spp., *Stolephorus* spp., *Sardinella* spp., *Dussumieria* spp., *squilla, Penaeus* spp., *Metapenaeus* spp., and other intermediate prey (Chiou et al., 2006).

India is a major exporter of ribbon fish, whereas China is the main buyer. Gujarat is a key player in this export, as evidenced by a compound growth rate (CGR) of 6.15% in quantity and 12.5% in unit price over the last 15 years (2003-2018) (DGFT-India database, 2018). Food Chain Disruption: Contaminated fish affect predator species and overall aquatic biodiversity (Khushbu et al., 2022). Long-term Environmental Impact: Heavy metals persist in ecosystems, leading to chronic health issues in aquatic organisms and humans (Chatha et al., 2023). While heavy metals pose significant threats, some studies suggest potential resilience in certain fish species, indicating a need for further research on adaptive mechanisms (Santhosh et al., 2024).

2. Materials and methods

2.1. Seasonal Variation and Accumulation of Heavy Metals in Water and Selected Fish Organs and Determination of heavy metals in water

Water samples were collected monthly in polyvinyl chloride Van Dorn bottles (5 L capacity) from two meters depth in the selected two stations from June 2022 to July 2023. Water samples were kept in a one-litter polyethylene bottle in the icebox and analyzed in the laboratory.

Total heavy metals (Zn, Cu, Mn, Cr, Pb, Cd, and Ni) were measured after digestion using Graphite Furnace AA (GFAA) spectroscopy. A mixture of nitric acid and the material to be analyzed was a relaxed Edina-covered Griffin beaker. After the digest had been brought to a low volume, it was cooled and brought up in dilute nitric acid (3% v/v). The sample was filtered, allowed to settle, and prepared for analysis. It is to be noted that, most of the parameters in the two stations were relatively close to each other; therefore the averages were calculated by the end of the measurement period.

2.2. Determination of heavy metals in the fish sample

Fresh fish samples were collected by using long line or nets from the selected sites during the period from June 2022 to July 2023. After taking the morph metric parameters (Table 4.5-4.6), fishes were dissected in the pre-cleaned dish with stainless steel dissection apparatus, major organs- muscle, skin, gills, and intestine were separated, washed in de-ionized water and oven dried until constant weight. The shell fishes organs of crab (hepto pancreas, muscle and gills) , prawn organs (head, flesh and shell) were separated, smashed in to small pieces and dried to constant weight. Each tissue was put in a separate Petri dish and dried in an oven at 110°C for 48 hours until a constant weight was reached. 0.5 g of each dry tissue was weight and put in a separate test tube. The nitric acid (HNO_3) and perchloric acid ($HCLO_4$) in 2:1 ratio was added to each sample and left overnight at room temperature. The sample was digested in a water bath set to 100oc water boiling temperature and the content was boiled for about 2h until all the tissues dissolved. The digest was allowed to cool and 5 ml of distilled water was added. The solution transferred to 25 ml volumetric flask and made up to mark with 1% HNO_3 (FAO, 1984). The digest was kept in plastic bottles and accumulated heavy metals concentrations in mg/g dry weight were determined using atomic absorption spectrophotometer (Shah and Altindag, 2005).

List of fin fishes collected for the study and Morphometric parameters of fishes

The scientific name of fish	Vernacular Name	Length (cm)	Weight (g)
Lepturacanthus savala	Silver ribbon fish	21	3 kg

2.3. Risk assessment of heavy metal contamination in stations 1 and 2

The methodology followed in this chapter includes a fish and fin fish consumption survey in the study area and the data derived from the survey was used to estimate the exposure risk of heavy metals to the community.

2.4. Fish and shellfish consumption survey

For the dietary survey and community health risk assessment, the questionnaire (Annexure-I) was designed according to standard survey methods (USEPA, 1998). The questions were prepared to gather information about (1) personal data such as sex, age, body weight, occupation, and community (2) fish consumption habits such as how long they are eating fish, approximate number of fish meals, and approximate weight of fish consumed and (3) probable symptoms of chronic heavy metal toxicity by contaminated fish consumption.

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A total of 400 families were randomly selected from two locations, i.e. Nizamaptnum harbor and kothapalem sea shore area. (200 families from each location). The survey team members directly approached and interviewed one or more members of the family with the questionnaire. House wives (ladies) were mostly consulted for the interview for getting more accurate information about the dietary habits and health status of the family members.

2.5. Estimated Daily Intake (EDI) and Estimated Weekly Intake (EWI)

EDI and EWI are two frequently used indices to estimate the risk of heavy metal contaminated fish and fin fish consumption to the local community (Griboff *et al.* 2017). The EDI and EWI was calculated based on fish and fin fish consumption quantity, heavy metal levels of the samples and average body weight of local people in the study area.

$$\mathbf{EDI = MS \times C / BW}$$

MS= Daily food ingestion rate per day 34 g / day
C= Metal content in fish muscles (µg/g)
BW= Average body weight (70 kg).
EWI= EDI X 7.

3.0 Results

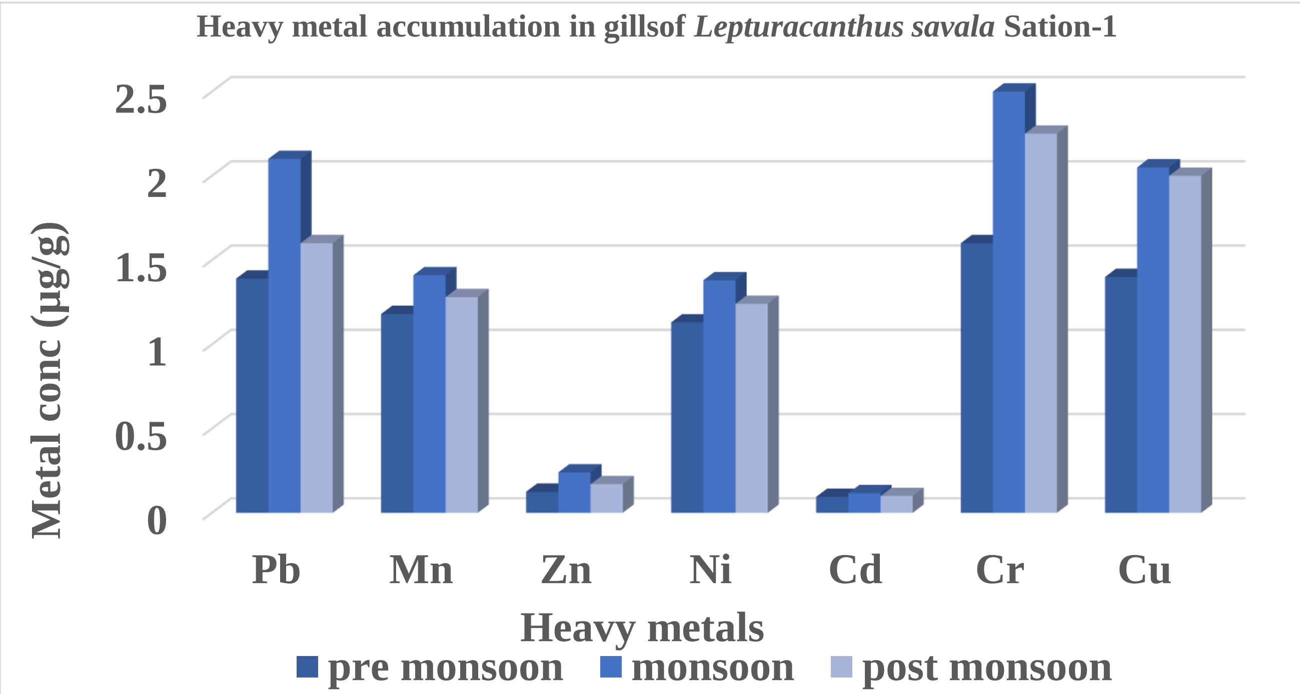

Figure 01: Accumulation of heavy metals (µg/g)) in the Gills of *Lepturacanthus savala* in station 1 during the study period of June 2022-July 2023 (Mean ±S.E.)

Seven metals were assessed: lead (Pb), manganese (Mn), zinc (Zn), nickel (Ni), cadmium (Cd), chromium (Cr), and copper (Cu). Data, presented as mean ± standard error, were analyzed across pre-monsoon, monsoon, and post-monsoon periods using one-way ANOVA.

The seasonal fluctuations in lead (Pb) and manganese (Mn)**,** both show the highest concentrations during the monsoon**.** Pb reached a peak of 2.1 µg/g, and Mn 1.41 µg/g, with p-values of 0.00 for both, indicating a strong seasonal influence. Zinc (Zn)**,** nickel (Ni)**,** cadmium (Cd)**,** chromium (Cr)**,** and copper (Cu) showed minimal variation between seasons. While Zn and Cu concentrations were higher during the monsoon, these changes were not statistically significant, with p-values of 0.32, 0.80, and 0.94, respectively.

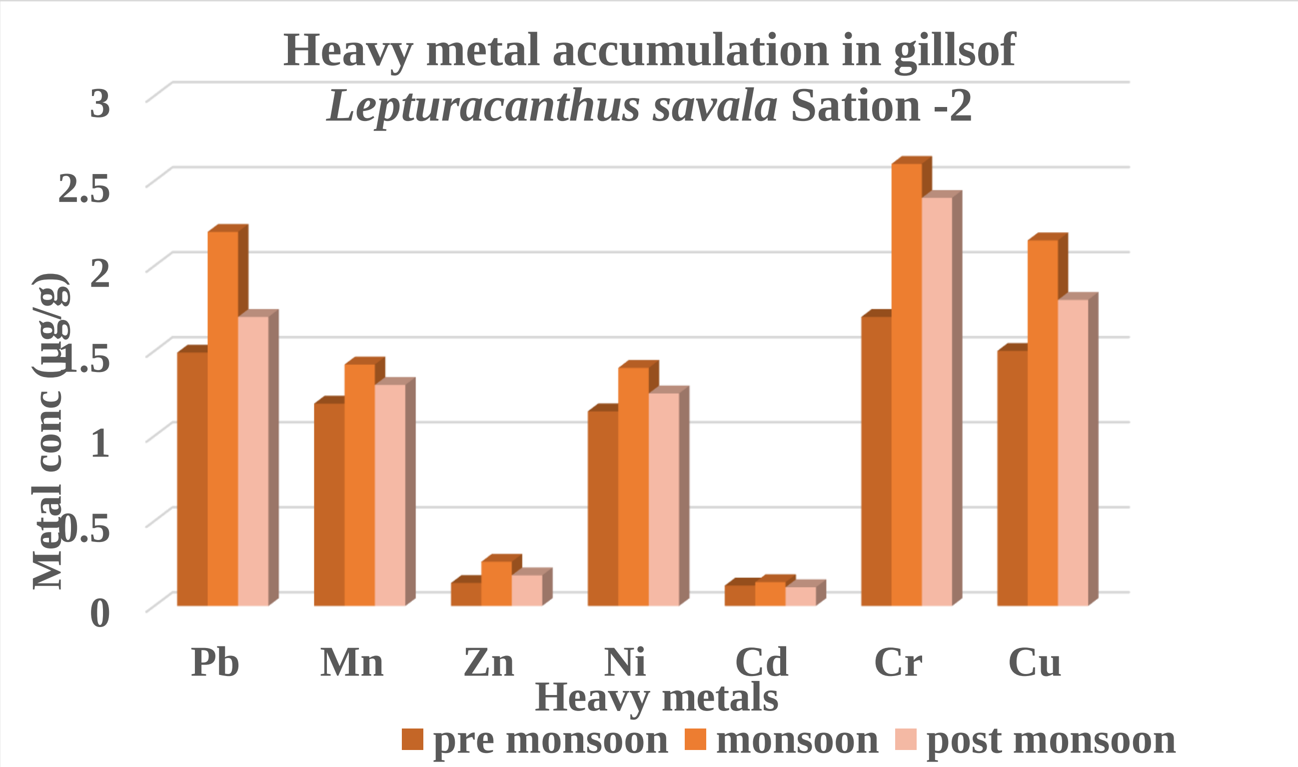

Figure 02 Accumulation of heavy metals (µg/g) in the Gills of *Lepturacanthus savala* at station 2 during the study period from June 2022 to July 2023 (Mean ± SE).

The results showed lead (Pb) and manganese (Mn) exhibited the most notable seasonal fluctuations. Pb levels were significantly higher during the monsoon (2.2 µg/g) compared to the pre-monsoon (1.49 µg/g) and post-monsoon (1.7 µg/g) periods, with a p-value of 0.00, indicating strong seasonal variation. Similarly, Mn concentrations peaked in the monsoon (1.42 µg/g), showing significant seasonal variation (p-value = 0.00). Other metals, such as zinc (Zn), increased slightly during the monsoon but the change was not statistically significant (p-value = 0.32). Nickel (Ni), cadmium (Cd), chromium (Cr), and copper (Cu) levels remained stable across seasons, with no significant differences observed.

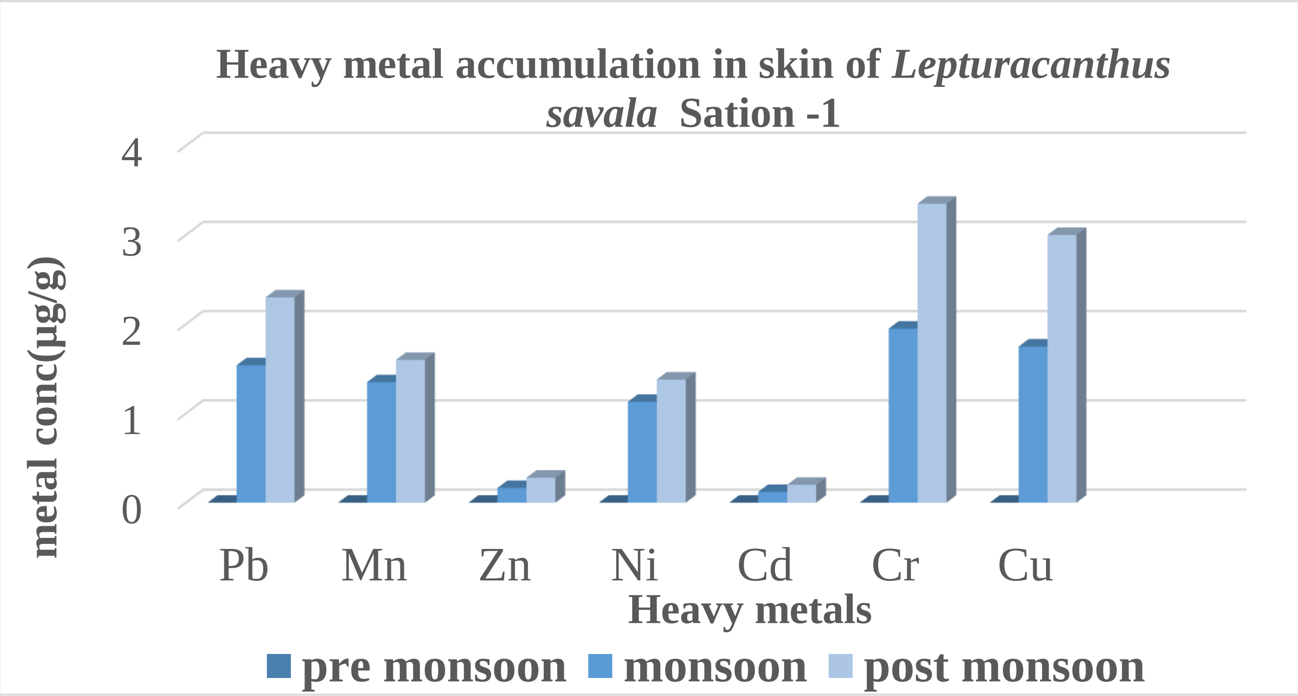

Figure 03: Accumulation of heavy metals (µg/g) in the skin of *Lepturacanthus savala* in station 1 during study period of june2022-July 2023 (Mean ±S E)

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The results are represented in Lead (Pb) levels exhibited a significant seasonal variation, peaking during the monsoon (2.3 µg/g), with a significant difference from the pre-monsoon (1.54 µg/g) and post-monsoon (2.0 µg/g) periods (p-value = 0.00). Manganese (Mn) concentrations were similarly elevated during the monsoon (1.6 µg/g), also showing significant seasonal variation (p-value = 0.00). In contrast, zinc (Zn) exhibited only a slight increase in the monsoon (0.28 µg/g) compared to pre-monsoon (0.165 µg/g) and post-monsoon (0.20 µg/g), but the change was not statistically significant (p-value = 0.32). Nickel (Ni), cadmium (Cd), chromium (Cr), and copper (Cu) concentrations remained stable throughout the study period, with no significant seasonal differences (p-values = 0.66, 0.6, 0.74, and 0.40, respectively).

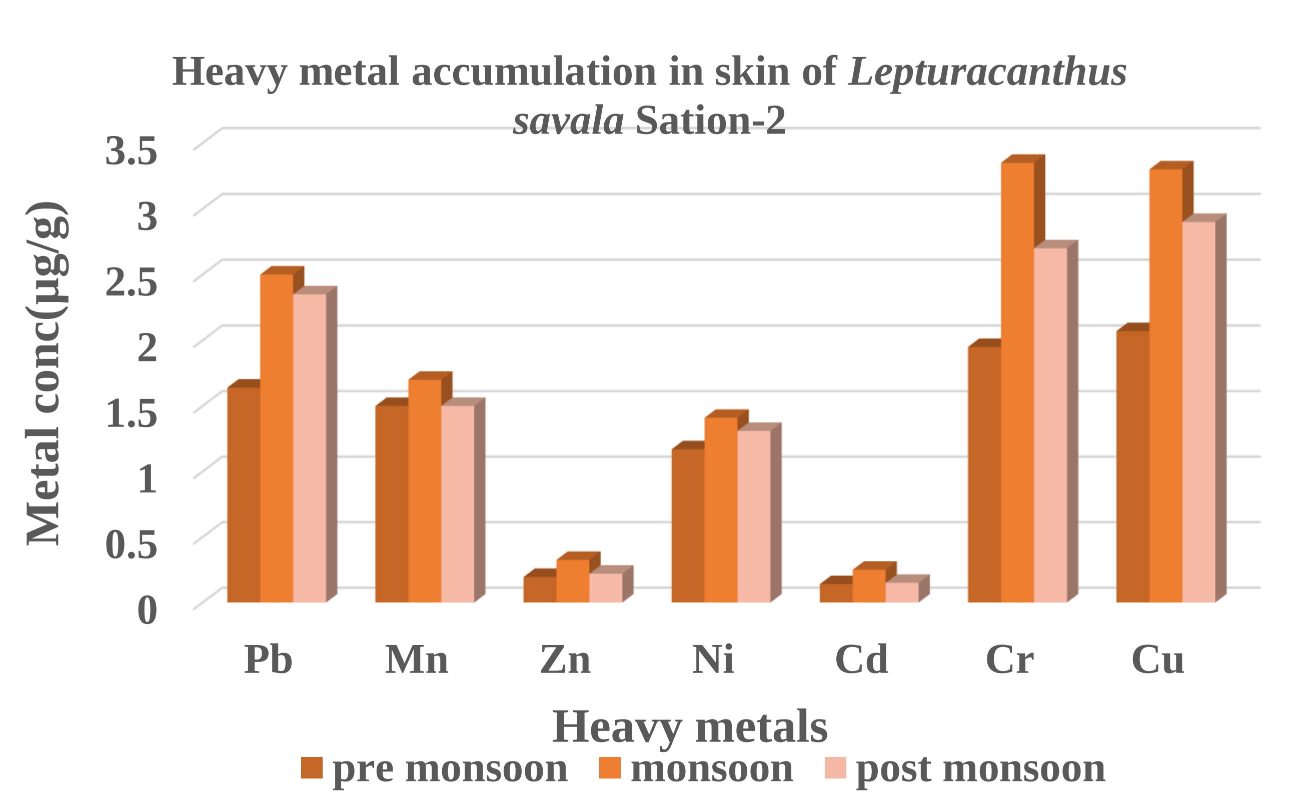

Figure 04: Accumulation of heavy metals (µg/g) in the skin of *Lepturacanthus savala* in station 2 during the study period of June 2022-July 2023 (Mean ± S E)

The results revealed that Pb concentrations were highest during the monsoon season, with a significant increase (2.5 µg/g) compared to both the pre-monsoon (1.64 µg/g) and post-monsoon (2.35 µg/g) periods (p-value = 0.00). Similarly, Mn levels peaked during the monsoon (1.7 µg/g), showing a significant seasonal difference (p-value = 0.00). Zinc levels were slightly elevated in the monsoon (0.325 µg/g) compared to the other seasons but did not show statistical significance (p-value = 0.32). In contrast, Ni, Cd, Cr, and Cu concentrations remained relatively stable throughout the year, with no significant seasonal fluctuations (p-values = 0.66, 0.5, 0.64, 0.50).

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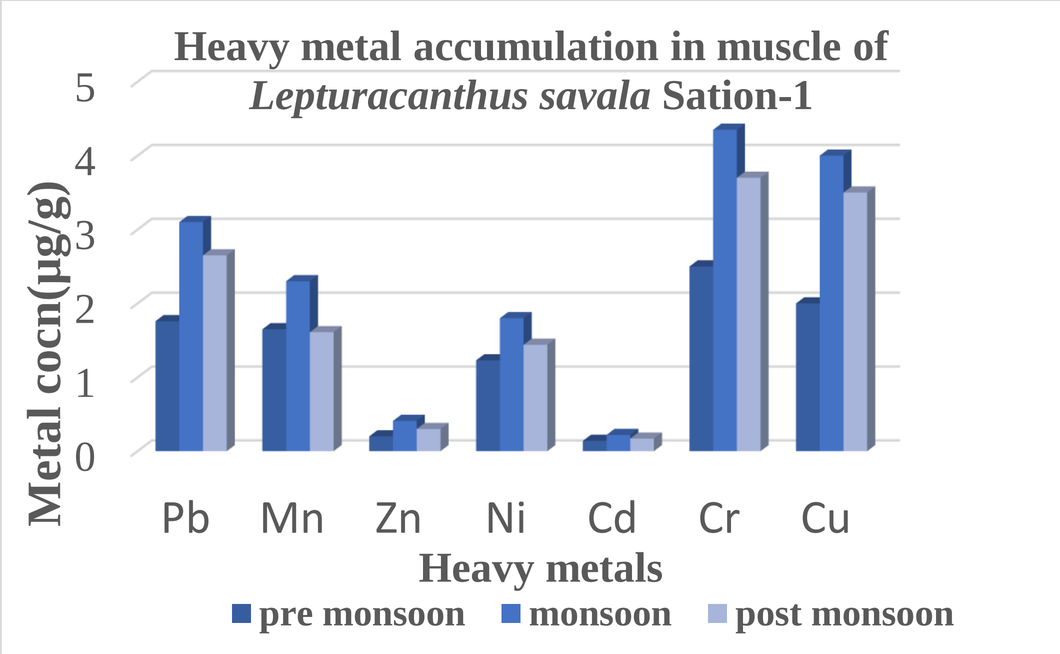

Figure: 05 Accumulation of heavy metals (µg/g) in the muscle of *Lepturacanthus savala* in station 2 during the study period of June 2022-July 2023 (Mean ± S E)

The results revealed that lead (Pb) concentrations were significantly higher during the monsoon season (3.1 µg/g), compared to pre-monsoon (1.76 µg/g) and post-monsoon (2.65 µg/g) levels (p-value = 0.00). A similar trend was observed for manganese (Mn), with the highest levels recorded during the monsoon (2.3 µg/g) (p-value = 0.00). In contrast, zinc (Zn) showed a slight increase during the monsoon (0.41 µg/g) compared to pre-monsoon (0.20 µg/g) and post-monsoon (0.30 µg/g), but this change was not statistically significant (p-value = 0.32). The concentrations of nickel (Ni), cadmium (Cd), chromium (Cr), and copper (Cu) remained relatively stable across all seasons, with no significant seasonal variation observed (p-values = 0.66, 0.86, 0.94, 0.80).These findings highlight the significant seasonal fluctuations in Pb and Mn, likely linked to environmental factors like increased runoff during the monsoon. This study underscores the importance of ongoing monitoring of heavy metal accumulation in marine organisms to assess environmental health risks.

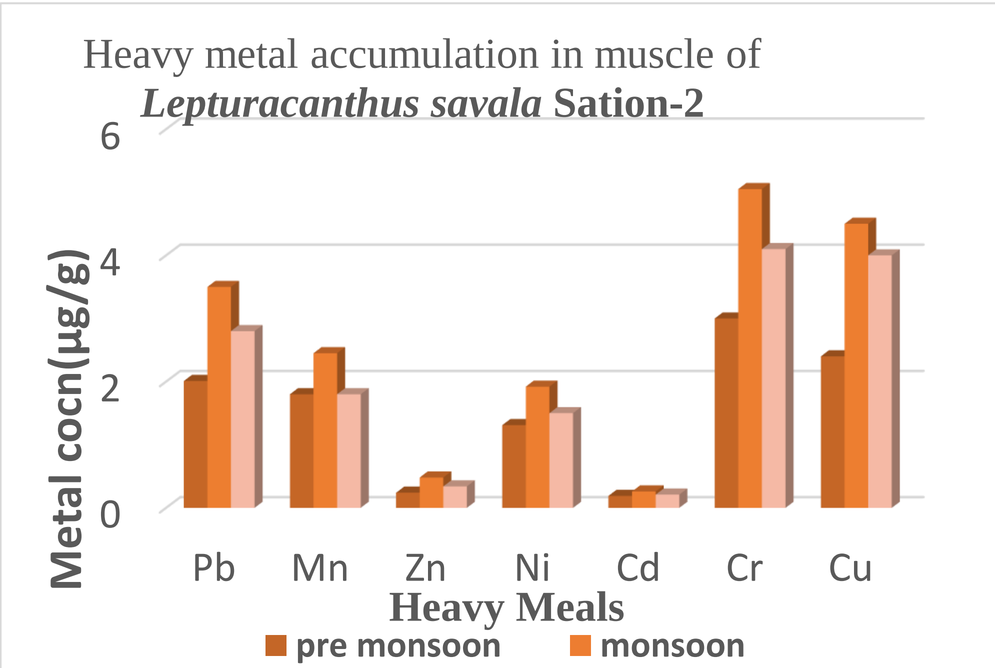

Figure 06: Accumulation of heavy metals (µg/g) in the muscle of *Lepturacanthus savala* in station 2 during the study period of June 2022-July 2023 (Mean ± S E)

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Key findings revealed that lead (Pb) concentrations peaked during the monsoon season at 3.5 µg/g, significantly higher than the pre-monsoon (2.01 µg/g) and post-monsoon (2.8 µg/g) levels (p-value = 0.00). Similarly, manganese (Mn) concentrations also showed a marked increase during the monsoon (2.45 µg/g) compared to pre-monsoon (1.8 µg/g) and post-monsoon (1.8 µg/g) periods (p-value = 0.00). Zinc (Zn) exhibited a minor increase during the monsoon (0.48 µg/g) relative to pre-monsoon (0.24 µg/g) and post-monsoon (0.34 µg/g), but the difference was not statistically significant (p-value = 0.32). Conversely, nickel (Ni), cadmium (Cd), chromium (Cr), and copper (Cu) concentrations remained consistent throughout the seasons with no significant variation (p-values = 0.66, 0.86, 0.94, 0.80).

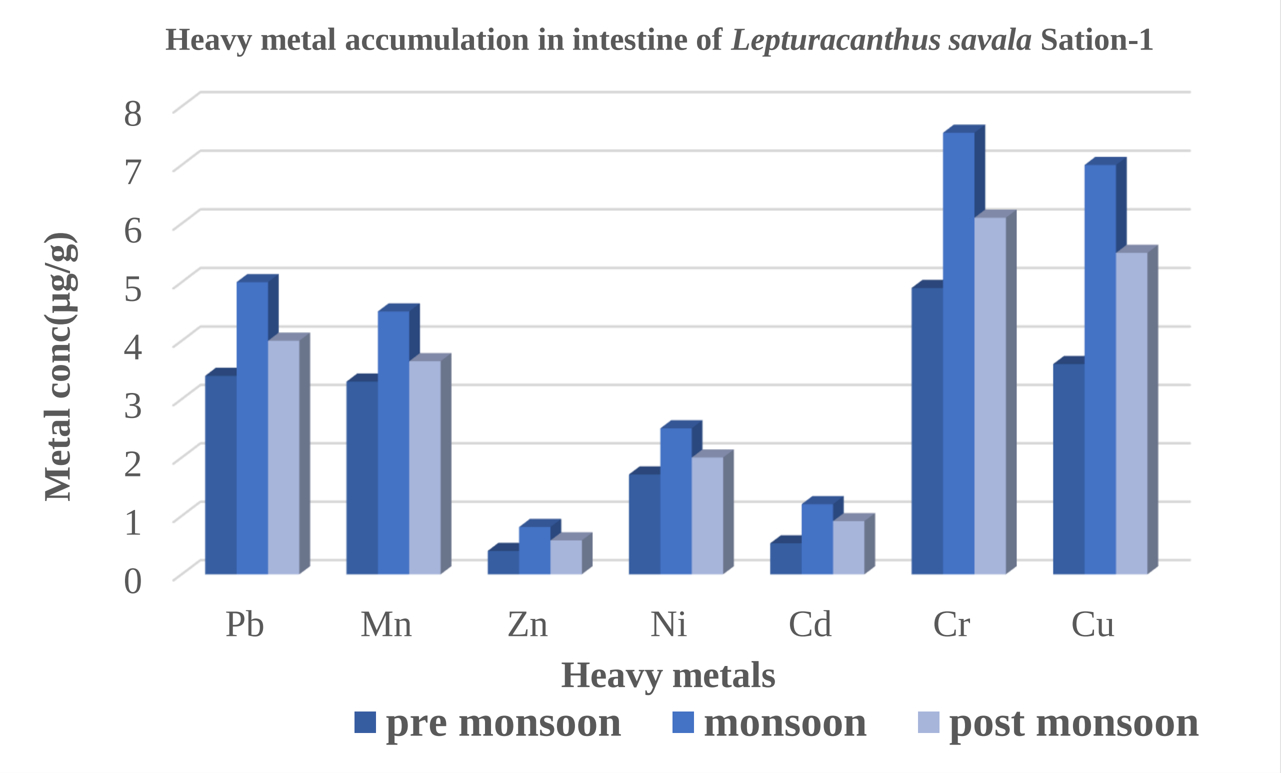

Figure 07: Accumulation of heavy metals (µg/g) in the intestine of *Lepturacanthus savala* in station 2 during the study period of June 2022-July 2023 (Mean ± S E)

Key findings revealed significant seasonal differences in the concentrations of certain metals. Lead (Pb) concentrations were highest during the monsoon (5 µg/g), significantly greater than in the pre-monsoon (3.4 µg/g) and post-monsoon (4 µg/g) periods (p-value = 0.00). Similarly, Manganese (Mn) levels were elevated during the monsoon (4.5 µg/g), significantly higher than the pre-monsoon (3.3 µg/g) and post-monsoon (3.65 µg/g) concentrations (p-value = 0.00). Zinc (Zn) showed an increase during the monsoon (0.81 µg/g), compared to pre-monsoon (0.4 µg/g) and post-monsoon (0.58 µg/g), but this change was not statistically significant (p-value = 0.32). Other metals, including Nickel (Ni), cadmium (Cd), chromium (Cr), and copper (Cu), exhibited stable concentrations across all seasons, with no significant variations (p-values = 0.66, 0.86, 0.94, 0.80).

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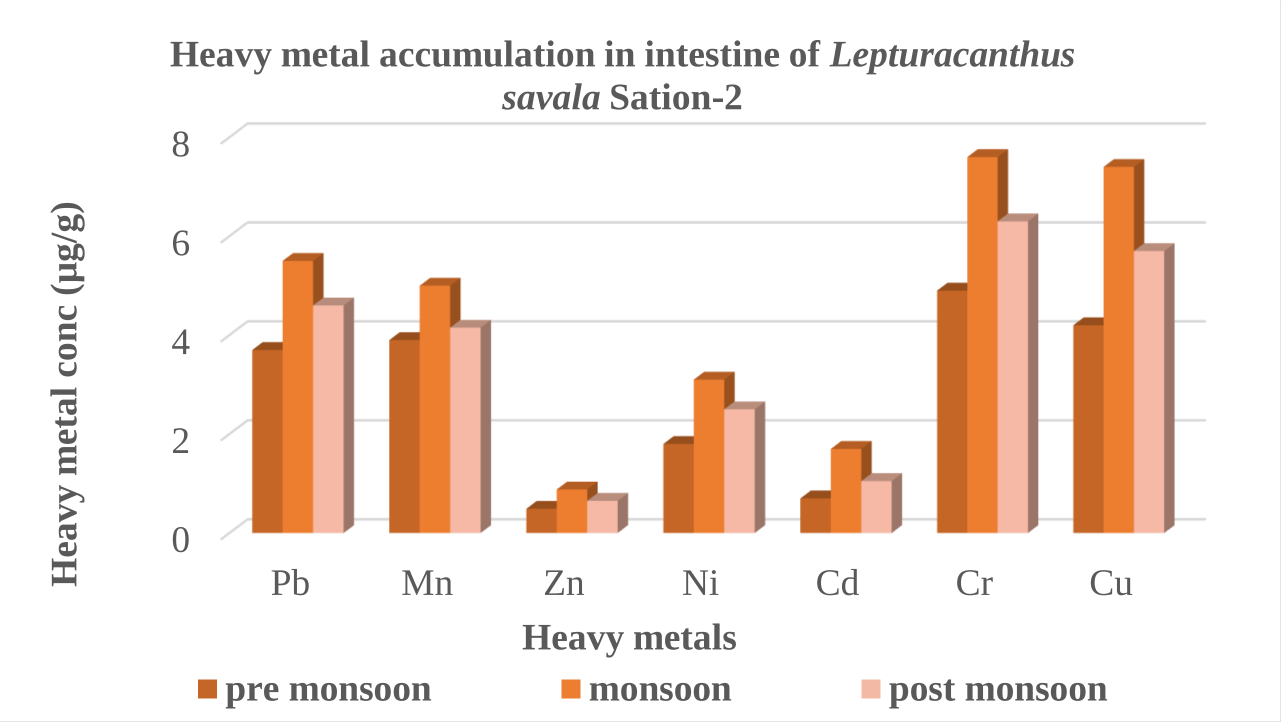

Figure 08: Accumulation of heavy metals (µg/g) in the intestine of *Lepturacanthus savala* in station 2 during the study period of June 2022-July 2023 (Mean ± S E)

Heavy metals were analyzed in three seasonspre-monsoon: Pb (3.7), Mn (3.9), Zn (0.49), Ni (1.8), Cd (0.7), Cr (4.9), Cu (4.2), monsoon: Pb (5.5), Mn (5), Zn (0.88), Ni (3.1), Cd (1.7), Cr (7.6), Cu (7.4), post-monsoon: Pb (4.6), Mn (4.15), Zn (0.65), Ni (2.5), Cd (1.05), Cr (6.3), Cu (5.7). Ranked as follows: Monsoon > Post-monsoon > Pre-monsoon 7 heavy metals: Pb (5.5 > 4.6 > 3.7), Mn (5 > 4.15 > 3.9), Zn (0.88 > 0.65 > 0.49), Ni (3.1 > 2.5 > 1.8), Cd (1.7 > 1.05 > 0.7), Cr (7.6 > 6.3 > 4.9), Cu (7.4 > 5.7 > 4.2). Research on heavy metal accumulation in fish from various Indian water bodies reveals seasonal variations and tissue-specific patterns. Channa striata in the Krishna River exhibited elevated levels of Zn and Pb in muscle and liver tissues throughout various seasons (Krishna Pv et al., 2021). According to Jithesh and Radhakrishnan (2017), the Chaliyar River's Trichiuruslepturus showed the highest metal buildup in their gills during the monsoon season, with Fe > Zn > Mn > Cu > Cr > Pb. In the Cochin backwaters, liver consistently accumulated higher levels of metals than gill or muscle across various fish species, as reported by Rejomon George et al. (2012). The metal concentrations in Mumbai Harbour fish varied by species, with the greatest concentrations found in J. elongatus and C. dussumieri (Velusamyet al., 2014).

Discussion

This study on the seasonal bioaccumulation of heavy metals in *Lepturacanthus savala* at Station 2 offers valuable insights into the fluctuations of seven metals—lead (Pb), manganese (Mn), zinc (Zn), nickel (Ni), cadmium (Cd), chromium (Cr), and copper (Cu)—in the fish's intestine over a year-long period from June 2022 to July 2023. The results revealed significant seasonal variations, particularly for Pb and Mn, which showed marked increases during the monsoon season. Pb concentrations reached 5 µg/g, and Mn peaked at 4.5 µg/g, both with p-values of 0.00, indicating that seasonal factors significantly influence the accumulation of these metals in fish tissue.

The observed seasonal peaks in Pb and Mn are likely a result of increased environmental runoff during the monsoon season. Heavy rainfall can wash metals from surrounding terrestrial environments into water bodies, contributing to elevated concentrations in aquatic organisms. These findings are consistent with other regional studies that have documented similar seasonal fluctuations in heavy metal levels in fish from Indian water bodies. For instance, research on fish from the Krishna River and the Cochin backwaters indicated elevated metal concentrations during the monsoon season, especially for metals like Pb, Zn, and Mn (Krishna Pv et al., 2021; Rejomon George et al., 2012).

Interestingly, metals such as Zn, Ni, Cd, Cr, and Cu did not exhibit significant seasonal variation in this study. These metals remained relatively stable across the pre-monsoon, monsoon, and post-monsoon periods, suggesting that their bioaccumulation may be less influenced by seasonal runoff or other environmental factors. This stability could be attributed to the fact that these metals might not be as readily mobilized into the water column during the monsoon as Pb and Mn, or they may have other pathways of entry into the marine food web that are less influenced by seasonal changes in rainfall.

The findings of this study underscore the importance of ongoing monitoring of heavy metals in marine ecosystems, particularly for metals that show significant seasonal variation like Pb and Mn. Monitoring such bioaccumulation patterns is crucial to assessing the potential ecological and health risks associated with heavy metal exposure in marine organisms. The seasonal fluctuations observed in Pb and Mn could be a cause for concern, as these metals are toxic at higher concentrations and can accumulate in the food chain, potentially affecting human health through the consumption of contaminated fish.

Conclusion

The study reinforces the need for comprehensive environmental monitoring, particularly during the monsoon season when runoff msay exacerbate the accumulation of hazardous metals. By continuously tracking heavy metal concentrations in marine species like *Lepturacanthus savala*, we can better understand the dynamics of pollution and mitigate potential risks to both marine ecosystems and human health.

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