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Bioaccumulation of Heavy Metals in Different Tissues of Lates Calcarifer from Nizampatnam harbour and Kothapalem beach Areas, Andhra Pradesh

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Abstract:

This study aimed to assess the seasonal variation and bioaccumulation of heavy metals in different tissues of the marine fish *Lates calcarifer*, collected from two selected stations in the coastal region. The analysis was conducted during the pre-monsoon, monsoon, and post-monsoon seasons to evaluate the distribution of heavy metals in the gills, muscle, skin, and intestine tissues. The heavy metals analyzed included chromium (Cr), copper (Cu), manganese (Mn), lead (Pb), zinc (Zn), and cadmium (Cd), using standard analytical methods. The results indicated significant seasonal and tissue-specific variations in heavy metal concentrations. Among all the analyzed metals, chromium (Cr) consistently displayed the highest concentration across all tissues during the three seasons at both sampling stations. In the pre-monsoon season, the intestine showed the highest accumulation of chromium, with concentrations of 7.9µg/g at Station1 and 8.9µg/g at Station 2, followed by copper, manganese, and lead. During the monsoon season, the intestine again exhibited the highest metal accumulation, with chromium reaching 9.55µg/g, followed by copper at 9.0 µg/g and manganese at 6.5µg/g. Post-monsoon observations also indicated elevated chromium concentrations in the intestine, with values of 8.155µg/g at Station1 and 9.15µg/g at Station 2. Copper, lead, and manganese were recorded as the next predominant metals in all tissues. Among the examined tissues, the intestine demonstrated the highest bioaccumulation of heavy metals throughout the study period, highlighting its significant role in metal absorption and metabolism. The skin tissue consistently exhibited manganese as the third most accumulated metal during all seasons at both stations. In contrast, zinc (Zn) and cadmium (Cd) showed the lowest concentrations across all analyzed tissues. This study underscores the influence of seasonal variations on heavy metal accumulation in fish tissues and emphasizes the importance of continuous monitoring of coastal aquatic ecosystems to assess environmental pollution and potential risks to human health.

Keywords: Heavy metals, bioaccumulation, *Lates calcarifer*, Tissues.

Introduction

Heavy metal pollution in marine ecosystems has become a significant global issue in recent years. Toxic heavy metals enter aquatic environments through various means, including atmospheric deposition, geological weathering, and the release of industrial waste. Due to their toxic nature, persistence, and ability to bio-accumulate in marine organisms, public concern about the distribution and effects of heavy metal contamination in vulnerable coastal areas has notably increased (Martorell *et al.,* 2009). Aquatic ecosystems serve as major repositories for a wide range of pollutants, including agricultural pesticides and heavy metals released from human activities such as industrial processing, mining, and waste disposal. While trace amounts of heavy metals are naturally present in water and sediments, excessive accumulation caused by human activities can harm aquatic organisms, disrupt ecosystem stability, and pose risks to human health through bio-magnification within the food chain.

However, human activities have significantly increased the natural concentration of heavy metals from parts per billion (ppb) to levels close to 10 parts per million (ppm) (Kelkar *et al.,* 2001). The occurrence and toxicity of trace elements and heavy metals in aquatic environments, including fish, have been extensively researched and documented (Zhuang and Gao, 2014). In aquatic ecosystems, heavy metals are introduced through natural processes such as the weathering of rocks and soils, volcanic eruptions, and through human activities, including mining operations and the use of metal-containing compounds. Currently, the contamination of water bodies due to industrial effluents and domestic sewage has increased significantly (Kumar et al., 2004). Most researchers have found that heavy metals in water and sediments predominantly exist in physicochemical forms. The presence of both inorganic and organic heavy metal pollutants is of particular concern due to their non-biodegradable nature and persistence in the environment. These metals tend to accumulate in lower trophic organisms and subsequently magnify through the food chain, leading to elevated concentrations in higher organisms. This phenomenon has been widely discussed by Lu (2015) and Chao et al. (2017). According to Manju Mahurpawar (2015), the adverse effects of heavy metal contamination are not limited to aquatic organisms but also extend to humans. One major concern is the high stability of heavy metals, which makes their removal through oxidation or precipitation processes difficult. As a result, even at low concentrations, heavy metals can persist in aquatic environments for long periods and accumulate in aquatic organisms through the process of bioaccumulation.

Fish is an important dietary resource for humans and plays a crucial role in various ecological food chains. It is a significant source of fats, fat-soluble vitamins, and high-quality protein that positively impacts human health more than the protein found in meat and poultry. The composition of fish includes protein ranging from 15% to 24%, carbohydrates between 1% and 3%, lipids from 0.1% to 22%, inorganic compounds making up 0.8% to 2%, and water content ranging from 66% to 84%.

Monitoring heavy metal pollution is an important area of research in Andhra Pradesh, India. This is due to the fact that heavy metal concentrations in aquatic ecosystems directly affect the fish industry, which is a vital source of livelihood for many people (Ochieng et al., 2008). According to Allinson et al. (2009), fish absorb metals through various mechanisms, including the ingestion of suspended particulate matter in water, the consumption of contaminated food, the exchange of dissolved metals across lipophilic membranes (such as the gills), and the adsorption of metals onto tissue and membrane surfaces.

Figure1. Selected fish *Lates calcarifer* for the heavy metal analysis

Material and Methods

Study Area

Two stations were selected in the Bapatla: Station I (Nizampatnam Fish Harbor; Latitude 15°54′N, Longitude 80°40′E) and Station II (Kothapalem; Latitude 10.8851°N, Longitude 78.5791°E). Station I is located in the Bapatla district of the Indian state of Andhra Pradesh. The Bapatla district is characterized by industrial activities, including cement and dye manufacturing industries. Station II is situated approximately 16 km away from Station I.

Sample Collection

The study was carried out over a period of 12 months, from June 2022 to July 2023. Monthly water samples were collected throughout the study period, covering three different seasons. Water samples were collected from harbour areas at a depth of 1–1.5 m. The samples were collected in clean, dried plastic cans with a capacity of 2 litres and transported immediately to the laboratory for analysis. Sampling was conducted during the morning hours between 7:00 a.m. and 9:30 a.m. Monthly sampling was performed continuously throughout the study period from June 2022 to July 2023.

Seasonal variation and accumulation of heavy metals in water and in selected fish organs

The study was carried out for the seasonal variation; in which accumulation of heavy metals in water in selected fish organs, determination of heavy metals in water determination of heavy metals in soil and Risk assessment of heavy metal contamination in stations 1 and 2 for the study.

Results and Discussion

Metal concentrations exhibit seasonal variations, with elevated levels frequently recorded in summer (Murugaiyan, 2020). According to FAO/WHO recommendations, metal concentrations were generally within safe limits for human consumption, even though they frequently surpassed natural background levels (Krishna Pv *et al.,* 2021). During the pre-monsoon season, data collected from Stations 1 and 2 revealed variations in heavy metal concentrations in different tissues of the aquatic species *Lates calcarifer*. Among all the analysed metals, chromium (Cr) had the highest concentration in all tissues compared to the others. At Station 1, the intestine showed the highest accumulation of chromium at 7.9 mg/kg, followed by copper (Cu) at 7.6 µg/g, manganese (Mn) at 5.6 µg/g, and lead (Pb) at 5.4 µg/g. Similarly, Station 2 recorded higher concentrations of chromium at8.9 µg/g, followed by copper at8.2 µg/g, manganese at6.5 µg/g, and lead at6.3 µg/g. The lowest concentrations of heavy metals, cadmium (Cd) and zinc (Zn) were observed in all tissues of the studied fish species (Fig. 2&3; Table. 1 to 8). Seasons and species affect the amount of heavy metals that accumulate in fish tissues, with summertime seeing the highest concentrations (Hussain *et al.,* 2021). Liver and kidney tissues typically exhibit higher metal accumulation compared to gills or muscle (Hussain *et al.,* 2021).

During the monsoon season, the data collected indicated that chromium (Cr) had the highest concentration in samples from both Stations 1 and 2. This was followed by copper (Cu), lead (Pb), and manganese (Mn) in the gills, muscles, skin, and intestinal tissues. Among the various tissues analysed, the intestine showed the highest accumulation of heavy metals, with recorded concentrations of chromium at 9.55 µg/g, copper at 9.0 µg/g, and manganese at6.5 µg/g at both stations. In contrast, lower concentrations of cadmium (Cd) and zinc (Zn) were found in the gills, skin, and intestinal tissues. However, in muscle tissue, the concentrations of zinc were slightly higher than those of cadmium at both sampling stations (Fig. 4&5; Table 1&8).

During the post-monsoon season, analysis results from Stations 1 and 2 indicated that chromium (Cr) had the highest concentration in all examined tissues. Among the tissues analyzed, the intestine showed the maximum accumulation of chromium, with concentrations of 8.155µg/g at Station 1 and 9.15µg/g at Station 2. This was followed by copper (Cu), which had concentrations of 4.9 µg/g at Station 1 and 8.75 µg/g at Station 2, lead (Pb) with 5.6 µg/g at Station 1 and 7.1 µg/g at Station 2, and manganese (Mn) with 5.65 µg/g at Station 1 and 5.6 µg/g at Station 2. In addition, skin tissue exhibited manganese as the third highest accumulated metal during all three seasons at both sampling stations. In contrast, zinc (Zn) and cadmium (Cd) showed the lowest concentrations across all tissues collected from the two selected stations (Fig. 6,7&8; Table 1&8). The sequence of metal abundance frequently differs among water, sediment, and fish tissues (M. Akila *et al.,* 2022). According to Akila *et al.,* (2022), the most common metals in fish samples from Pulicat Lake were Cu and Cr. Likewise, Zn and Pb were more common in *Channa striata* in the Krishna River (Krishna Pv *et al.,* 2021).

Conclusion:

The present study demonstrated significant seasonal and tissue-specific variations in heavy metal accumulation in the aquatic species *Lates calcarifer*, collected from two selected stations. Among all the analyzed heavy metals, chromium (Cr) consistently exhibited the highest concentration across all tissues during the pre-monsoon, monsoon, and post-monsoon seasons. The intestine showed the maximum accumulation of heavy metals compared to the gills, muscle, and skin tissues, indicating its significant role in metal absorption, digestion, and metabolic activities. During all three seasons, chromium was followed by copper (Cu), lead (Pb), and manganese (Mn) as the predominant metals accumulated in fish tissues. The monsoon season recorded comparatively higher concentrations of heavy metals, suggesting the influence of runoff, industrial discharge, and anthropogenic inputs into the aquatic ecosystem. Skin tissue consistently showed manganese as one of the dominant accumulated metals throughout the study period. In contrast, zinc (Zn) and cadmium (Cd) were found at comparatively lower concentrations in all tissues at both sampling stations. This study highlights the bioaccumulation potential of heavy metals in commercially important fish species and indicates possible environmental contamination in the study area. The continuous accumulation of heavy metals in edible fish tissues may pose ecological and human health risks through the food chain. Therefore, regular monitoring of heavy metal pollution in aquatic ecosystems is essential for environmental protection, sustainable fisheries management, and safeguarding public health.

The study is particularly useful for identifying pollution trends in aquatic ecosystems affected by industrial discharge, agricultural runoff, and other anthropogenic activities. Since chromium (Cr), copper (Cu), lead (Pb), and manganese (Mn) showed higher accumulation in fish tissues, especially during the monsoon season, the results can assist environmental agencies in developing effective pollution control and coastal management strategies. The research is also highly beneficial for public health awareness because fish muscle is widely consumed by humans. Continuous monitoring of heavy metal accumulation in edible fish tissues can help determine food safety levels and reduce the risk of heavy metal exposure through the food chain. The study may further support government authorities in establishing environmental quality standards, fisheries regulations, and pollution mitigation policies. In addition, the findings can serve as a foundation for future multidisciplinary research involving environmental toxicology, aquatic biology, marine ecology, food safety, and climate-related pollution studies. Overall, the study contributes to sustainable fisheries management, conservation of aquatic biodiversity, and protection of human health in coastal regions.

Author contribution

The practical design and manuscript preparation were carried out under the guidance of our research supervisor, Prof. Sumanth Kumar Kunda, Department of Zoology and Aquaculture, Acharya Nagarjuna University. The first author, Nagaseshulu K., conducted the fieldwork, performed the laboratory experiments, and assisted the research supervisor throughout the study.

Conflict of Interest statement

The authors declared that they have no interest of conflicts.

Table: 1. Accumulation of heavy metals (µg/g) in gills of *Lates calcarifer* in station1 during study Period of June 2022-July2023 (Mean±S.E.).

Seasons	Heavy metal (µg/g)	Pb	Mn	Zn	Ni	Cd	Cr	Cu
Pre monsoon	**Mean**	1.9	1.45	0.285	1.4	0.24	3.05	2.75
	Std. Er	0.03	0.02	0.09	0.19	0.25	0.27	0.19
	Range	0.14	0.04	0.03	0.03	0.02	0.3	0.3
	Min	1.82	1.43	0.27	1.39	0.23	2.9	2.6
	Max	1.98	1.47	0.30	1.41	0.25	3.2	2.9
Monsoon	**Mean**	3.9	2.5	0.41	1.69	0.46	5.15	4.55
	Std. Er	0.02	0.02	0.09	0.19	0.27	0.27	0.02
	Range	0.5	0.2	0.07	0.13	0.04	0.6	0.6
	Min	3.7	2.4	0.38	1.62	0.44	4.9	4.2
	Max	4.1	2.6	0.45	1.75	0.48	5.4	4.9
Post monsoon	**Mean**	3.6	1.86	0.325	1.44	0.36	3.65	3.4
	Std. Er	0.03	0.02	0.09	0.18	0.23	0.27	0.20
	Range	0.4	0.06	0.09	0.07	0.3	0.5	0.2
	Min	3.4	1.83	0.30	1.41	0.23	3.4	3.3
	Max	3.8	1.89	0.35	1.48	0.26	3.9	3.5
One-way ANOVA	**F-value**	**1.1**	**1.3**	**1.06**	**0.42**	**0.25**	**0.1**	**0.3**
	P-value	**0.00***	**0.00***	**0.32**	**0.66**	**0.86**	**0.1**	**0.80**

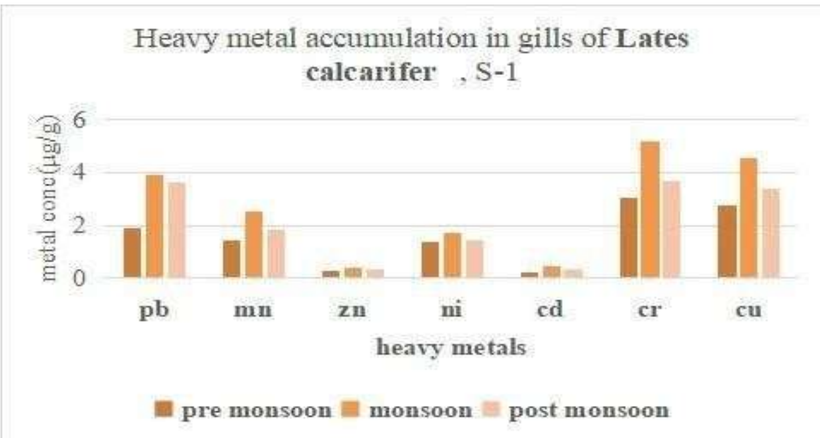

Figure: 2. Heavy metal analysis in gills of ***Lates calcarifer*** Station-1 (Nizampatnum Harbour)

Table: 2. Accumulation of heavy metals (µg/g) in gills of *Lates calcarifer* in station 2 during study period of June2022-July2023. (Mean±S.E.).

Seasons	Heavy metal (µg/g)	Pb	Mn	Zn	Ni	Cd	Cr	Cu
Pre monsoon	**Mean**	2.09	1.51	0.355	1.5	0.28	3.6	3.1
	Std. Er	0.02	0.02	0.09	0.19	0.25	0.27	0.19
	Range	0.1	0.07	0.07	0.03	0.05	0.2	0.5
	Min	1.96	1.49	0.32	1.49	0.26	3.5	2.9
	Max	2.23	1.53	0.39	1.51	0.31	3.7	3.3
Monsoon	**Mean**	4.2	2.9	0.565	1.89	0.62	6	4.85
	Std. Er	0.02	0.02	0.09	0.19	0.27	0.27	0.12
	Range	0.6	0.3	0.11	0.33	0.5	0.6	0.5
	Min	3.9	2.7	0.51	1.83	0.59	5.6	4.6
	Max	4.5	3.1	0.62	1.95	0.65	6.4	5.1
Post monsoon	**Mean**	3.7	2.39	0.51	1.57	0.31	5.1	3.55
	Std. Er	0.03	0.02	0.09	0.18	0.23	0.27	0.20
	Range	0.4	0.06	0.07	0.07	0.1	0.3	0.3
	Min	3.5	2.36	0.48	1.53	0.28	4.9	3.4
	Max	3.9	2.42	0.55	1.61	0.34	5.3	3.7
One-way ANOVA	**F-value**	**1.0**	**1.1**	**1.0**	**0.22**	**0.25**	**0.1**	**0.1**
	p-value	**0.00***	**0.00***	**0.32**	**0.00**	**0.86**	**0.94**	**0.00**

Figure: 3. Heavy Metal Analysis in Gills of ***Lates calcarifer*** Station-2 (Kothapalem Beach)

Table: 3. Accumulation of heavy metals (µg/g) in skin of *Lates calcarifer* in station1 during study Period of June2022-July2023. (Mean±S.E.)

Seasons	Heavy metal (µg/g)	Pb	Mn	Zn	Ni	Cd	Cr	Cu
Pre monsoon	Mean	2.05	3.6	0.34	1.30	0.4	4.4	4.35
	Std. Er	0.01	0.02	0.09	0.01	0.25	0.27	0.19
	Range	0.19	0.4	0.3	0.03	0.02	0.2	0.3
	Min	1.96	3.4	0.33	1.41	0.39	4.3	4.2
	Max	2.15	3.8	0.35	1.44	0.41	4.5	4.5
Monsoon	Mean	4.1	5.15	0.58	1.80	0.77	6.95	6.4
	Std. Er	0.02	0.02	0.09	0.19	0.27	0.27	0.19
	Range	0.6	0.4	0.07	0.33	0.03	0.3	0.2
	Min	3.8	4.9	0.55	1.68	0.65	6.8	6.3
	Max	4.4	5.4	0.62	1.91	0.89	7.1	6.5
Post monsoon	Mean	3.35	3.95	0.465	1.48	0.58	5.3	5.1
	Std. Er	0.03	0.02	0.09	0.18	0.23	0.2	0.20
	Range	0.3	0.2	0.04	0.7	0.3	0.2	0.2
	Min	3.2	3.7	0.44	1.45	0.57	5.2	4.9
	Max	3.5	4.2	0.49	1.52	0.60	5.4	5.3
One-way ANOVA	F-value	**1.1**	**1.3**	**1.0**	**0.34**	**0.1**	**0.10**	**0.11**
	p-value	**0.00***	**0.00***	**0.32**	**0.66**	**0.6**	**0.94**	**0.80**

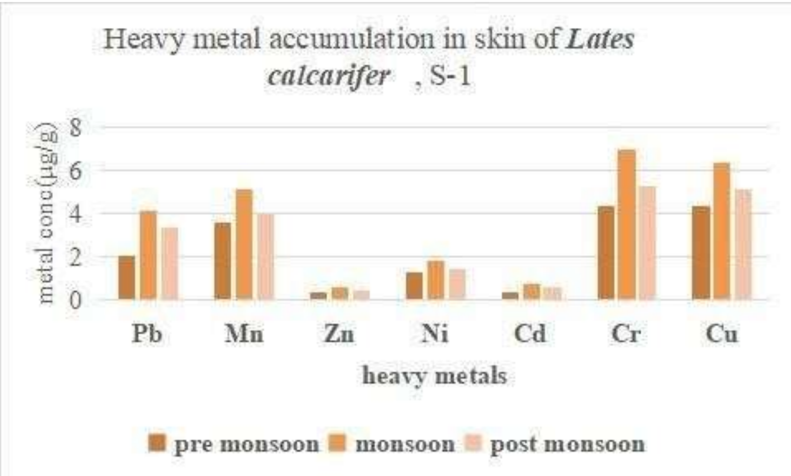

Figure: 4. Heavy metal analysis in skin of ***Lates calcarifer*** Station-1 (Nizampatnum Harbour)

Table: 4. Accumulation of heavy metals (µg/g) in skin of *Lates calcarifer* in station2 during study Period of June2022-July2023. (Mean±S.E.).

Seasons	Heavy metal (µg/g)	Pb	Mn	Zn	Ni	Cd	Cr	Cu
Pre monsoon	Mean	2.6	4.65	0.40	1.47	0.51	4.9	4.65
	Std. Er	0.01	0.02	0.09	0.01	0.25	0.27	0.19
	Range	0.24	0.3	0.05	0.03	0.02	0.2	0.3
	Min	2.25	4.5	0.37	1.45	0.49	4.8	4.5
	Max	2.94	4.8	0.42	1.49	0.53	5.0	4.8
Monsoon	Mean	5.65	7.15	0.69	2.18	0.87	7.35	6.2
	Std. Er	0.02	0.02	0.09	0.19	0.27	0.27	0.19
	Range	0.6	0.4	0.05	0.33	0.06	0.3	0.2
	Min	5.2	6.9	0.65	1.98	0.79	7.2	6.1
	Max	6.1	7.4	0.73	2.37	0.95	7.5	6.3
	Mean	4.8	5.55	0.53	1.7	0.62	5.7	5.5

Post monsoon	**Std. Er**	0.03	0.02	0.09	0.18	0.23	0.2	0.20
	Range	0.5	0.2	0.04	0.7	0.3	0.2	0.3
	Min	4.5	5.3	0.50	1.65	0.60	5.6	5.4
	Max	5.1	5.8	0.55	1.75	0.63	5.8	5.7
One-way ANOVA	**F-value**	**1.27**	**1.5**	**1.02**	**0.44**	**0.1**	**0.11**	**0.22**
	P-value	**0.00***	**0.00***	**0.32**	**0.66**	**0.6**	**0.94**	**0.80**

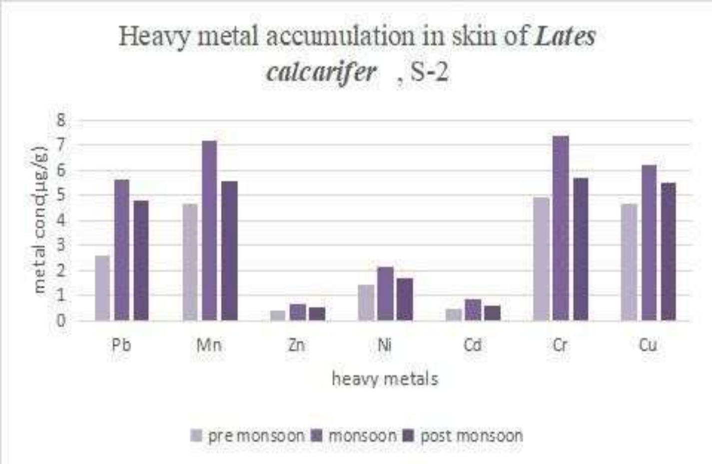

Figure: 5. Heavy metal analysis in skin of ***Lates calcarifer*** Station-2 (Kothapalem Beach)

Table: 5. Accumulation of heavy metals (µg/g) in muscle of *Lates calcarifer* in station1 during study Period of June2022-July2023 (Mean±S.E.)

Seasons	Heavy metal (µg/g)	Pb	Mn	Zn	Ni	Cd	Cr	Cu
Pre monsoon	**Mean**	3.6	2.75	0.4	1.47	0.27	5.5	4.7
	Std. Er	0.01	0.02	0.01	0.11	0.2	0.27	0.11
	Range	0.6	0.3	0.06	0.04	0.02	0.6	0.2
	Min	3.3	2.6	0.37	1.45	0.26	5.2	4.6
	Max	3.9	2.9	0.43	1.49	0.28	5.8	4.8
Monsoon	**Mean**	4.8	3.9	0.64	2.085	0.41	7.35	6.9
	Std. Er	0.02	0.02	0.02	0.10	0.2	0.27	0.19
	Range	0.2	0.4	0.05	0.27	0.04	0.3	0.2
	Min	4.7	3.7	0.61	1.95	0.38	7.2	6.8
	Max	4.9	4.1	0.66	2.22	0.44	7.5	7.0
Post monsoon	**Mean**	3.95	2.76	0.5	1.75	0.34	5.7	5.5
	Std. Er	0.01	0.01	0.02	0.11	0.11	0.11	0.10
	Range	0.3	0.22	0.04	0.07	0.04	0.2	0.2
	Min	3.9	2.7	0.48	1.71	0.32	5.6	5.4
	Max	4.4	2.82	0.52	1.78	0.36	5.8	5.6
One-way ANOVA	**F-value**	**1.27**	**1.13**	**1.0**	**0.44**	**0.25**	**0.13**	**0.33**
	p-value	**0.00***	**0.00***	**0.32**	**0.66**	**0.86**	**0.94**	**0.80**

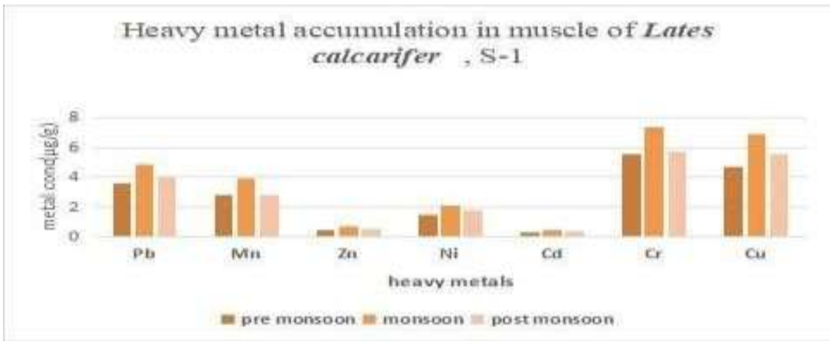

Figure: 6. Heavy metal analysis in muscle of ***Lates calcarifer*** Station-1 (Nizampatnum) Harbour

Table: 6. Accumulation of heavy metals (µg/g) in muscle of *Lates calcarifer* in station2 during study Period of June2022-July2023 (Mean±S.E.).

Seasons	**Heavy metal (µg/g)**	**Pb**	**Mn**	**Zn**	**Ni**	**Cd**	**Cr**	**Cu**
Pre monsoon	**Mean**	4.25	3.4	0.4	1.52	0.37	7	6
	Std. Er	0.01	0.02	0.01	0.11	0.2	0.27	0.11
	Range	0.36	0.2	0.04	0.04	0.02	0.6	0.2
	Min	4.1	3.3	0.38	1.50	0.36	6.8	5.9
	Max	4.4	3.5	0.42	1.54	0.38	7.2	6.1
Monsoon	**Mean**	5.2	4.45	0.8	3.19	0.51	9.05	8.6
	Std. Er	0.02	0.02	0.02	0.10	0.2	0.27	0.19
	Range	0.2	0.4	0.05	0.13	0.04	0.7	0.4
	Min	5.1	4.3	0.77	3.13	0.48	8.7	8.4
	Max	5.3	4.6	0.82	3.25	0.54	9.4	8.8
Post monsoon	**Mean**	4.65	3.5	0.56	1.86	0.42	8	6.35
	Std. Er	0.01	0.01	0.02	0.11	0.11	0.11	0.10
	Range	0.3	0.22	0.04	0.07	0.04	0.4	0.5
	Min	4.5	3.4	0.54	1.82	0.40	7.8	6.1
	Max	4.8	3.62	0.58	1.89	0.44	8.2	6.6
One-way ANOVA	**F-value**	**1.37**	**1.14**	**1.06**	**0.46**	**0.25**	**0.11**	**0.1**
	p-value	**0.00***	**0.00***	**0.32**	**0.66**	**0.86**	**0.94**	**0.80**

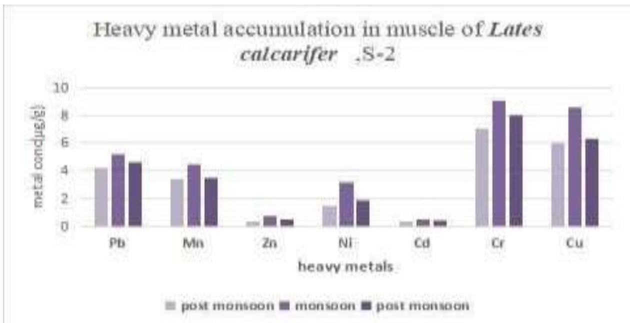

Figure: 7. Heavy metal analysis in muscle of ***Lates calcarifer*** Station-2 (Kothapalem Beach)

Table: 7. Accumulation of heavy metals (µg/g) in intestine of *Lates calcarifer* in station1 during study Period of June2022-July2023 (Mean±S.E.).

Seasons	Heavy metal (µg/g)	Pb	Mn	Zn	Ni	Cd	Cr	Cu
Pre monsoon	Mean	5.4	5.6	0.63	2.23	0.93	7.9	7.6
	Std. Er	0.01	0.02	0.01	0.10	0.02	0.07	0.11
	Range	0.6	0.4	0.04	0.07	0.04	0.6	0.6
	Min	5.1	5.4	0.61	2.20	0.91	7.6	7.3
	Max	5.7	5.8	0.65	2.27	0.95	8.2	7.9
Monsoon	Mean	7	6.5	1.7	4.7	3.1	9.55	9
	Std. Er	0.02	0.02	0.02	0.11	0.02	0.02	0.1
	Range	0.4	0.6	0.06	0.6	0.2	0.7	0.2
	Min	6.8	6.2	1.4	4.6	2.9	9.2	8.9
	Max	7.2	6.8	2.0	4.8	3.3	9.9	9.1
Post monsoon	Mean	5.6	5.65	1.09	3.9	2.2	8.1	8.5
	Std. Er	0.03	0.02	0.02	0.01	0.03	0.1	0.10
	Range	0.4	0.3	0.21	0.2	0.18	0.7	0.2
	Min	5.4	5.5	0.99	3.8	2.1	7.8	8.4
	Max	5.8	5.8	1.2	4.0	2.3	8.5	8.6
One-way ANOVA	F-value	**1.47**	**1.15**	**1.0**	**0.45**	**0.15**	**0.10**	**0.11**
	p-value	**0.00***	**0.00***	**0.32**	**0.66**	**0.86**	**0.94**	**0.80**

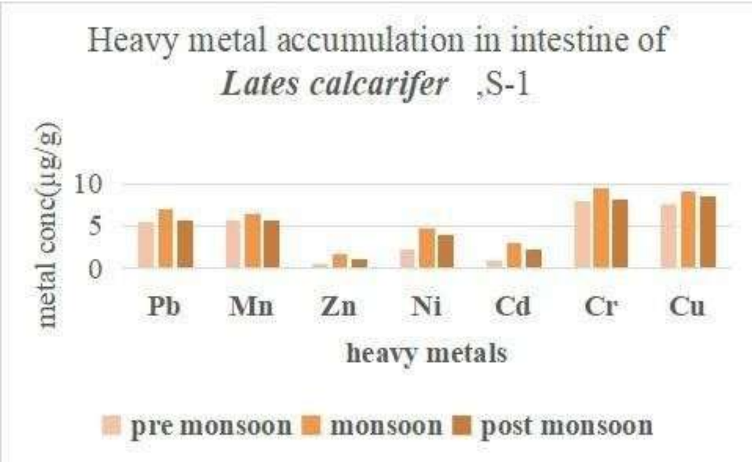

Figure: 8. Heavy metal analysis in intestine of ***Lates calcarifer*** Station-1 (Nizampatnum Harbour)

Table: 8. Accumulation of heavy metals (µg/g) in intestine of *Lates calcarifer* in station 2 during study Period of June2022-July2023 (Mean±S.E.).

Seasons	avy metal (µg/g)	Pb	Mn	Zn	Ni	Cd	Cr	Cu
Pre monsoon	Mean	6.3	6.5	0.78	2.96	1.15	8.9	8.2
	Std. Er	0.01	0.02	0.01	0.10	0.02	0.07	0.11
	Range	0.4	0.6	0.05	0.06	0.1	0.6	0.6
	Min	6.1	6.2	0.76	2.93	1.1	8.6	7.9
	Max	6.5	6.9	0.81	2.99	1.2	9.2	8.5
	Mean	7.8	8.3	2.2	5.1	3.65	11.55	10.4
	Std. Er	0.02	0.02	0.02	0.11	0.02	0.02	0.1
	Range	0.4	0.6	0.08	0.6	0.3	0.7	0.2
	Min	7.6	8.0	2.1	4.8	3.5	11.2	10.3

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Monsoon	**Max**	8.0	8.6	2.3	5.4	3.8	11.9	10.5
	Mean	7.1	7.15	1.5	4.5	2.85	9.15	8.7
	Std. Er	0.03	0.02	0.02	0.01	0.03	0.1	0.10
	Range	0.4	0.5	0.07	0.2	0.3	0.7	0.2
	Min	6.9	6.9	1.4	4.4	2.7	8.8	8.6
Post monsoon	**Max**	7.3	7.4	1.6	4.6	3.0	9.5	8.8
One-way ANOVA	**F-value**	**1.57**	**1.20**	**1.1**	**0.48**	**0.17**	**0.11**	**0.12**
	p-value	**0.00***	**0.00***	**0.32**	**0.66**	**0.86**	**0.94**	**0.80**

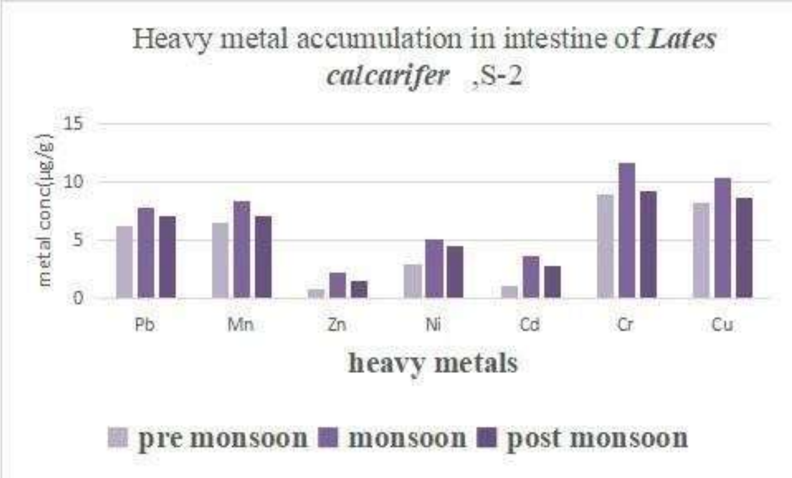

Figure: 9 Heavy metal analysis in intestine of ***Lates calcarifer*** Station-2 (Kothapalem Beach)

References:

1. Akila M, Anbalagan S, Lakshmisri NM, Janaki V, Ramesh T, Jancy Merlin R and Kamala-Kannan S (2022). Heavy metal accumulation in selected fish species from Pulicat Lake, India, and health risk assessment, *Environmental Technology & Innovation*,Vol (27):102744.
2. Allison EH, Perry AL, Badjeck MC, Neil Adger W, Brown K, Conway KD, Halls AS, Pilling GM, Reynolds JD, Andrew NL and Dulvy NK (2009). Vulnerability of national economies to the impacts of climate change on fisheries. *Fish Fish*. 10 (2): 173–196.
3. Babar Hussain, Muhammad,Jawad Umer, Jumei Li, Yibing Ma, Yawar Abbas, Muham madNadeem Ashraf, Nazia Tahir, Aman Ullah, Nirmali Gogoi(2021). Muhammad Faroo qSt ategies for reducing cadmium accumulation in rice grains; vol (286).
4. Chao AM, Jastreboff AM, White MA, Grilo CM and Sinha R (2017). Stress, cortisol, and other appetite-related hormones: Prospective prediction of 6-month changes in food cravings and weight. Obesity (Silver Spring). Apr; 25(4):713-720. doi: 10.1002/oby.21790. PMID: 28349668; PMCID: PMC5373497.
5. Krishna PV, M Sai Mounika, BVL Aradhya Sarma and B Padmaja (2021). Health risk assessment of heavy metal accumulation in the food fish, Channa striata from Krishna river, Andhra Pradesh; International Journal of Fisheries and Aquatic Studies 2021; 9(2): 180-184.
6. Kumar HM, Gajaria SC and Radha KS (2004). Growth and development of catla (*Catla catla*) fed with different levels of diet containing *Spirogyra* sp, *Biores. Technol*, 95 (1): 73–76.
7. Lokhande, Rama and Kelkar .N (2000). Studies on Heavy Metals in Water of Vasai Creek, Maharashtra. *Indian J. Environ. Protect*. (19): 664-668.

8. Murugaiyan K (2020). Distribution of heavy metals in padina pavonica (brown algae), seawater and sediment of tuticorin coast, southeast coast of India; environmental Science and Research;281-313.
9. Washington Y, Ochieng and Shaojun Feng (2008). User Level Integrity Monitoring and Quality Control for High Accuracy Positioning Using GPS/INS Measurements; *Journal of Global Positioning Systems* (2008); Vol. 7, No. (2): 104-114.
10. Zhuang W and Gao X (2014). Integrated Assessment of Heavy Metal Pollution in the Surface Sediments of the Laizhou Bay and the Coastal Waters of the Zhangzi Island, China: Comparison among Typical Marine Sediment Quality Indices. *PLOS ONE* 9(4): e94145. https://doi.org/10.1371/journal.pone.0094145.