Evaluation of selected heavy metals in the Ghost Crab *Ocypode cursor* along Sabratha Coast, Libya

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Abstract

Heavy metals can accumulate in coastal organisms and provide useful information about environmental contamination in marine ecosystems. This study investigated the concentrations of lead (Pb), cadmium (Cd), and zinc (Zn) in seawater and in the carapace and visceral tissues of the ghost crab *Ocypode cursor* at three sandy beach sites in Sabratha, western Libya. Samples were collected during winter and summer to assess seasonal and spatial variation in metal contamination. Metal concentrations were determined using atomic absorption spectrophotometry after acid digestion. In seawater, Pb and Zn concentrations were higher in summer than in winter. The highest Pb concentration was recorded at site B in summer (0.34 ± 0.01 mg/L), while the highest Zn concentration was also recorded at site B in summer (8.33 ± 0.20 mg/L). Cd remained relatively stable across sites and seasons. Two-way ANOVA indicated that season significantly affected Pb and Zn in seawater, whereas site significantly affected only Zn. Significant season × site interactions were observed for Pb and Zn, indicating the combined influence of seasonal conditions and local site characteristics. In crab tissues, Pb and Zn concentrations were higher in visceral tissue than in the carapace, particularly during summer. The highest Pb concentration was recorded in visceral tissue at site C during summer (122.2 µg/g dry weight), and the highest Zn concentration occurred in visceral tissue at site B during summer (402.5 µg/g dry weight). The highest Cd concentrations was recorded in visceral tissue at site A during winter (1.313 µg/g dry weight). Season, site, and their interaction significantly affected Pb, Cd, and Zn concentrations in crab tissues ($P < 0.001$). Bioaccumulation factors varied among metals, tissues, sites, and seasons, with higher values in visceral tissue. These findings indicates that *Ocypode cursor* is exposed to spatially and seasonally variable metal contamination along the Sabratha coast. Visceral tissue appears to be a more sensitive than the carapace for assessing metal accumulation, supporting the potential use of *Ocypode cursor* as a bioindicator of heavy metal contamination.

Keywords: Heavy metals; *Ocypode cursor*; bioaccumulation; carapace; visceral tissue; Sabratha; Libya.

1.Introduction

Coastal environments receive metal inputs from human activities, making contamination a concern for marine ecosystem health (Marcelo-Silva & Christofoletti, 2019; Banaee *et al*., 2024). Measuring metals in both seawater and organisms can help distinguish environmental exposure from biological accumulation.

Heavy metals are persistent contaminants in aquatic environments because they cannot be degraded and may remain available to organisms long after their initial release. At elevated concentrations, metals such as lead (Pb), cadmium (Cd), and zinc (Zn) can disrupt physiological processes, impair growth and reproduction, and pose risks to both aquatic organisms and human consumers. Their uptake and accumulation in biota depend on metal bioavailability, exposure duration, and the organism's capacity for regulation, detoxification, and excretion (Taweel *et al.*, 2013). Therefore, measuring metal concentrations in both environmental media and organism tissues is important for assessing contamination and potential ecological and human health risks.

Metal concentrations in aquatic animals reflect the balance between uptake, storage, detoxification, and elimination (Rainbow, 2002). Consequently, tissue specific measurements are important when interpreting contamination and evaluating organisms for biomonitoring.

Crustaceans are susceptible to metal exposure, with potential consequences for growth, reproduction, and survival (Banaee *et al.*, 2024; Waqas *et al.*, 2024). This provides a basis for investigating metal accumulation in coastal crab species.

The ghost crab, *Ocypode cursor* inhabits Mediterranean sandy beaches and responds to recreational disturbances (Galil *et al.*, 2024). Although such responses support ecological assessments, its suitability for monitoring metal contamination requires further investigation.

The present study examined Pb, Cd, and Zn concentrations in seawater and in the carapace and visceral tissues of *O. cursor* at three sites along the Sabratha coast of western Libya. The sites represented different levels of human influence. The study assessed spatial and seasonal variation, compared accumulation between tissues, and calculated bioaccumulation factors to evaluate the species potential as a coastal metal contamination bio monitor.

2. Materials and Methods

2.1. Study area:

The study was conducted along the Sabratha coast, approximately 70 km west of Tripoli, Libya. Three sampling sites were selected to represent different levels of human influence. Site A: Wadi area, east of Sabratha which considered clean area. Site B: Sabratha Teaching Hospital beach which considered polluted area. Site C: Talil beach, west of Sabratha which considered affected area. Sampling was conducted during winter and summer to assess seasonal difference in metal concentrations.

2.2. Sample collection:

Seawater samples were collected from each site during winter and summer. Ghost crabs were collected manually from burrow entrances and beneath rocks during nocturnal activity periods, with additional sampling during early morning hours. Collected crabs were rinsed with seawater to remove sand and adhering material, then placed in labelled polyethylene bags, and transported to the laboratory in a cool box. A total of 12 crab samples were collected across the three sites and two seasons, with two individuals collected per site in each season.

2.3. Tissue preparation:

Crabs were separated into two tissue fractions; the carapace and visceral tissues. Samples were rinsed several times with distilled water, dried at 105^0C until a constant weight was obtained, and ground into a homogeneous powder using an electronic blender. The powdered samples were stored in clean, sealed polyethylene containers until chemical analysis.

2.4. Metal analysis:

For metal extraction, 1 g of dried carapace or visceral tissue was placed in a 100 mL conical flask. 5 mL of nitric acid HNO_3, 65% and 5 mL of perchloric acid $HClO_4$, 60% were added for digestion. After digestion, samples were filtered and transferred to polyethylene containers for analysis. Metal concentrations were measured using an atomic absorption spectrophotometer (CONTRAA 700, Analytik Jena). Pb, Cd, and Zn concentrations in crab tissues were expressed as micrograms per gram dry weight (µg/g dw), while concentrations in seawater were expressed as milligrams per litre (mg/L).

2.6. Bioaccumulation factor:

Bioaccumulation factors were calculated to compare metal concentrations in crab tissues with concentrations in seawater. Higher bioaccumulation values indicate greater accumulation of a metal in crab tissue relative to its concentration in the surrounding seawater.

2.7. Statistical analysis:

Statistical analysis were performed using SPSS version 25. Two-way ANOVA was used to examine the effects of season, site, and season by site interaction on metal concentrations in seawater and crab tissues. Tukey's test was used for post hoc comparisons where appropriate. Differences were considered statistically significant at $P < 0.05$.

3. Results

3.1. Heavy metals in seawater:

Pb concentrations in seawater were generally higher during summer than winter (Table 1). The highest Pb concentration was recorded at site B during summer (0.34 ± 0.01 mg/L), followed by site C (0.18 ± 0.02 mg/L) and site A (0.16 ± 0.03 mg/L). During winter, Pb concentrations were lower, ranging from 0.04 mg /L at site B to 0.08 mg / L at site A.

Cadmium (Cd) concentrations were relatively similar among sites and seasons. The highest Cd value was recorded at site C during summer (0.09 ± 0.01 mg/L), while the lowest value was recorded at site C during winter (0.05 ± 0.03 mg/L).

Zinc (Zn) concentrations showed greater variation. The highest Zn concentration was recorded at site B during summer (8.33 ± 0.2 mg/L), while the lowest value was recorded at site A during summer (0.5 ± 0.3 mg/L).

Table 1. Concentrations of Pb, Cd, and Zn in seawater (mg/L) at the three study sites during winter and summer.

Site	Pb		Cd		Zn	
	Winter	Summer	Winter	Summer	Winter	Summer
Site A	0.08 ± 0.04	0.16 ± 0.03	0.07 ± 0.03	0.08 ± 0.02	3.60 ± 0.50	0.50 ± 0.30
Site B	0.04 ± 0.02	0.34 ± 0.01	0.069 ± 0.02	0.07 ± 0.02	2.28 ± 0.03	8.33 ± 0.20
Site C	0.06 ± 0.03	0.18 ± 0.02	0.05 ± 0.03	0.09 ± 0.01	2.21 ± 0.02	0.60 ± 0.30

3.2. Seasonal and spatial effects on seawater metals

Two-way ANOVA showed that season had a significant effect on Pb ($F = 3.512$, $P < 0.05$) and Zn ($F = 577.183$, $P < 0.05$), but not on Cd ($P > 0.05$). Site had a significant effect only on Zn ($F = 11.833$, $P < 0.05$), whereas Pb and Cd did not differ significantly among sites. The interaction between season and site was significant for Pb ($F = 36.856$, $P < 0.05$) and Zn ($F = 522.466$, $P < 0.05$), but not for Cd ($P > 0.05$) (Table 2). These results indicate that Pb and Zn concentrations were influenced by both seasonal conditions and site-specific factors, whereas Cd showed a more stable across the study area.

Table 2. Two-way ANOVA results for the effects of season, site, and their interaction on Pb, Cd, and Zn concentrations in seawater.

Source of variation	Pb *F* value	Pb *P* value	Cd *F* value	Cd *P* value	Zn *F* value	Zn *P* value
Season	3.512	< 0.05	0.268	> 0.05	577.183	< 0.05
Site	0.169	> 0.05	0.129	> 0.05	11.833	< 0.05
Season × Site	36.856	< 0.05	1.620	> 0.05	522.466	< 0.05

3.3. Heavy metals in crab tissues:

Metal concentrations were generally higher in visceral tissues than in the carapace, particularly during summer. The highest Pb concentration was recorded in visceral tissue at site C during summer (122.2 µg/g dw), followed by site A (65.9 µg/g dw) and Site B (37.86 µg/g dw) (Table 3,4).

Cadmium (Cd) concentrations were also higher in visceral tissues than in carapace samples. The highest Cd value was recorded in visceral tissue at site A during winter (1.313 µg/g dw). Zinc (Zn) concentrations in visceral tissue were particularly high during summer, reaching (230.8 µg/g dw) at Site A (402.5 µg/g dw) at Site B, and (112.4 µg/g dw) at Site C.

Table 3. Concentrations of Pb, Cd, and Zn (µg/g dry weight) in the carapace tissues of *Ocypode cursor* during winter and summer.

Site	Pb (Winter / Summer)	Cd (Winter / Summer)	Zn (Winter / Summer)
Site A	5.25 ± 0.23 / 1.40 ± 1.10	0.788 ± 0.1 / 0.205 ± 0.03	26.96 ± 1.0 / 9.81 ± 1.00
Site B	3.30 ± 2.10 / 5.47 ± 1.10	0.30 ± 0.01 / 0.288 ± 0.03	17.3 ± 0.1 / 8.46 ± 3.10
Site C	0.666 ± 0.01 / 122.2 ± 6.70	0.524 ± 0.1 / 0.462 ± 0.02	44.90 ± 6.6 / 1.60 ± 0.50

Table 4. Concentrations of Pb, Cd, and Zn (µg/g dry weight) in the viscera tissues of *Ocypode cursor* during winter and summer.

Site	Pb (Winter / Summer)	Cd (Winter / Summer)	Zn (Winter / Summer)
Site A	0.08 ± 0.01 / 65.9 ± 1.10	1.313 ± 0.2 / 0.482 ± 0.02	20.23 ± 1.6 / 230.8 ± 18.5
Site B	2.90 ± 0.07 / 37.86 ± 1.30	0.40 ± 0.05 / 1.123 ± 0.02	9.66 ± 9.4 / 402.5 ± 7.90
Site C	0.431 ± 0.02 / 1.22 ± 3.18	0.722 ± 0.03 / 0.630 ± 0.04	52.52 ± 8.12 / 112.4 ± 12.90

3.4. Effect of season and site on tissue metal concentrations:

Two-way ANOVA showed significant effects of season, site, and season by site interaction on Pb, Cd, and Zn concentrations in crab tissues (Table 5). Season had the strongest effect on Pb (F = 146.03), followed by Cd (F = 16.67) and Zn (F = 12.23), all with P < 0.001.

Site also had a significant effect on all three metals. The strongest site effect was observed for Pb (F = 92.22), followed by Cd (F = 13.10) and Zn (F = 8.45). The interaction between season and site was significant for all metals, indicating that metal accumulation in *Ocypode cursor* depend on the combined influence of seasonal conditions and local environmental quality.

Table 5. Two-way ANOVA results for the effects of season, site, and their interaction on Pb, Cd, and Zn concentrations in *O. cursor* tissues.

Source of variation	Pb *F* value	Pb *P* value	Cd *F* value	Cd *P* value	Zn *F* value	Zn *P* value
Season	146.03	< 0.001	16.67	< 0.001	12.23	< 0.001
Site	92.22	< 0.001	13.10	< 0.001	8.45	< 0.001
Season × Site	88.33	< 0.001	8.25	< 0.001	12.57	< 0.001

3.5. Bioaccumulation factors:

Bioaccumulation factors varied among sites, tissues, and seasons (Table 6). For lead (Pb), the highest values were generally recorded during winter in visceral tissue at site A (65.5) and carapace tissue at site C (54.3). For cadmium (Cd), the highest values occurred during summer, in visceral tissue at site A (75) and carapace tissue at site C (52.6). Zinc (Zn) showed a less consistent pattern, with the highest value recorded in visceral tissue at site A during winter (89.9).

Table 6. Bioaccumulation factors for Pb, Cd, and Zn in the carapace and visceral tissues of *Ocypode cursor*.

Site	Tissue	Pb (Winter / Summer)	Cd (Winter / Summer)	Zn (Winter / Summer)
Site A	**Carapace**	32.90 / 0.30	4.80 / 45.70	42.00 / 30.60
Site A	**Viscera**	65.50 / 4.70	6.80 / 75.00	89.90 / 34.00
Site B	**Carapace**	6.00 / 22.12	8.00 / 15.22	2.80 / 7.60
Site B	**Viscera**	38.50 / 3.70	16.90 / 4.40	67.00 / 2.20
Site C	**Carapace**	54.30 / 2.80	8.90 / 52.60	6.70 / 22.80
Site C	**Viscera**	1.40 / 2.20	9.90 / 35.80	2.99 / 22.89

Table 7 shows the mean concentrations (in mg/kg dry weight) of Pb, Cd and Zn in crab carapace and viscera in winter and summer. Because replicate measurements were not available for each individual site, the values are mean and SD of the three site means (the SD, calculated in this way, is a measure of the variation between sites). The tests for significance are not meaningful since the SDs measure differences between sites, but the comparison of the means shown here is descriptive. Lead (Pb) was more abundant in both tissues in winter, falling from a mean of 31.07 in winter to 8.41 in summer in the carapace and from 35.13 to 3.53 in the viscera. The lowest mean and SD were observed in the summer viscera (3.53 ± 1.26).

Cadmium (Cd) was the other season directional. The means were higher in summer than in winter in the carapace 37.84 and 7.23 and in the viscera 38.40 and 11.20. The means of the two tissues were similar in summer.

A similar pattern between the two seasons was observed in the same sample, zinc (Zn) resulted in 53.30 in the viscera in winter and 19.70 in summer. With regard to the carapace, high values for the two seasons were found 17.7 in winter and 20.33 in summer.

Table 7. Concentrations of heavy metals (Pb, Cd, and Zn; µg/g dry weight, mean ± SD) in the carapace and visceral tissues of *Ocypode cursor* across different sampling sites during winter and summer.

Metal	Site	Carapace		Viscera	
		Winter	Summer	Winter	Summer
Pb	Site A	5.25 ± 0.23	1.40 ± 1.10	0.08 ± 0.01	65.9 ± 1.10
Pb	Site B	3.30 ± 2.10	5.47 ± 1.10	2.90 ± 0.07	37.86 ± 1.30
Pb	Site C	0.666 ± 0.01	122.2 ± 6.70	0.431 ± 0.02	1.22 ± 3.18
Cd	Site A	0.788 ± 0.1	0.205 ± 0.03	1.313 ± 0.2	0.482 ± 0.02
Cd	Site B	0.30 ± 0.01	0.288 ± 0.03	0.40 ± 0.05	1.123 ± 0.02
Cd	Site C	0.524 ± 0.1	0.462 ± 0.02	0.722 ± 0.03	0.630 ± 0.04
Zn	Site A	26.96 ± 1.0	9.81 ± 1.00	20.23 ± 1.6	230.8 ± 18.5
Zn	Site B	17.3 ± 0.1	8.46 ± 3.10	9.66 ± 9.4	402.5 ± 7.90

Zn	Site C	44.90 ± 6.6	1.60 ± 0.50	52.52 ± 8.12	112.4 ± 12.90

4. Discussion:

The results indicate that metal contamination along the Sabratha coast is influenced by both seasonal conditions and local environmental characteristics. The higher Pb and Zn concentrations recorded during summer at site B, may reflect increased human activity, greater runoff, or changes in the physical and chemical conditions of coastal waters. The significant interaction between season and site suggests that pollution is not evenly distributed and may vary according to local conditions.

The higher concentrations of metals in visceral tissue than in the carapace are consistent with the biological role of internal organs in digestion, absorption, and detoxification. In crustaceans, the hepatopancreas and associated visceral tissues are major sites of metal accumulation because they are directly exposed to metals ingested with food and water (Machado *et al.,* 2021; de Almeida Rodrigues *et al.,* 2022). By contrast, the carapace may reflect external exposure, adsorption from seawater or sediment, or shorter-term absorption across the body surface (Machado *et al.,* 2021; Tanhan *et al.,* 2022). This pattern supports the use of visceral tissue as a more sensitive compartment for monitoring metal accumulation in ghost crabs, although tissue specific accumulation can differ substantially among metals and species (Rainbow, 1993; Depledge and Rainbow, 1990)

The higher bioaccumulation of Cd during summer may reflect greater metal availability, increased metabolic activity, or enhanced uptake under warmer conditions. Seasonal variation has been reported to influence metal accumulation in crustaceans and other seafood organisms, with temperature, feeding rate, metabolism, and environmental metal concentrations among the likely contributing factors (Tanhan *et al.,* 2022). In contrast, Pb showed higher bioaccumulation values during winter at several sites, suggesting that Pb accumulation may be governed by site specific exposure conditions rather than temperature alone.

The more variable pattern for Zn is likely related to its role as an essential element, which is subject to physiological regulation within the crab; decapod crustaceans can regulate body Zn concentrations by balancing uptake and excretion across a range of dissolved Zn availabilities (White and Rainbow, 1982, 1984; Rainbow, 1998).

Overall, the study suggests that *O. cursor* can accumulate metals from its coastal environment and may serve as a useful biological indicator of metal contamination. However, further studies should include sediment analysis, larger sample sizes, and repeated seasonal sampling to better understand the sources and dynamics of metal contamination in the area (Khiari *et al.,* 2025; Hassaan *et al.,* 2026).

5. Conclusion

This study demonstrated spatial and seasonal variation in Pb, Cd, and Zn concentrations in seawater and in the tissues of *Ocypode cursor* along the Sabratha coast. Metal concentrations were generally higher in visceral tissues than in the carapace during summer. The results indicate that *Ocypode cursor* may be exposed to variable metal contamination and that visceral tissue is a more sensitive compartment for assessing metal accumulation. The findings highlight the importance of monitoring heavy metal contamination in coastal environments and support the potential use of *Ocypode cursor* as a bioindicator species for assessing pollution in Mediterranean sandy beaches.

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