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Original article

# The effects of sex and seasonality on the metal levels of different muscle tissues of mature Atlantic blue crabs (*Callinectes sapidus*) in Mersin Bay, north-eastern mediterranean

**Deniz Ayas[1]* & Yesim Ozogul[2]**

1 Department of Seafood Processing Technology, Faculty of Fisheries, Mersin University, Mersin, Turkey
2 Department of Seafood Processing Technology, Faculty of Fisheries, Cukurova University, Adana, Turkey

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**Summary** The objective of this study was to determine the seasonal and sexual effects on metal levels of lump crabmeat (LCM) and chela crabmeat (CCM) of mature Atlantic blue crabs, *Callinectes sapidus*, caught in the Mersin Bay, the north-eastern Mediterranean. The findings indicated that the annual ranges of metal levels in the LCM of Atlantic blue crab were as follows: 0.44–0.61 μg Cd $g^{-1}$, 0.30–0.60 μg Cr $g^{-1}$, 0.24–0.52 μg Pb $g^{-1}$, 9.72–43.70 μg Cu $g^{-1}$, 39.52–97.26 μg Zn $g^{-1}$, 11.97–32.48 μg Fe $g^{-1}$. The annual range of metal levels in the CCM of Atlantic blue crab were as follows: 0.52–1.07 μg Cd $g^{-1}$, 0.24–0.61 μg Cr $g^{-1}$, 0.28–0.56 μg Pb $g^{-1}$, 22.17–68.09 μg Cu $g^{-1}$, 93.92–175.21 μg Zn $g^{-1}$, 8.81–19.47 μg Fe $g^{-1}$. Cd, Cu, Zn levels in CCM of Atlantic blue crabs were higher than in LCM, whereas Fe levels were found lower ($P < 0.05$). Fe metal specifically accumulated in LCM, and Cd, Cu and Zn metals accumulated in CCM. Metals such as Cu, Zn and Fe showed seasonal variations. It was found out that Cu, Zn and Fe levels of muscle tissues of the Atlantic blue crab in spring and summer seasons were higher than in autumn and winter seasons.

**Keywords** Atlantic blue crab, *Callinectes sapidus*, contamination, metal, season, sex.

## Introduction

Atlantic blue crab, *Callinectes sapidus*, is a crustacean species which lives in the waters of the western Atlantic Ocean. This portunid crab species has been introduced to the Mediterranean waters via blast water. Atlantic blue crabs are commonly distributed in the north-eastern Mediterranean shores in Turkey.

Atlantic blue crab is one of crab species, which have economic value. Thus, this species is caught both in the world and in Turkey. According to Anonymous (2010), seventeen and seventy-seven tons of Atlantic blue crabs were caught in 2008 and 2009, respectively, in Turkey.

The pollution of aquatic environment makes it necessary to determine seafood contamination levels. Thus, some studies have been conducted on levels of metal contamination of seafood, particularly fish, cephalopods and crab species, for a long time in Turkey and in the world (Olusegun *et al*., 2009; Beltrame *et al*., 2010; Özden, 2010; Ersoy, 2011).

Although generally, metal level changes in crabs are not observed related to size and sex, changes can be seen in big sea crabs depending on seasons or different muscle tissue types. For instance, Beltrame *et al*. (2010) indicated that there was no relationship between sex, size and bio-accumulated metals of Burrowing Crab (*Neohelice granulata*) caught from a coastal lagoon in Argentina. Olusegun *et al*. (2009), Gökoğlu & Yerlikaya (2003) reported variations in metal levels of different muscle tissues of *Callinectes* species. Beltrame *et al*. (2010) also reported that concentrations of some metals (Cd, Cu) in *N. granulata* showed seasonal changes.

Mature Atlantic blue crabs need moulting to grow up. Taylor *et al*. (2007) report that samples of cuticle are removed from blue crabs, *C. sapidus*, and within 1 h, soft-shell stage begins, following this stage, blue crabs go into paper-shell stage in 12 h and lastly, their hard-shell stage begins in 7 days after moulting. Following moulting, metal levels of blue crabs decrease to a great extent. Bergey & Weis (2007) reported metal eliminations during the moulting of carapace in crabs and a reduction in their Cu and Zn metal levels by 3–12% and 8–22%. In a similar study, Benjakul & Sutthipan (2009) reported decreases by nearly 100% in Cu, Fe and Zn levels of soft shell crabs compared with hard shell crabs.

Mersin Bay has been contaminated with the industrial, agricultural and domestic wastes. Fertilizers and pesticides are widely used in agricultural areas in

*Correspondent: Fax: (90) 324 3413025;
e-mail: ayasdeniz@mersin.edu.tr

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Mersin. Besides, until Mersin Waste Treatment Facility was founded, domestic waste was discharged directly to the bay. Furthermore, there are a large number of streams connected to the Gulf of Mersin. Hence, terrestrial pollution is easily transported to the sea. There are a large number of industrial plants such as Mersin port, oil industry, chromium industry, fertilizer industry in the city of Mersin. Owing to these reasons, Mersin Bay is faced with domestic, agricultural and industrial pollution. As invertebrate sea animals like big sea crabs have weak detoxification mechanisms, contamination levels should be kept under control in the bays, which are vulnerable to pollution.

Atlantic blue crabmeat contains high levels of Cu, Zn and Fe (Job *et al*., 1997; Gökoğlu & Yerlikaya, 2003; Türkmen *et al*., 2006; Olusegun *et al*., 2009). Although there are many studies on the metal levels of Atlantic blue crabs, there is hardly any available information about metal levels in Atlantic blue crabs living in Mersin Bay. Thus, the objective of this study was to compare and determine the seasonal and sexual effects on the metal levels of LCM and CCM of mature Atlantic blue crabs in Mersin Bay, north-eastern Mediterranean.

## Materials and methods

### Materials

Atlantic blue crabs, *C. sapidus*, were caught by dip net from Mersin Bay in all the seasons in 2008 on the coast of north-eastern Mediterranean. The samplings were performed in April (spring), July (summer), October (autumn) and December (winter). In the fishing procedure, dip net that had mesh size of 32 mm was used. In each season, thirty male and thirty female individuals were caught and kept in polystyrene boxes with ice. When the crabs were brought to the laboratory, they were still alive. The moulting of crabs was observed in October, and the crabs caught in this month were semisoft shell crabs.

### Sample preparation

The crabs were weighed, and some morphometric measurements [carapace length (CL), carapace width (CW)] were determined by calliper. Thirty individuals for each sex group and each season were used. Carapaces of all of raw specimens were removed, and the two largest portions of meat connected to the swimming legs (lump crabmeat – LCM) and meat from chela (chela crabmeat – CCM) were carefully scraped out with a scalpel. All assays were conducted on triplicate samples of the homogenates.

### Metal analysis

The LCM and CCM samples (0.5 g dry weight) used for metal analysis were dried at 105 °C to reach constant weights, and then concentrated nitric acid (4 mL, Merck, Darmstadt, Germany) and perchloric acid (2 mL, Merck) were added to the samples. Digested samples were put on a hot plate set to 150 °C until all tissues were dissolved (Canlı & Atlı, 2003). Inductively Coupled Plasma Atomic Emission (ICP-AES, Varian Model, Liberty series II, Sydney, Australia) was used to determine metals. The metal levels (Cr, Cd, Pb, Cu, Fe and Zn) in samples were detected as μg metal $g^{-1}$ dry weight. High Purity Multi Standard (Charleston, SC 29423) was used for the determination of the metal analyses.

### Statistical analysis

Statistical analysis of data was carried out with the SPSS 16.0. Duncan test was used to evaluate the seasonal and sexual effects on metal levels of LCM and CCM of Atlantic blue crabs.

## Results and discussion

The average carapace width (CW) was 125.0–185.0 mm for Atlantic blue crabs (Table 1). In a study carried out

**Table 1** Morphological measurements of Atlantic blue crabs in Mersin Bay

| Season | NS | CL $\bar{X} \pm S_{\bar{X}}$ | Min–max (mm) | CW $\bar{X} \pm S_{\bar{X}}$ | Min–max (mm) | Weight $\bar{X} \pm S_{\bar{X}}$ | Min–max (g) | Sex |
|---|---|---|---|---|---|---|---|---|
| Spring | 30 | 71.27 ± 4.13$^a$ | **63.0**–80.0 | 154.30 ± 9.40$^a$ | 129.5–170.0 | 171.67 ± 25.77$^a$ | **115.27**–225.92 | ♀ |
| | 30 | 74.17 ± 3.79$^a$ | 68.0–80.5 | 151.65 ± 8.64$^a$ | 128.0–163.0 | 191.11 ± 25.58$^a$ | 154.03–237.93 | ♂ |
| Summer | 30 | 69.83 ± 2.53$^a$ | 66.0–75.0 | 153.37 ± 6.49$^a$ | 141.5–162.0 | 164.86 ± 16.12$^a$ | 140.16–195.56 | ♀ |
| | 30 | 73.40 ± 4.19$^a$ | 64.5–79.5 | 149.90 ± 12.31$^a$ | **125.0**–165.0 | 233.01 ± 33.21$^a$ | 165.90–290.78 | ♂ |
| Autumn | 30 | 68.97 ± 2.58$^a$ | 65.0–72.0 | 149.87 ± 4.32$^a$ | 145.0–156.0 | 160.65 ± 12.51$^a$ | 140.07–175.01 | ♀ |
| | 30 | 77.33 ± 3.64$^b$ | 73.0–82.0 | 153.42 ± 9.43$^a$ | 145.0–169.0 | 262.06 ± 39.67$^b$ | 205.11–321.85 | ♂ |
| Winter | 30 | 71.45 ± 4.37$^a$ | 67.0–79.0 | 153.70 ± 8.91$^a$ | 142.0–168.0 | 168.89 ± 20.29$^a$ | 145.93–203.09 | ♀ |
| | 30 | 79.23 ± 4.29$^a$ | 73.5–**90.5** | 164.58 ± 12.03$^a$ | 145.5–**185.0** | 312.68 ± 44.68$^b$ | 247.19–**386.10** | ♂ |

NS, number of specimens; CL, carapace length; CW, carapace width.
Different letters (a, b) in the same columns for each season indicate significant differences ($P < 0.05$).

**Table 2** The effects of season and sex on metal levels of different muscle tissues of Atlantic blue crabs (μg $g^{-1}$)

| Metal | Sex | Spring $\overline{X}\pm S_{\overline{X}}$ | Summer $\overline{X}\pm S_{\overline{X}}$ | Autumn $\overline{X}\pm S_{\overline{X}}$ | Winter $\overline{X}\pm S_{\overline{X}}$ | Muscle |
|---|---|---|---|---|---|---|
| Cd | ♀ | $0.50 \pm 0.01^{a,y}$ | $0.59 \pm 0.02^{a,z}$ | $0.46 \pm 0.01^{a,x}$ | $0.44 \pm 0.01^{a,x}$ | LCM |
| | | $0.65 \pm 0.02^{b,y}$ | $0.75 \pm 0.02^{b,z}$ | $0.52 \pm 0.02^{b,x}$ | $0.66 \pm 0.01^{c,y}$ | CCM |
| | ♂ | $0.50 \pm 0.02^{a,x}$ | $0.57 \pm 0.02^{a,y}$ | $0.47 \pm 0.01^{a,x}$ | $0.61 \pm 0.03^{b,y}$ | LCM |
| | | $0.68 \pm 0.02^{b,y}$ | $0.71 \pm 0.02^{b,y}$ | $0.58 \pm 0.04^{b,x}$ | $1.07 \pm 0.02^{d,z}$ | CCM |
| Cr | ♀ | $0.58 \pm 0.03^{b,z}$ | $0.60 \pm 0.03^{b,z}$ | $0.36 \pm 0.03^{b,x}$ | $0.47 \pm 0.03^{a,y}$ | LCM |
| | | $0.50 \pm 0.04^{a,y}$ | $0.48 \pm 0.04^{a,y}$ | $0.24 \pm 0.04^{a,x}$ | $0.43 \pm 0.03^{a,xy}$ | CCM |
| | ♂ | $0.56 \pm 0.03^{b,z}$ | $0.60 \pm 0.03^{b,z}$ | $0.30 \pm 0.03^{ab,x}$ | $0.44 \pm 0.02^{a,y}$ | LCM |
| | | $0.60 \pm 0.03^{b,z}$ | $0.61 \pm 0.03^{b,z}$ | $0.34 \pm 0.03^{b,x}$ | $0.42 \pm 0.03^{a,y}$ | CCM |
| Pb | ♀ | $0.52 \pm 0.02^{a,y}$ | $0.32 \pm 0.04^{ab,x}$ | $0.29 \pm 0.03^{a,x}$ | $0.26 \pm 0.03^{a,x}$ | LCM |
| | | $0.56 \pm 0.05^{a,y}$ | $0.29 \pm 0.02^{ab,x}$ | $0.30 \pm 0.01^{a,x}$ | $0.28 \pm 0.01^{a,x}$ | CCM |
| | ♂ | $0.50 \pm 0.01^{a,z}$ | $0.24 \pm 0.03^{a,x}$ | $0.30 \pm 0.03^{a,y}$ | $0.30 \pm 0.03^{a,y}$ | LCM |
| | | $0.51 \pm 0.03^{a,z}$ | $0.40 \pm 0.04^{b,y}$ | $0.31 \pm 0.02^{a,x}$ | $0.29 \pm 0.01^{a,x}$ | CCM |
| Cu | ♀ | $34.12 \pm 0.84^{a,y}$ | $37.72 \pm 1.07^{a,z}$ | $10.09 \pm 0.33^{a,x}$ | $9.82 \pm 0.20^{a,x}$ | LCM |
| | | $49.44 \pm 0.71^{c,z}$ | $56.86 \pm 1.25^{c,q}$ | $28.80 \pm 0.97^{c,y}$ | $24.15 \pm 0.87^{c,x}$ | CCM |
| | ♂ | $32.13 \pm 0.47^{a,y}$ | $43.70 \pm 1.35^{b,z}$ | $9.72 \pm 0.21^{a,x}$ | $10.70 \pm 0.43^{a,x}$ | LCM |
| | | $43.24 \pm 1.01^{b,y}$ | $68.09 \pm 1.32^{d,z}$ | $22.70 \pm 0.59^{b,x}$ | $22.17 \pm 0.25^{b,x}$ | CCM |
| Zn | ♀ | $90.81 \pm 0.69^{b,z}$ | $97.26 \pm 2.74^{b,q}$ | $44.14 \pm 0.50^{b,y}$ | $39.52 \pm 0.54^{a,x}$ | LCM |
| | | $174.35 \pm 1.62^{d,z}$ | $175.21 \pm 1.45^{d,z}$ | $93.92 \pm 0.43^{c,x}$ | $102.56 \pm 0.81^{d,y}$ | CCM |
| | ♂ | $82.36 \pm 0.69^{a,z}$ | $88.14 \pm 1.91^{a,q}$ | $41.99 \pm 0.57^{a,x}$ | $44.31 \pm 0.63^{b,y}$ | LCM |
| | | $164.93 \pm 0.95^{c,z}$ | $157.23 \pm 2.19^{c,y}$ | $97.52 \pm 0.49^{d,x}$ | $98.85 \pm 0.82^{c,x}$ | CCM |
| Fe | ♀ | $32.48 \pm 0.16^{d,z}$ | $22.05 \pm 0.70^{c,y}$ | $13.05 \pm 0.43^{b,x}$ | $12.09 \pm 0.56^{b,x}$ | LCM |
| | | $14.83 \pm 0.60^{a,z}$ | $13.48 \pm 0.24^{a,y}$ | $8.81 \pm 0.15^{a,x}$ | $9.21 \pm 0.46^{a,x}$ | CCM |
| | ♂ | $27.67 \pm 0.63^{c,q}$ | $22.36 \pm 0.39^{c,z}$ | $11.97 \pm 0.54^{b,x}$ | $17.11 \pm 0.25^{c,y}$ | LCM |
| | | $19.47 \pm 0.50^{b,z}$ | $16.85 \pm 0.28^{b,y}$ | $9.79 \pm 0.39^{a,x}$ | $9.57 \pm 0.55^{a,x}$ | CCM |

Different letters (a, b, c, d) in the same columns for each metal indicate significant differences ($P < 0.05$). Different letters (x, y, z, q) in the same rows for each different muscle tissues (LCM, CCM) significant differences ($P < 0.05$). $\overline{X} \pm S_{\overline{X}}$: mean ± SE.

on the coast of Nicoya Gulf in Costa Rica by Fischer & Wolff (2006), male and female blue crabs (*Callinectes arcuatus*) with the carapace width (CW) over 95 mm were accepted as adults. In a similar study carried out in shore water of Brazilia, Baptista-Metri *et al.* (2005) accepted male and female blue crabs (*Callinectes danae*) with the CW over 60 mm as adults. Thus, according to the results of this study, male and female Atlantic blue crabs used in our study were adults.

## Annual metal levels of Atlantic blue crabs

The size relationships generally found in the metal levels of Atlantic blue crabs in all the seasons were as follows: Zn > Cu > Fe > Cd > Cr ≥ Pb (Table 2). Türkmen *et al.* (2006) reported Cd, Cr, Pb, Cu, Zn and Fe levels of Atlantic blue crabs (*C. sapidus*) as 1.77 μg $g^{-1}$, 4.53 μg $g^{-1}$, 3.51 μg $g^{-1}$, 7.02 μg $g^{-1}$, 9.07 μg $g^{-1}$ and 14.36 μg $g^{-1}$, respectively, in the Gulf of Iskenderun, in the north-eastern Mediterranean. In the present study, lower levels of Cd, Cr, Pb were obtained in their findings. However, in their study, Cu and Zn levels were lower than those obtained in the current study. The differences in the Cd, Cr, Pb, Cu, Zn levels in the studies mentioned earlier may have stemmed from the contamination levels of catching area. On the other hand, Fe levels were similar to those obtained in our study. Gökoğlu & Yerlikaya (2003) found out that Cu, Zn and Fe levels of Atlantic blue crabs were 25.3–31.3 μg $g^{-1}$, 40.7–60.9 μg $g^{-1}$ and 10.4–11.3 μg $g^{-1}$, respectively, in the Gulf of Antalya, on the coast of Mediterranean, Turkey. The ranges of metal levels were similar to those obtained in this study. In a similar study conducted by Olusegun *et al.* (2009), the ranges of Cd, Cr, Pb and Zn levels in muscle tissues of blue crabs (*C. amnicola*) caught from Nigeria coast were 0.29–0.31 μg $g^{-1}$, 0.48–0.61 μg $g^{-1}$, 2.33–3.06 μg $g^{-1}$ and 11.13–12.93 μg $g^{-1}$, respectively. The Cd and Zn levels were lower than those found in this study. This could be owing to the differences in species and the region where species were caught. Furthermore, the ranges of Cd, Pb, Cu and Zn levels in muscle tissues of Atlantic blue crabs (*C. sapidus*) were reported as 0.05–0.40 μg $g^{-1}$, 0.01–0.12 μg $g^{-1}$, 15.95–16.20 μg $g^{-1}$ and 31.25–32.76 μg $g^{-1}$, respectively, by Jop *et al.* (1997) in two Connecticut Estuaries (Quinnipiac river, Connecticut river), USA. These levels were lower than those found in this study. This could be the different contamination levels in these regions where the specimen used was caught.

### The relationship between the metal levels and the size of Atlantic blue crabs

Generally, no significant differences ($P > 0.05$) in size of all crabs were observed regardless of sex and season. However, there was a significant difference ($P < 0.05$) in only males in autumn. The highest levels of metals (Cu, Zn, Fe) in muscle tissues of Atlantic blue crabs were observed in spring and summer, whereas the lowest levels of these metals were obtained in autumn and winter ($P < 0.05$) (Table 2). In this study, it was found that there was no relationship between specimen size and accumulation of metals. Beltrame *et al.* (2010) also indicated that there was no relationship between size and bio-accumulated metals of burrowing crab (*N. granulata*) caught from a coastal lagoon in Argentina. This result correlates with the results of the present study.

### The sexual variations in metal levels of muscle tissues of Atlantic blue crabs

The findings indicated that there was no significant difference ($P > 0.05$) in male and female crabs in terms of metal accumulation (Table 2). In the present study, it was also found that there was no relationship between sex and metal accumulation. Beltrame *et al.* (2010) also indicated that there was no relationship between sex and bio-accumulated metals of burrowing crab (*N. granulata*) caught from a coastal lagoon in Argentina. Furthermore, Chen *et al.* (2005) reported that there was no relationship between sex and metal accumulation in muscle tissues of the rock crab (*Thalamita crenata*), in Dapeng Bay, Taiwan.

### The metal level variations in different muscle tissues of Atlantic blue crabs

In the present study, Cd, Cu, Zn levels in CCM of Atlantic blue crabs were higher than in LCM whereas Fe levels were found lower in CCM of Atlantic blue crabs ($P < 0.05$). Gökoğlu & Yerlikaya (2003) also indicated that Zn levels (69.9 $\mu g\ g^{-1}$) in CCM of Atlantic blue crabs (*C. sapidus*) were higher than Zn levels (47.0 $\mu g\ g^{-1}$) in LCM. In addition, they reported that Fe levels (10.4 $\mu g\ g^{-1}$) in CCM were lower than Fe levels (11.3 $\mu g\ g^{-1}$) in LCM, in the Gulf of Antalya, the north-eastern Mediterranean, Turkey. In a similar study carried out by Olusegun *et al.* (2009), Zn levels (15.75–16.20 $\mu g\ g^{-1}$) in CCM of blue crabs (*C. amnicola*) were higher than Zn levels (8.31–9.83 $\mu g\ g^{-1}$) in LCM. Chen *et al.* (2005) reported that Cu levels (10.84–11.66 $\mu g\ g^{-1}$) and Zn levels (43.60–47.40 $\mu g\ g^{-1}$) in CCM were higher than Cu levels (7.96–9.29 $\mu g\ g^{-1}$) and Zn levels (29.20–32.00 $\mu g\ g^{-1}$) in LCM of the rock crab (*T. crenata*), in Dapeng Bay, Taiwan. Conclusively, Cd, Cu and Zn metals of Atlantic blue crabs specifically accumulated in CCM, and Fe metal accumulated in LCM.

### The seasonal variations in metal levels of muscle tissues of Atlantic blue crabs

In the present study, the levels of some metals in *C. sapidus* showed seasonal variations. Seasonally, metals such as Cd, Cr, Pb metals showed small variations, whereas metals such as Cu, Zn and Fe showed great variations ($P < 0.05$) (Table 2). It was also observed that Cu, Zn and Fe levels in muscle tissues of Atlantic blue crabs in spring and summer seasons were higher than in autumn and winter seasons. Beltrame *et al.* (2010) also reported that concentrations of some metals (Cd, Cu) in *N. granulata* showed seasonal changes.

### Effect of moulting on metal content of blue crab

The moulting of Atlantic blue crabs in Mersin Bay was observed in October, and the crabs caught in this month were semisoft shell crabs. Cu, Zn and Fe metal levels in muscle tissues of Atlantic blue crabs were found higher in spring and summer than in autumn and winter (Table 2). Reductions in feeding in autumn and winter compared with the other seasons (Kucharski & Da Silva, 1991) and carapace moulting in autumn might have played roles in the occurrence of these results.

In the present study, moulting caused differences in metal levels depending on the kinds of metal and muscle tissues. Besides, moulting reduced the metal levels of Atlantic blue crabs by nearly 70%. In addition, the decreases in metal levels in CCM were lower than those in LCM. Bergey & Weis (2007) also reported metal eliminations and a reduction in Cu and Zn metal levels by 3–12% and 8–22% during the moulting of carapace in crabs. These results support our findings. In a similar study carried out by Benjakul & Sutthipan (2009), decreases by 100% in Cu, Fe and Zn levels of soft shell crabs were reported compared with hard shell crabs. The researchers reported that the decreases in LCM were higher than those in CCM.

### The metal contamination levels in Atlantic blue crabs

In the present study, annually, Cd metal levels in muscle tissues of blue crabs ranged from 0.4 to 1.1 $\mu g$ Cd $g^{-1}$ (Table 2). The Cd limit levels for crabs were 0.5 $\mu g$ Cd $g^{-1}$ (Anonymous, 2001, 2005). Therefore, Atlantic blue crabs living in Mersin Bay were contaminated with Cd metal. Cr metal levels in muscle tissues of Atlantic blue crabs ranged from 0.2 to 0.6 $\mu g$ Cr $g^{-1}$ (Table 2). The Cr limit levels reported by U.S. Food and Drug Administration (2005) were 12 $\mu g$ Cr $g^{-1}$ for crabs. Thus, these numbers indicate that Atlantic blue crabs living in Mersin Bay were not contaminated with

Cr metal. Pb metal levels in muscle tissues of Atlantic blue crabs varied between 0.2 and 0.6 μg Pb $g^{-1}$ (Table 2). Anonymous (2001, 2005) set Pb limit level for crabs as 0.5 μg Pb $g^{-1}$. Taking this limit level into consideration, the present study showed that Pb levels of Atlantic blue crabs were only high in spring.

Cu metal levels in muscle tissues of Atlantic blue crabs ranged from 9.7 to 68.1 μg Cu $g^{-1}$ (Table 2). The Cu limit level reported by Anonymous (2005) for crabs was 20 μg Cu $g^{-1}$. In the present study, Cu levels in LCM of Atlantic blue crabs were lower than the limit level in only autumn and winter. Cu levels in all muscle tissues of Atlantic blue crabs were higher than reported limit level by Anonymous (2005) except Cu levels in LCM of Atlantic blue crabs in autumn and winter.

According to our study, annual Zn metal levels in muscle tissues of blue crabs varied between 39.5 and 175.2 μg Zn $g^{-1}$ (Table 2). Anonymous (2005) set limit level for Zn metal as 50 μg Zn $g^{-1}$. Zn metal levels showed similarities with Cu metal levels, and Zn levels in all muscle tissues of Atlantic blue crabs were higher than reported limit level by Anonymous (2005) except Zn levels in LCM of Atlantic blue crabs in autumn and winter.

## Conclusion

The results of this study showed that Atlantic blue crabs caught from Mersin Bay are contaminated with Cd, Cu and Zn metals. Generally, it was observed that the contamination levels in muscle tissues of crabs are higher than limit levels in all seasons. Regarding to these heavy metals, there was no relationship observed between not only specimen size and metal accumulation but also sex and metal accumulation. While Cd, Cu and Zn metals of Atlantic blue crabs were specifically accumulated in CCM, Fe metal was accumulated in LCM. Seasonally, Cd, Cr, Pb showed small variations although Cu, Zn and Fe showed great variations.

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