Research Article

Bioaccumulation of Some Heavy Metals in the Tissues of Needlefish *Tylosurus crocodilus* (Péron and Lesueur, 1821) from Iraqi Marine Waters

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Abstract | Heavy metals pollution is one of the main reasons for water quality decline. The accumulation of toxic metals in fish tissue and their potential harm to humans are still a major concern. In the current study, the heavy metals levels (Pb, Ni, Mn, Fe, Cu, and Cd) were estimated in different organs, such as the liver, gills, ovaries, and muscles of the Needlefish *Tylosurus crocodilus* with an average weight of (1096.3) gm and an average length of (781) mm. According to the findings, the concentrations of Cd, Cu, Fe, Mn, Ni, and Pb in muscles were 26.55, 9.93, 439.43, 20.59, 7.45, 0.01 µg/g (dry weight), respectively. The liver was found to contain 33.83, 6.12, 119.24, 46.8, 23.62, and 0.006 µg/g (dry weight), and in the gills were 29, 13.24, 264.98, 28.08, 31.49, 0.008 µg/g (dry weight). The ovarian values were demonstrated in the following order: 27.88, 9.93, 845.74, 65.53, 20.99, and 0.004. The accumulated concentrations values showed that the elements were Fe < Cd < Mn < Ni < Cu < Pb, the seasons were autumn < summer < winter < spring, and the majority of metals deposited were in the following order: ovaries > muscles > gills > liver.

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Introduction

Heavy elements still continue to attract much attention because they are able to be accumulated in fish tissues and can harm human health if consumed through food (Moiseenko and Gashkina, 2020). Because of their constant emissions from both natural and industrial sources, heavy metals are among the most harmful pollutants in the environment, leading to an increase in their concentrations in the atmosphere (Shah *et al*., 2020). Most heavy metal ions are toxic or carcinogenic and threaten human health and the environment (Burch, 2023). There are also many biochemical processes and environmental factors that control the transfer and readiness of heavy elements in the aquatic environment, such as adsorption, the formation of complexes on sediment organic compounds, and biological absorption through the effect of temperature and pH (Kraemer and Hering, 2004; Mohamed *et al*., 2012). The amount of these elements absorbed depends directly on their concentration in water and exposure time, as absorption increases with each increase (Shah *et al*., 2020). Currently, exposure to heavy metal pollution is regarded as one of the most dangerous things because heavy elements find their way into the environment through a variety of consumer products used by humans, eventually accumulating in high concentrations above their natural levels in water and living organisms, particularly fish (Al-Najare *et al*., 2017). Finally, transferred to higher trophic food levels through the food chain such as, to humans (Van den *et al*., 2002).

In general, humans can be exposed to the effects of heavy elements through industrial activity sources such as, fossil fuels, mining operations, agricultural fields, pharmaceuticals and technology applications (Seiyaboh and Izah., 2017; Al-yassein, 2022) as well as, the nature sources like the biosphere, rocks erosion, and earthquakes (Latif *et al*., 2022). Therefore, the amount and rate of heavy elements in the environment vary, whether they are within or above the required levels, depending on the sources that enter the environment, whether natural or industrial (Seiyaboh and Izah., 2017). Furthermore, it can affect and accumulate in various parts of fish organs, such as gills, muscles, liver, and reproductive organs, and lead to morphological changes in them (Al-Najare et al., 2022; Abed *et al*., 2025). Exposure to the high level of heavy metals impacts fish tissue histology (Hashim and Al-yassein, 2020). In addition, heavy metal pollutants are important and induce oxidative stress in many aquatic animals (Sevcikova *et al*., 2011). Thus, by monitoring fish bioaccumulation, risks that could endanger both human health and the aquatic population can be reduced; this makes it possible for researchers to take the necessary safety measures to lessen pollution of the marine environment (Naeem *et al*., 2010; Tsurkan *et al*., 2020; Aldoghachi *et al*., 2025).

Fish consuming is an essential part of healthy diet worldwide, as it is a highly valued source of digestible protein (Naeem *et al*., 2005) and omega-3 fatty acids (Isangedighi and David, 2019). An estimated 179 million tons of fish were produced worldwide in 2018, of which 156 million tons were consumed by humans, making the seas and oceans a significant source of animal protein (FAO, 2020). They are also one of the most important markers for determining the degree of heavy metal contamination in aquatic environments (FAO, 2020; Karim *et al*., 2022; Zaghloul *et al*., 2024). *Tylosurus crocodilus* is considered a fish that lives in the open sea and far from the coast, where it comes in the form of individuals or small groups that feeds on fish. They have a broad distributed across the Red Sea and East Africa, as well as in the tropical and warm temperate parts of the Indian and western Pacific oceans (Deidun *et al*., 2021; Yaseen *et al*., 2024). Therefore, the object of the current project was estimating the bioaccumulation of different heavy metals in different tissues of Needlefish *T. crocodilus* caught from Iraqi marine waters and demonstrate the possibility of using them for human consumption.

Material and Methods

Description of the study area

Samples of needlefish *T. crocodilus* were collected from the area marked by dots (5422767°5'41.7161"E 3476416°31'40.7591"N) Figure 1. The station is characterized by the proliferation of medium-sized and small fishing boats using trawl and drift gill nets (Al-Shamary, 2020).

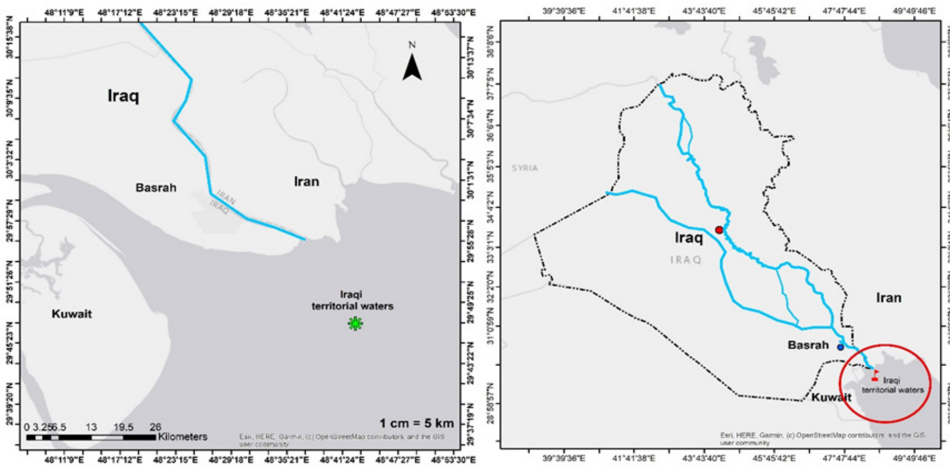

Figure 1: *Map of the sample collection area.*

Fish sample preparation and analysis marine flame

The goal of the study was to quantify the amount of heavy metals that were accumulated of *Tylosurus crocodilus*. Drifting gill nets with a length of 200-500 m and a height of 2.5 m, with holes of different sizes (15-35 mm), were used to catch fish in February, 2023. *T. crocodilus* on a fishing boat is 16 meters long and 3.5 meters wide, has 150 horsepower, and its fishing speed is 2 knots (Carpenter *et al*., 1997; Eschmeyer, 2017). About 50 seasonal samples of *T. crocodilus* were used. The average size was 1096.3 g, and the average length was 781 mm. The tissues (muscle, liver, gills, and ovaries) are represented in a specimen (0.5 g) from each sample of frozen fish in a freeze dryer, ground, and digested in 3 ml of a mixture of concentrated perchloric acid HCLO4 and nitric acid HNO3 in a ratio of 1:1 in tubes. The tubes were placed in a water bath at 70°C for 30 minutes, and after that transferred to a heating plate to complete the digestion process. The contents were condensed to 25 ml with double-distilled water, then filtered and transferred to a sterile plastic container with a screw top to allow it to cool. The container was labeled and kept at 4°C until analysis was required by using a Flame Atomic Absorption Spectrophotometer (FAAS, Shimadzu model AA 7000) equipped with a hollow cathode lamp for each element (Jakhrani *et al*., 2019).

Statistical analysis

SPSS version 20 was conducted to analyze the results statistically. The significance of the differences between the means was tested using the least significant difference (L.S.D) test at a significant level (0.05) (Al-Rawi *et al*., 2000).

Results

All the current study results indicated an important difference ($P < 0.05$) in metal concentration in fish tissues and seasons at different sampling sites.

Cadmium (Cd)

The quantity of cadmium in fish tissues varies seasonally. The highest amount was in the winter in the muscles, liver, gills, and ovaries (26.5515, 33.831, 29.0035, and 27.8835 μg/g dry weight, respectively). The lowest ratio was in the ovaries and gills (0.8055, 9.666) μg/g dry weight, respectively in spring (Figure 2).

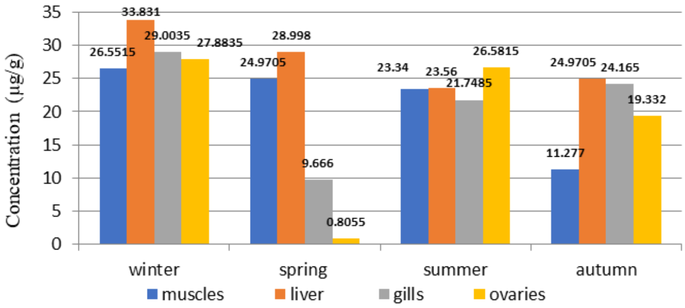

Figure 2: *Seasonal rates of cadmium concentration (μg/g dry weight) in the tissues of T. crocodilus*

Copper (Cu)

The seasonal averages of copper concentration in the fish tissues studied are shown in (Figure 3). However, there were no significant differences ($P>0.05$) between muscles and ovaries in spring. The results show that the highest values were muscles, liver, gills, and ovaries were (9.927, 6.118, 13.236, and 9.927) μg/g dry weight, respectively, in the spring. In the winter the liver and gills had the lowest values (1.6545, 2.6545 μg/g dry weight, respectively), followed by the muscles and ovaries (0.041, 1.3345) in the summer.

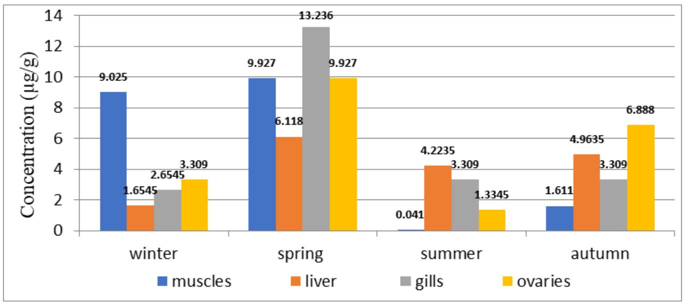

Figure 3: *Seasonal rates of copper concentration (μg/g dry weight) in the tissues of T. crocodilus.*

Iron (Fe)

The results show that the lowest concentration values in the muscles, liver, gills, and ovaries were (90.5362, 26.4984, 46.3722, 68.4542) μg/g dry weight was recorded in the spring season, while the highest concentrations of iron in the muscles and liver were (439.4318, 119.2428) μg/g dry weight respectively in summer, and (264.984) μg/g dry weight for gills in winter, and in autumn, the highest concentration of Iron was recorded in the ovaries 845.7406 μg/g dry weight (Figure 4).

Manganese (Mn)

In the spring season, the muscles and gills had the highest concentrations (20.5942 and 28.083 μg/g dry weight, respectively), while the liver and ovaries had the lowest concentrations (2.0088 and 2.8833).

During the autumn season, the liver and ovaries had the highest concentrations (46.805 and 65.527 µg/g dry weight, respectively), while during the winter and spring seasons the ovaries had the lowest concentration (3.7444) (2.8833) µg/g dry weight (Figure 5).

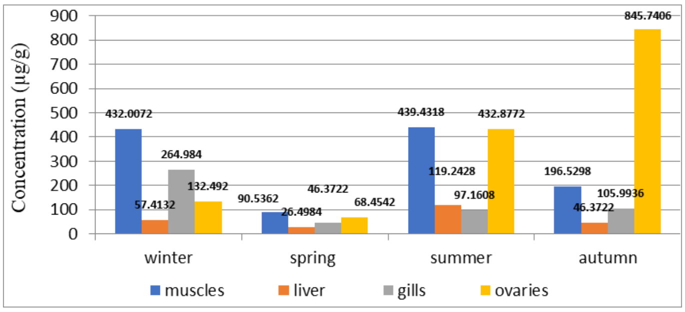

Figure 4: *Seasonal rates of iron concentration (µg/g dry weight) in the tissues of T. crocodilus*

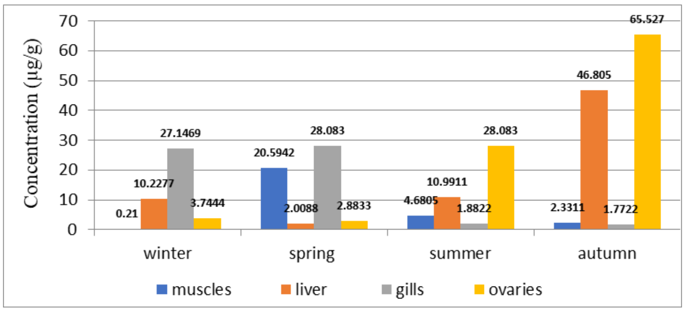

Figure 5: *Seasonal averages of manganese concentration (µg/g dry weight) in the tissues of T. Crocodilus*

Nickel (Ni)

During the autumn season, fish tissues had the highest concentrations of nickel (7.4445, 23.6174, 31.4898, and 20.9932 µg/g dry weight) for muscles, livers, gills, and ovaries respectively, while the muscles and ovaries had the lowest concentrations (2.6241 and 0.048 µg/g dry weight, respectively during the winter). At springtime liver and gills had the lowest concentrations (2.2415 and 0.043 µg/g dry weight, respectively) (Figure 6).

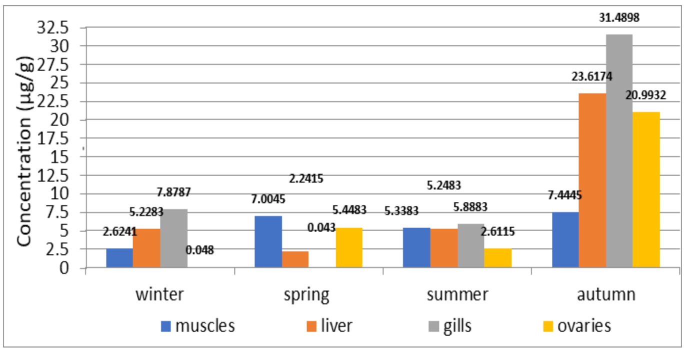

Figure 6: *Seasonal rates of nickel concentration (µg/g dry weight) in the tissues of T. crocodilus*

Lead (Pb)

There were no significant differences (P>0.05) between the gills and the ovaries in the winter, otherwise, in the spring, between the liver and the ovaries and the liver and the gills. There are no significant differences (P>0.05) in the summer season between the gills and the ovaries, alternatively, between the liver and the gills. The highest and lowest lead concentration levels of muscles were in the winter and spring, which were (0.011and0.001) µg/g dry weigh respectively. Throughout the spring and winter, the liver reported concentrations of (0.006 and 0.001) µg/g dry weigh as the highest and lowest, respectively. The gills had the lowest and greatest concentrations in the summer and autumn measuring at (0.003, 0.011) µg/g dry weigh. The highest and lowest concentrations (0.004, 0.001) µg/g dry weight were found in the ovaries during the spring and autumn seasons respectively (Figure 7).

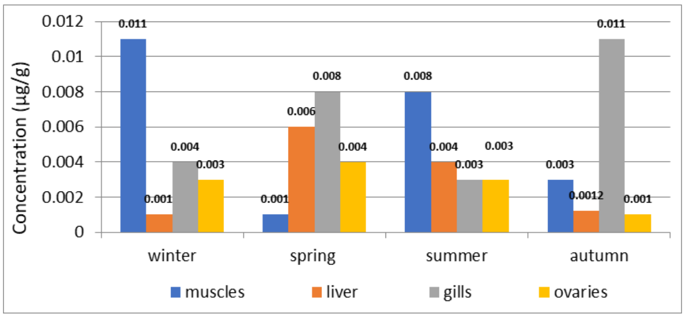

Figure 7: *Seasonal averages of lead concentration (µg/g dry weight) in the tissues of T. crocodilus*

Discussion

Heavy metals primarily originate from industrial and human activities in the environment, along with wastewater from oil installations (Pourang *et al*., 2019). Consequently, pollutants discharge into water bodies represent a significant global issue. Heavy metal pollution has harmful effects on marine organisms only after organisms have taken up these metals and accumulated them in their biomass (Jezierska and Witeska, 2006). Various factors, including fish habitat, size, sex, and physiological metabolism status, influence the accumulation of contaminates in fish tissue (Naeem *et al*., 2010; Ismat *et al*., 2013; Luczyńska *et al*., 2020). According to the accumulated concentrations values, the heavy metal elements were Pb < Cu < Ni < Mn < Fe. It has been shown that metals accumulate in all organs and tissues of the organism concurrently, indicating that they are absorbed and dispersed throughout the body (Moiseenko and Gashkina, 2020). Lead is the most hazardous metal found in large quantities in the marine environment and the crust of the earth (Zaghloul *et al*., 2024). Latif *et al*. (2022) found that tissues values of *Ctenopharyngodon Idella* and *Tor putitora* exposed to lead in the following order: muscle > skin > gill > liver > gut.

The present study illustrated that the fish's liver had the highest quantity, while its muscle had the lowest. The liver is the largest part of a fish's body, having a high capacity to absorb contaminants and also having a vital role in detoxification (Fernandes *et al*., 2008). Chronic exposure to heavy metal pollution will lead to tissue damage, which would negatively impact the detoxification process of the liver and muscles damaged by the accumulation of metal ions (Siraj *et al*., 2016). Therefore, cases of chronic or long-term heavy metal contamination are linked to elevated liver levels of some heavy metals (Allen-Gil and Martynov, 1995). All fish species showed that the liver had the highest amount of biochemical content (Zaghloul *et al*., 2024). In accordance with Mishra *et al*. (2024), the muscles of Baikari *Clupisoma garua* showed the lowest Pb ratio (0.07 µg/g), while the liver had the highest ratio (8.86 µg/g). Further, *Dicentrachus labrax* and *Solae solea* had the highest concentrations of Pb and Cu in their livers, whereas *Angiula anguila* had the highest values of Cd and Zn (Zaghloul *et al*., 2024). Baikari fish liver had the greatest observed Mn content (53.19 µg/g) (Mishra *et al*., 2024). On the other hand, the greatest concentrations of numerous compounds, including cadmium, iron, and nickel, were found in the liver of Black Sea (Bulgaria) at 0.25,69.30, and 505.75mg/kg w.w (Fazio *et al*., 2020). Due to the strong relationship between Cd metabolism and critical metals, particularly zinc, Cd can replace zinc in many crucial enzymatic reactions as well as disrupt and inhibit these (Annabi *et al*., 2013).

Heavy metal pollution can enter a fish's body through a variety of routes, including the gills, body surface, and digestive tract, when the fish consumes food that has contains heavy metal (Garai *et al*., 2021). Several fish species had varying levels of heavy metal accumulated; for instance, gill tissue had the highest concentration of lead after 24 hours of exposure was 4.113 ± 0.831 mg/g, however, copper was (0.266 ± 0.029 mg/g), respectively (Shah *et al*., 2020). It was been observed a strong correlation ($P \leq 0.05$) of *T. crocodilus* (Belonidae) between the standard length and Cu concentration in the muscle and gill tissues (Ebrahimi Yazdanabad *et al*., 2014). The highest concentration of Cr has been found at the gill of *Labeo dyocheilus* and *Wallago attu*, especially chromium which is a highly hazardous metal that can harm aquatic species' embryos and cause cancer (Shah *et al*., 2020). On the other hand, the findings demonstrated that in three different fish species (*Catla catla*, *Cirrhinus mirigala*, and *Labeo rohita*) taken from ponds in the Pakistani province of Kashmore, bioaccumulation of trace elements was higher in the gills than in the liver and muscles (Jakhrani *et al*., 2019). The trend of zinc accumulation in *Anabas testudineus* had the greatest accumulation shown in the gills, which are thought to be the main entrance point for this metal (Nanda, 2014).

The concentration of metals in the marine animals muscles is particularly concerning, as these fish are abundant in protein that are widely eaten by humans (Shah *et al*., 2020). Generally, the bioaccumulation of metal levels increases with increasing duration of exposure (Latif *et al*., 2022). There was a variation in heavy metal level in fish muscles. For example, highest concentration of lead was found in the muscles of *C. idella*, followed by chromium and copper respectively (Shah *et al*., 2020). On the contrary, the lowest Pb concentration was found in *A. testudineus* muscle tissues (Nanda, 2014). The levels of Cu in the muscles of *T. crocodilus* were found to be lower than the WHO (Zaghloul *et al*., 2024). Fish has a lower metabolic rate than other tissues, there is less metal buildup in their muscles. Another important issue is that muscles have less broad blood circulation than other essential organs like the liver, kidney, and gills (Adhikari *et al*., 2009). The accumulation levels of (Cu, Zn) content in muscles was more than that of hazardous elements (Cd and Pb), with Zn > Cu > Pb > Cd. For every metal, the order is muscles < gills < liver, with the exception of Pb, which is in the reverse order (Zaghloul *et al*., 2024). Some fishes such as *Gudusia chapra* and *Eutropiichthy vacha* had Cu levels ranging from 10.26–20.53 and 10.11–14.82 mg/kg, respectively, with mean concentrations of 12.63 and 11.18 mg/kg. These findings can be considered a serious warning against anyone considering eating fish (Ajala *et al*., 2022). The organism's natural adsorption of Cu may be the cause of the increased concentration of these elements in fish muscles (Kalipci *et al*., 2023). Zinc is necessary for healthy growth and regular metabolic activities in living organism (Kalipci *et al*., 2023). Additionally, it has been demonstrated to affect the physiology state of fish species, such as reproductive physiology and behavior (Garai *et al*., 2021). Among the elements examined, zinc content in *G. chapra* was the highest at 14.37 mg/kg. This could be because this species is omnivorous, which encourages the accumulation of Zn from a variety of food sources (Paul *et al*., 2020). Moreover, Zn elevation concentrations it could be because of anthropogenic activities in the research area, which include the dumping of domestic waste and raw sewage materials (Ajala *et al*., 2022). Several histopathological effects were observed in fish muscles as a consequence of Ni and Cd accumulation, so fish functioned as bio-indicators of pollution, which can be used to predict the direction of medical study in the search for detrimental impacts (Moiseenko *et al* 2018; Hahim and Al-yassein, 2020).

In our study there are no obvious differences between the ovaries and other tissues and seasons exposed to the Pb. Conversely, the highest levels of lead were found in the ovary. The Pb accumulation trend went as follows: ovary > liver > gill > muscle (Nanda, 2014). It was observed that exposure to metals like lead, mercury, and cadmium clearly affected the catfish *Heteropneustes fossilis's* oocyte maturation and ovulation (Gautam and Chaube, 2018). Out of all the tissues examined, gills and liver, the ovary has the highest level of zinc accumulation with factor (4.08), as compared to the control in *A. testudineus* that might affect the reproduction mechanism of the fish (Nanda, 2014). Along with, a significant annual average value of heavy metal concentrations was found in *Tilapia zillii* ovary. As heavy metal concentrations rise, the proportion of mature oocytes falls and atresia rises, it was observed that certain fish ovaries at a station with the greatest quantities of heavy metals stopped maturing (Azab *et al*., 2019). Fish growth, development, reproduction, and survival, may be seriously threatened by the toxicity of heavy metals in water (Gautam and Chaube, 2018). Due to economic and nutritional significance of *T. crocodilus's* and the increasing levels of toxins in Iraq's marine waters, it is imperative to monitor environmental hazardous chemicals and their impact on the aquatic biota in order to assess the health of fish (Al-Najare et al., 2022).

The results of the current study showed that the concentrations of the heavy metals studied (copper, lead, nickel, and manganese) were at their lowest limits in the muscles, which is the edible part of the fish, and were within the permissible limits set by the Food and Agriculture Organization and the World Health Organization (FAO/WHO, 1984), and also according to Malaysian Food Regulations (MFD, 1985) Table 1.

Table 1: *Permissible limits for heavy metals in fish (μg/g dry weight).*

References	Ni	Mn	Fe	Cd	Pb
FAO/WHO 84 (Swami *et al*., 2001)	----	5.4	----	2	1.5
(MFR, 1985) (Swami *et al*., 2001)	20	4.5	55	1	2
FDA (2001) (Swami *et al*., 2001)	80	----	40	4	1.7

The results of the current study showed a significant difference in the values of the heavy elements studied when compared with other studies conducted on species in Iraqi marine waters (Table 2). The reason may be that the accumulation of heavy metals is linked to feeding habits and behavior and also depends on the nature of the fish's presence in the water, whether it is surface, benthic, or in the water column. In addition, the region is affected by tidal movements that can bring many pollutants from the coasts of neighboring countries, which are active with the movement of oil and commercial ships.

According to the results of the current study, a noticeable increase in iron, nickel, and cadmium was recorded in ovarian cells, as there is increasing concern about the increase in chemicals and heavy metals disrupting the reproductive cycle in aquatic organisms (Azab *et al*., 2019), and exposure to toxic agents. As a result, it may lead to metabolic disorders, genetic mutation, embryo damage, and decreased fertility (FAO, 2022). As Yokote (1982) pointed out, increased pollution may lead to damage to sperm cell tissue and enlargement of ovarian cells in most cases. This leads to an imbalance in the estrogen hormone and immaturity of the egg.

Conclusions and Recommendations

The results demonstrated that the heavy metal accumulation levels varied seasonally through all of the needlefish *Tylosurus crocodilus's* organs. The highest impact was Ni, Mn, Fe, Cu, and Cd levels in μg/g dry weight. A significant variation in the lead results,

Table 2: *Comparison of heavy metal concentrations of some marine fish species with the current study.*

References	Species	Pb	Ni	Mn	Fe	Cu	Cd
Al-Najare, *et al,* (2012a)	Acanthopagrus latus	--	ND	3.82	81.12	4.78	3.9
Al-Najare, (2012)	Liza subviridis	-	109	6.72	-	9.5	5.9
Al-Najare, *et al,* (2013)	Acanthopagrus latus	--	321.43	5.6	232.22	16.68	4.15
Al-Najare, (2014)	Chirocentrus dorab	5.3	12.6	--	984.5	29.4	--
Al-Najare, *et al,* (2015)	Tenulosa ilisha	0.19	1.7	0.1	-	63.9	4.6
Al-Najare, (2015)	Otolithes ruber	1.3	11.99	--	835	29.4	--
Al-Najare, *et al,* (2017)	Nemipterus japonicus	--	130	4-ND	80-5	8-ND	14-ND
Al-Imarah, *et al,* (2017)	Epinephelus coioides	0.12	0.28	0.99	--	4.01	1.36
	Euryglossa orientalis	0.45	0.56	2.12	--	16.7	1.09
Al-Najare, *et al,* (2018)	Scomberoides commersonnianus	2.17	6.7	27.51	3422.9	327.7	20.8
Al-Najare, *et al,* (2022)	Saurida tumbil	2.85	4.56	--	8.44	1.45	--
Present study	Tylosurus crocodilus	0.001	2.624	0.21	90.54	0.041	11.28
		--	--	--	--	9.93	--
		0.011	7.44	20.59	439.43		26.55

among other tissues, and a significant reduction for the ovaries during the fall. The levels of copper, lead, nickel, and manganese in muscles were at their lowest but still within permissible limits.

Acknowledgements

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Novelty Statement

Fish bioaccumulation measurements are essential for evaluating environmental health and safeguarding human consumers. Because they live at different trophic levels in the food chain and are vulnerable to pollutants from water, fish make ideal bioindicators.

Author's Contribution

Rajaa N. Al-yassein: Designed the experimentation.
Kadhim H. Younis: Wrote the manuscript.
Ghassan A. Al-Najare: Wrote the first draft of the manuscript.
Khalid W. Farnar: Statistical analysis.
Zainab J. Obaid and Zahraa K. Shakir: Technical and operational support

Generative AI or AI assisted technology statement
This entire research endeavor was conducted without the aid of artificial intelligence technology.

Conflict of interest
The authors have no conflict of interest.

Reference

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