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ORIGINAL ARTICLE

Heavy metal accumulation in the tissue and food web of the Greater Lizardfish *Saurida tumbil* fish in Iraqi marine waters

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Abstract
To understand the bioaccumulation of trace metals in greater lizardfish, *Saurida tumbil* in Iraqi marine water, fish were monthly collected from May 2021 to April 2022. Heavy metals, including Pb, Ni, Fe, Co, and Cu in surface water, food web, and fish tissues were analyzed. The food of *S. tumbil* included three fish, crustacea, and squid. Surface water Pb and Fe concentrations were higher during the year, ranging from 10.5±2.83 to 19.98±3.69μg/L and 24.77±2.99 to 29.08±2.67μg/L, respectively. The concentration of heavy metals in different food webs showed that Fe and Pb were higher in fish, Cu was higher in fish and shrimp, and Co was highest in squid. The highest concentration of heavy metals (Pb, Ni, Fe, Co, and Cu) in lizard fish tissues was found in the summer. The food web was responsible for the greatest accumulation of Pb and Ni, in the tissues of lizard fish during summer and winter, whereas seawater was responsible for the greatest accumulation of other trace metals (Fe, Co, and Cu). Heavy metal accumulation in tissues of greater lizardfish concerning seawater was on the order of Ni>Fe>Co>Cu>Pb, regarding the food web, it was in the order of Pb>Ni>Fe>Cu>Co. The results indicated that seawater is responsible for Ni, and Fe accumulation in greater lizardfish tissues, and the food web is responsible for Pb and Ni accumulation. Depending on the mineral, metal concentrations in food or water can be used to predict metal concentrations in fish tissues.

Keywords: Bioaccumulation, Food web, Lizard fish, Heavy metals.

INTRODUCTION

Heavy metals are chronic pollutants that bioaccumulate throughout the food chain, endangering both the environment and human health. Metals, unlike other harmful compounds, are transformed rather than produced or destroyed. In terms of the accumulation of minerals at higher food levels, such as fish, marine plankton has the lowest levels of heavy metal accumulation among many food chains due to their impact on food transport (Chouvelon et al. 2019). Bioaccumulation of heavy metals has been observed in aquatic food webs, with top levels in carnivorous fish (Nfon et al. 2009). To identify which food webs are more vulnerable to bioaccumulation, it is difficult to comprehend the process of bioaccumulation in aquatic systems (McIntyre & Beauchamp 2007). Heavy metal regulatory processes (for example, absorption, storage, and elimination) for taxa and species have been used to explain both necessary and not necessary metals (Wang & Rainbow 2010). Their concentrations and speciation in biotic (food source) and abiotic (habitat) environments control their accumulation in organisms and movement between biogeochemical compartments and increased food chains (Neff 2002; Rainbow 2002). As a result, dissolved and trophic pathways are the primary routes by which marine organisms are exposed to contaminants and accumulate pollutants, with the latter being the primary process by which heavy metals reach medium- to high-trophic level consumers like fish (Mathews & Fisher 2009; Pouil et al. 2016).

Heavy metals are commonly regarded as high-risk micropollutants due to their toxicity, persistence, bioaccumulation, and biomagnification in water and fish tissues. This is due to the environmental and human health risks they may

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pose (WHO 1996; Lipy et al. 2021). Fish intended for human consumption may become contaminated with heavy metals through absorption or direct intake of water or organisms. Several studies have been conducted to investigate heavy metal concentrations in Iraqi marine fishes (Al-Saad et al. 2008; Al-Najare 2012; Al-Najare et al. 2013; Al-Najare 2014; Al-Najare et al. 2015; Al-Najare et al., 2016; Al-Imarah et al., 2017; Al-Khafaji et al. 2018; Cunningham et al. 2019; Alhamadany et al. 2021). The Iraqi marine waters were chosen for the current investigation due to the economic considerations of its fish species. Economically, Iraqi marine water has the potential to be a fish breeding ground; however, this area is home to many sources of pollution, such as petroleum product loading and unloading, agricultural waste, industrialization, and urbanization along the discharge of the Shatt Al-Arab River. The current study aimed to investigate heavy metal levels of Pb, Ni, Co, Cu, and Fe in the water, greater Lizardfish, *Saurida tumbil* (Bloch, 1795), and its food web (fish, shrimp, and squid) to determine the extent to which these metals are bioaccumulating in fish's edible parts.

MATERIALS AND METHODS

Collection of Water Samples: The water samples were monthly collected from the Iraqi marine water, at a depth of 30cm from May 2021 to April 2022. The samples were then filtered using 0.45µm Whatman membrane filter paper and placed in polyethylene bottles. These bottles were prewashed with deionized water and (1N) HNO_3. The collected samples were mixed with 3mL of concentrated HNO_3 to prevent oxidation, and they were then kept at 4°C until analysis.

Fish samples: Greater lizardfish were collected monthly from the Iraqi Marine water, using a benthos trawl. Each fish was weighed (g) and measured for total length (cm). The abdominal cavity of each fish was opened, the gut was extracted, and the stomach was isolated. All fish samples were stored in a polyethylene bag with ice immediately after collection and frozen at -20º C before treatment.

Food content: The food of *S. tumbil* included three components, namely fish: long tongue sole (*Cynoglossus lingua*), congaturi halfbeak (*Hyporhamphus limbatus*), elongate ilisha (*Ilisha elongate*), crustacea: shrimp (*Penaeus* sp.), cephalopod: squid (Octopus and Sepia). Fish and shrimp formed the food of *S. tumbil* throughout the months of the year while the squid was limited to the summer months only. The fish formed more than 80.9% while shrimp made up 10.5% and squid 8.6% of the food of *S. tumbil*.

Analysis of heavy metals: Water, fish, and food item (fish, shrimp, and squid), were digested using the nitric acid, and perchloric acid method (APHA 1997). According to ROPME's (1982), the heavy metal concentrations of lead (Pb), nickel (Ni), iron (Fe), cobalt (Co), and copper (Cu) were extracted, and measurements were made using a flame atomic absorption spectrophotometer (Model PG, AA500).

Bioaccumulation factor (BAF): Following the formula of Mackay & Fraser (2000), the bioaccumulation factor (BAF) was determined as follows: BAF (concerning sea water)= CB/CWT and BAF (concerning food web)= CB/CFW, where CB = concentration of heavy metals in fish, CWT = concentration of heavy metals in water, and CFW = concentration of heavy metals in the food web.

Statistical analyses: The statistical differences in mean heavy metal concentration of surface water, food web, and fish tissue were investigated using the SPSS package program. The data were compared using one-way ANOVA and Duncan grouping. The findings were considered significant at $P<0.05$ level.

RESULTS

Heavy Metals in surface water: The concentration of heavy metals in the surface water is shown in Table 1. Pb and Fe concentrations were higher throughout the year. The values of these metals ranged from 10.5±2.83 to 19.98±3.69µg/L and 24.77±2.99 to 29.08±2.67µg/L, respectively,

Table 1. The mean concentrations (±SD) of heavy metals (µg/L) in the surface water of Iraqi marine water in different seasons.

Season	Pb	Ni	Fe	Co	Cu
Summer (2021)	19.98±3.69[a]	12.25±2.11[a]	26.52±2.95[a]	13.24±2.77[a]	13.71±2.71[a]
Autumn (2021)	15.72±2.53[ab]	11.22±2.24[a]	25.55±3.87[a]	9.56±1.87[a]	13.22±1.66[a]
Winter (2022)	10.5±2.83[b]	11.80±2.74[a]	24.77±2.99[a]	10.96±1.68[a]	12.82±0.22[a]
Spring (2022)	18.15±2.88[a]	12.11±2.76[a]	29.08±2.67[a]	12.6±3.58[a]	12.1±0.32[a]

Values (mean ±SD) in the same column with different superscript letters differ significantly (*P*<0.05).

Table 2. The mean heavy metal concentrations (µg/100g) in the Lizard fish food web (Fish, Shrimp, and Squid).

Season	Food item	Pb	Ni	Fe	Co	Cu
Summer (2021)	Fish	3.01±1.03	9.96±0.76	188.22±14.65	20.03±5.74	12.52±1.7
	Shrimp	2.31±0.99	32.88±6.89	119.46±13.88	18.65±3.89	20.12±2.87
	Squid	0	4.30±2.32	49.36±6.41	21.11±4.09	6.55±1.09
	Total	5.31±0.66[a]	47.14±3.32[a]	357.05±11.62[a]	59.79±4.57[b]	39.19±1.84[b]
Autumn (2021)	Fish	0	0	39.76±4.84	19.05±2.53	63.41±0.54
	Shrimp	0	0	23.50±2.86	6.92±0.47	16.12±3.73
	Squid	0	0	0	0	0
	Total	0	0	63.26±2.569[b]	25.97±1.002[c]	79.53±3.057[a]
Winter (2022)	Fish	1.09±0.02	3.32±0.88	114.82±15.62	17.49±1.95	6.013±0.85
	Shrimp	0.67±0.03	0.89±0.02	67.75±6.55	11.5±1.08	21.92±3.65
	Squid	0	0	0	0	0
	Total	1.76±0.01[b]	4.21±0.44[c]	182.57±11.09[b]	28.99±1.48[c]	27.93±2.26[c]
Spring (2022)	Fish	3.65±1.03	13.56±2.42	63.90±9.75	18.07±2.86	16.59±1.93
	Shrimp	2.19±1.11	0	12.59±2.07	51.7±4.99	10.96±1.22
	Squid	0	0	0	0	0
	Total	5.84±1.07[a]	13.56±2.42[b]	76.49±5.91[c]	69.77±3.93[a]	27.55±1.57[c]

Values (mean ±SD) in the same column with different superscript letters differ significantly (*P*<0.05).

Table 3. The mean concentrations (±SD) of heavy metals in Lizard fish *S. tumbil* tissues (µg/100g).

Season	Pb	Ni	Fe	Co	Cu
Summer (2021)	2.85±0.12[a]	4.65±0.21[a]	8.44±0.69[a]	2.33±0.18[a]	1.45±0.43[bc]
Autumn (2021)	0.64±0.03[d]	3.98±0.11[b]	5.19±0.44[c]	1.39±0.04[c]	2.37±0.55[a]
Winter (2022)	1.58±0.07[b]	3.25±0.18[c]	6.87±0.48[b]	1.82±0.07[b]	2.31±0.63[ab]
Spring (2022)	1.01±0.01[c]	2.34±0.09[d]	7.54±0.51a[b]	1.01±0.03[d]	1.18±0.11[c]

Values (mean ±SD) in the same column with different superscript letters differ significantly (*P*<0.05).

however, there are no significant differences (*P*>0.05). The values of Ni (12.25±2.11µg/L), Co (13.24±2.77µg/L), and Cu (13.71±2.71µg/L) were high in the summer season. The concentration of heavy metals in the surface water was in the order of Fe>Pb>Cu>Ni>Co.

Heavy metals in the food web of the *S. tumbil* fish: A total of 3 species comprising the food item in greater lizard fish food: fish (80.9%), shrimp (10.5%), and squid (8.6%). The concentration of trace metals in various foods shows that Pb and Fe were higher in fish (3.65±1.03 and 188.22±14.65µg/100g, respectively). Cu was higher in fish and shrimp (63.41±0.54, and 21.92±3.65 µg/100g, respectively). Ni is higher in shrimp (32.88± 6.89 µg/100g), while the highest concentration of Co was 21.11±4.09µg/100g in squid (Table 2). The concentration of heavy metals in the food items was in the order of Fe>Co>Cu>Ni>Pb.

Heavy metals in *S. tumbil* tissues: Table 3 represents the level of heavy metals in the tissues of lizard fish during year. The results showed significant differences (*P*<0.05) in the heavy metals concentration and the highest concentration was recorded in the summer for Pb, Ni, Fe, and Co (2.85±0.12, 4.65±0.21, 8.44±0.69, and 2.33±0.18 µg/100g, respectively), while Cu concentration was higher in autumn (2.37±0.55µg/100g).

Bioaccumulation (BAFs) of heavy metals in fish

Table 4. BAFs of trace metals in *S. tumbil* tissues concerning seawater.

Season	BFA concerning seawater	Trace metals				
		Pb	Ni	Fe	Co	Cu
Summer (2021)	Trace metals in Water (µg/L)	19.98±3.69	12.25±2.11	13.24±2.77	13.71±2.71	26.52±2.95
	BAF fish	0.14264264	0.379591837	0.318250377	0.175981873	0.105762217
Autumn (2021)	Water concentration (µg/L)	15.72±2.53	11.22±2.24	25.55±3.87	9.56±1.87	13.22±1.66
	BAF fish	0.04071247	0.354723708	0.203131115	0.14539749	0.179273828
Winter (2022)	Water concentration (µg/L)	10.5±2.83	11.80±2.74	24.77±2.99	10.96±1.68	12.82±0.22
	BAF fish	0.15047619	0.275423729	0.277351635	0.166058394	0.180187207
Spring (2022)	Water concentration (µg/L)	18.15±2.88	12.11±2.76	29.08±2.67	12.6±3.58	12.1±0.32
	BAF fish	0.05564738	0.193228737	0.259284732	0.08015873	0.097520661

Table 5. BAFs of trace metals in *S. tumbil* tissues concerning food web.

Season	BFA concerning food web	Trace metals				
		Pb	Ni	Fe	Co	Cu
Summer	Trace metals in the food web (µg/100g)	5.316	47.146	357.051	59.798	39.198
	BAF fish	0.53611738	0.09862979	0.02363808	0.03896451	0.03699168
Autumn	Trace metals in the food web (µg/100g)	0	0	63.26	25.97	79.53
	BAF fish	0	0	0.082042	0.053523	0.0298
Winter	Trace metals in the food web (µg/100g)	1.766	4.216	182.57	28.996	27.933
	BAF fish	0.89467724	0.77087287	0.0376294	0.06276728	0.08269788
Spring	Trace metals in the food web (µg/100g)	5.84	13.56	76.496	69.773	27.556
	BAF fish	0.172945	0.172566	0.098567	0.014476	0.042822

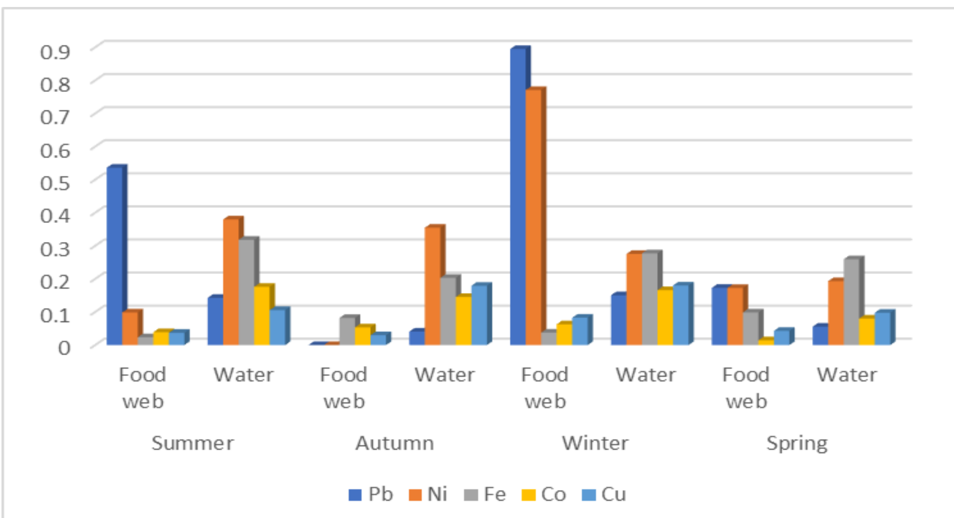

Fig.1. The accumulation of heavy metals in fish tissues concerning water and the food web during a different season.

tissues concerning seawater: Table 4 shows the accumulation of heavy metals in lizard fish tissues in referring to seawater. The highest accumulation of Pb and Cu were found in lizard fish tissues during the winter (0.15047619 and 0.180187207µg/100g), while the highest concentration of Ni, Fe, and Co (0.379591837, 0.318250377, and 0.175981873 µg/100g) were found in summer.

Bioaccumulation (BAFs) of heavy metals in fish tissues concerning the food web: The highest accumulation of Pb, Ni, Co, and Cu was found in lizard fish tissues during the winter (0.89467724, 0.77087287, 0.06276728, and 0.08269788g/100g), while the highest concentration of Fe (0.098567 g/100g) was found in spring (Table 5).

Bioaccumulation of heavy metals in fish tissue concerning the surface water and food web: The food web was responsible for the greatest accumulation of Pb and Ni, in the tissues of lizard fish during summer and winter, whereas the accumulation of other heavy metals (Fe, Co, and Cu) was caused by metal accumulation in the water

(Fig. 1).

DISCUSSION

Fishes are important part of the human diet because of their high nutritional quality (Roesijiadi et al. 1994). Since fish are at the top of the aquatic food chain, they often consume heavy metals along with other substances such as water, sediment, and food (Rainbow 2002). Toxic heavy metals present in fish can reduce their beneficial effects; heavy metals have long been known to have some negative effects on human health (Liu et al. 2019). Through direct water consumption, organismal consumption, or absorption processes, heavy metals can enter the food chain and can accumulate in the edible portion of fish (Paquin et al. 2003). Fish live in various tropic levels, therefore they are excellent markers of heavy metal toxicity in aquatic systems (Burger et al. 2002). Fish intake of heavy metals in a polluted aquatic environment varies depending on ecological requirements. Consumption of contaminated fish by humans has both immediate and long-term effects (Gale et al. 2004). The type of metal, its biological function, and the organisms exposed to it determine the level of toxic effects. These heavy metals affect the entire food chain, especially fish, after entering the food chain from primary producers (Lokhande et al., 2011).

According to the current study, the concentrations of Fe and Pb in surface waters were higher in all seasons. The concentration of heavy metals in various food webs showed that Fe and Pb were higher in fish, and Cu higher in fish, and shrimp, while squid had the highest concentration of Co. The highest concentration of heavy metals was in the tissues of lizard fishes in the summer for Pb, Ni, Fe, and Co, while the concentration of Cu was higher in the Autumn. The findings also indicated that heavy metal in greater lizard fish tissues from Iraqi marine water were relatively low and would be safe to consume by human (WHO 1996). Non-essential metals (Pb) are the most hazardous because regular exposure to its low concentrations in marine organisms can cause bioaccumulation and subsequent transfer to humans through the food chain. Fe content was higher than that of other metals, which could be explained by the fact that these necessary elements are needed for a variety of physiological and metabolic processes in daily activities (Vu et al. 2017).

The greater lizard, *S. tumbil* is a predatory species that feeds on small fish, shrimp, and squid. According to studies, carnivorous fish, which are at higher trophic levels, accumulate more heavy metals (Weber et al. 2013; Voigt 2015). Carnivorous fish mostly consume lower trophic levels of organisms like small fish, shrimp, crustaceans, and zooplankton, and accumulate high levels of heavy metals in their bodies (Karadede et al. 2010; Bawuro et al. 2018). The bioaccumulation of heavy metals in fish is a complex process governed by both exogenous and endogenous factors (Moiseenko & Kudryavtseva 2001).

The accumulation of trace metals in tissues of greater lizardfish concerning seawater was in the order of Ni>Fe>Co>Cu>Pb, whereas concerning the food web, it was in the order of Pb>Ni>Fe>Cu>Co. Pb is classified as a toxic metal that causes chemical hazards, various food standards agencies have recommended maximum residual levels for human consumption (FAO 1983; EC 2001). High-trophic or bottom-living fish accumulated higher levels of heavy metals (Bustamante et al. 2003; Jiang et al. 2018).

This study demonstrated that the accumulation of heavy elements caused by the food web is greater than that caused by water. As a result, fish species living in the same trophic guild tend to live closer to the sediment, the higher the metal content of their bodies. Additionally, high-trophic-guild fish have a high metal content because they can accumulate metal by feeding on lower-trophic-guild fish (Jiang et al. 2003; Chouvelon et al. 2019). To predict the occurrence of metal element accumulation in food or water sourced from the environment, the ratio of the heavy metal content of fish to that of water and food was used to calculate BAFs (Lau et al. 1998; Voigt et al. 2015). The BAF values are derived from the dissolved metal concentrations in the surface water of Iraqi marine water. Cu, Co, Fe, Ni, and Pb in the water had average BAF values that did not exceed one, which suggests that it is unlikely that these minerals will bioaccumulate in the water.However, this is not significant unless the BAF is greater than one, and BAF values below one is not taken into consideration (Hao et al. 2019). Except for Pb and Ni, which were close to one, all the studied metals in the food web had average BAF values less than one, indicating that Pb and Ni were relatively easy to accumulate from the food web than other metals. These results indicate that the presence of Pb and Ni in the marine waters of Iraq may pose a threat to the majority of fish species that inhabit those waters and that this issue requires more attention. According to Dallinger & Kautzky (1985), metals may be absorbed by fish, where they may then accumulate. Fish were more at risk from the food web than water. However, it is impossible to ignore metal pollution in the water because it eventually gets absorbed by suspended matter and settles into the sediment, posing a threat to fish survival (Gambrel et al. 1991; Riedel et al. 1999). This finding demonstrates once more that feeding is a significant pathway for metal accumulation in fish.

CONCLUSION

The study showed that Pb was among the studied elements in the Iraqi marine waters that was higher than the threshold. All other examined metals had low concentrations in the food chain and surface water. Additionally, the levels of metal in fish tissues were not high. According to the BAF results, Pb in the water and food web poses a potential threat to the majority of fish species that live there, fish metal content is more a function of the food chain than of water.

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مقاله کامل

تجمع فلزات سنگین در بافت و شبکه غذایی ماهی کیجار بزرگ *Saurida tumbil* در آب‌های دریایی عراق

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چکیده: برای مطالعه تجمع زیستی فلزات نادر در کیجار بزرگ، *Saurida tumbil* در آب‌های دریایی عراق، ماهی‌ها به‌صورت ماهانه از ماه می ۲۰۲۱ تا آوریل ۲۰۲۲ جمع‌آوری شدند. فلزات سنگین سرب، نیکل، آهن، کبالت و مس در آب سطحی، شبکه غذایی و بافت ماهی مورد تحلیل قرار گرفتند. غذای ماهی *S. tumbil* شامل ماهی، سخت‌پوستان و ماهی مرکب بود. غلظت سرب و آهن در آب سطحی در طول سال بالا بود و دامنه آن‌ها به‌ترتیب بین ۲/۸۳±۱۰/۵ تا ۳/۶۹±۱۹/۹۸ و ۲/۹۹±۲۴/۷۷ تا ۲/۶۷±۲۹/۰۸ میکروگرم در لیتر متغیر بود. غلظت فلزات سنگین در شبکه‌های غذایی نشان داد که آهن و سرب در ماهی، مس در ماهی و میگو و Co در ماهی مرکب بیشتر بود. بیشترین غلظت فلزات سنگین (سرب، نیکل، آهن، کبالت و مس) در بافت ماهی کیجار بزرگ در تابستان مشاهده شد. شبکه غذایی عامل بالابودن تجمع سرب و نیکل در طول تابستان و زمستان در بافت ماهی کیجار بزرگ بود، در حالی که آب دریا عامل تجمع سایر فلزات کمیاب (آهن، کبالت و مس) بود. تجمع فلزات سنگین در بافت‌های ماهی کیجار بزرگ از نظر از دریا به‌ترتیب به‌صورت Ni>Fe>Co>Cu>Pb و از نظر شبکه غذایی به‌ترتیب Pb>Ni>Fe>Cu>Co ثبت شد. نتایج نشان داد که آب دریا عامل تجمع نیکل و آهن در بافت‌های و شبکه غذایی عامل تجمع سرب و نیکل در ماهی کیجار بزرگ است. بسته به ماده معدنی، از غلظت فلزات در غذا یا آب می‌توان برای پیش‌بینی غلظت فلز در بافت ماهی استفاده کرد.

کلمات‌کلیدی: تجمع زیستی، شبکه غذایی، ماهی کیجار بزرگ، فلزات سنگین.