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ORIGINAL RESEARCH PAPER

Land use variation impacts on trace elements in the tissues and health risks of a commercial fish

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ABSTRACT

BACKGROUND AND OBJECTIVES: Tropical coastal ecosystems globally have been affected by land use changes. This condition has caused a discharge of pollutants into the water, affecting marine organisms, including fish. Due to their habitat preferences, fish are prone to elevate heavy metals in their tissue. Considering fish is consumable, heavy metal levels in fish can lead to health risks. One of the common edible fish in Southeast Asia is Pennahia argentata. Although widely consumed, there is limited information on how land use influences heavy metal levels in various tissues of this species and its health risk. Fish is one of the main food sources in this region, indicating this information's importance. This study aims to elaborate on and differentiate the heavy metal levels in tissues and land use types, including settlement and mangrove areas on the West Java coast of Indonesia.
METHODS: Locations of this study are the Jakarta coast representing anthropogenic influences in the form of settlements and the Subang coast as a site of mangrove covers. This study combined remote sensing and Geographic Information System analysis with heavy metal analysis using inductively coupled plasma and studied heavy metals, including cadmium, copper, and zinc, in fish tissues such as the gill, digestive tract, and muscle. Differences and correlation of heavy metal data in each tissue and location were statistically analyzed using Pearson correlation values (r), Analysis of Variance, and x2-test. The estimated Daily Intake was used to determine the health risk consumption of this species.
FINDINGS: All levels of heavy metals are below the World Health Organization's permissible limits. Zinc is consistently high in all tissues and locations, while cadmium is the lowest. The result shows that the digestive tract consistently has the highest heavy metal levels compared to other tissues in both locations. Heavy metal in muscle has the lowest level. Copper and zinc in the muscles of fish living on the settlement coasts were 62.69% and 37.18% higher ($P < 0.05$) than fish inhabiting mangrove coasts.
CONCLUSION: Trace elements in the commercial fish P. argentata were significantly affected by differences in land use. Variations in land use have elevated heavy metal levels in fish tissues. Given the high levels of heavy metals, the digestive tract can be chosen as a specific fish tissue to be used as a bioindicator to monitor cadmium, copper, and zinc, particularly on the West Java coast in Indonesia. Because the Estimated Daily Intake for zinc in Jakarta is high, consuming fish should be done with caution.

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75

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4

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INTRODUCTION

Southeast Asia is well known for having lucrative tropical coastlines with a major diversity of fish. Genus *Pennahia* of Sciaenidae (Huang *et al*., 2022) is among the most abundant commercial species in Asian water. Silver croaker or scientifically known as *Pennahia argentata* (Houttuyn, 1782) (Wang *et al*., 2018), is considered a high economic-value fish species (Yamaguchi *et al*., 2006). Fish consumption per capita in Indonesia is estimated to increase in 2024, 2025, 2026, 2027, and 2029. Among those fish species, *P. argentata* is one important commercial fish in Indonesia's coastal water (Alfian *et al*., 2020). This species is accounted for 3.36% of fish caught in Malela waters, Awangpone subdistrict, Bone district, Indonesia, equal to 10.42 kg (Patangngari *et al*., 2022). *P. argentata* was also inhabiting coastal ecosystems on Java island (Murhandini *et al*., 2022). A recent study by Takarina *et al*. (2022) confirmed that *P. argentata* individuals dominated the fish community, particularly in West Java coastal waters. Kirab *et al*. (2021) recorded that abundances of *P. argentata* accounted for 1557.3 kilograms per square kilometer (kg/km^2). According to Partasasmita *et al*. (2015), the West Java coast's coastal ecosystems are known to have a high fish species population, including families of Arridae (*Netuma thalassina*), Bothidae, Clupeidae, Haemulidae, Leiognathidae (*Leiognathus* spp.), Nemipteridae (*Nemipterus hexodon*), Plotosidae, Sciaenidae (*Pennahia* spp.), and Synodontidae (*Saurida tumbil*). Despite growing research on *Pennahia argentata*, the information about heavy metal levels in this species is still very limited. Coastal ecosystems are subjected to several anthropogenic activities. Anthropogenic disturbances caused by some activities, such as agriculture (Nuryanto *et al*., 2021), massive urbanization, and mangrove deforestation (Fabinyi *et al*., 2022), may contribute to the increasing levels of heavy metals. Because of anthropogenic activities in the coastal ecosystems that discharge heavy metals to the ecosystems, several commercial fish species have been reported to contain metals in their tissues. In Bangladesh on the Meghna coast (Ahmed *et al*., 2019), the edible tissues of *Aila coila, Clupisoma garua*, *Latis calcarifer*, *Otolithoides pama*, *Planiliza subviridis*, *Rhinomugil corsula, Silonia silondia*, and *Tenulosa ilisa* were known containing arsenic (As), cadmium (Cd), copper (Cu), chromium (Cr), and lead (Pb). *Johnius belangeri* and *Arius thalassinus* species in coastal waters of Kapar and Mersing, Malaysia, were reported to have high Zn with ranges of 13.12–739.6 µg/g (Bashir *et al*., 2013). Salam *et al*. (2019) reported that the consumed fish species in Tok Bali Port, Kelantan coast, Malaysia contained heavy metals (Zn, Pb, Ferro (Fe), Cd, and Cu) with an order of rarely consumed species according to the heavy metal accumulation is as follows *Descapterus macrosoma* < *Pampus argenteus* < *Leiognathus daura* < *Euthynnus affinis* for Cd and Pb, *Pampus argenteus* < *Descapterus macrosoma* < *Euthynnus affinis* < *Leiognathus daura* for Fe, *Leiognathus daura* < *Descapterus macrosoma* < *Pampus argenteus* < *Euthynnus affinis* for Cu, *Pampus argenteus* < *Descapterus macrosoma* < *Euthynnus affinis* < *Leiognathus daura* for Zn. Heavy metal levels were also reported in commercial fish on Indonesian coasts. In Barito and Donan coasts, Indonesia, several commercial fish contain metals. Cahyani *et al*. (2016) reported the Cd and Cu for edible *Silago sihama* were 0.56 and 1.39 miligram per kilogram (mg/kg), respectively, in Donan. On the Barito coast, the Cu levels for *Leiognathus brevirostris*, *Ophiocephalus striatus*, and *Rastrelliger kanagurta* were 0.01 mg/kg, 0.03 mg/kg, and 0.05 mg/kg. While the Cd levels were 0.03 mg/kg, 0.01 mg/kg, and 0.07 mg/kg (Dwiyitno *et al*., 2008). Despite Indonesia's coasts being enriched with fish resources, those coasts are recently threatened by the presence of land use conversion, and anthropogenic influences from intact mangrove forests converted to human settlements. In Indonesia, comprehensive studies of the heavy metal levels in fish species related to changes in coastal land uses are still lacking. At the same time, this information is needed as fish have commercial value and are consumed by nearby communities. According to Handayani *et al*. (2017), the West Java coast is disturbed by population density and anthropogenic activities that have caused land use changes and led to the fish community assemblages. Currently, the West Java coast has a population of 35 million, and this population keeps increasing. As a result, the West Java coast now has the second-largest urban population in the world (Octifanny and Hudalah, 2017) and can pose a significant threat to coastal fish resources. This condition has been confirmed by Takarina *et al*. (2022) that the numbers of fish species found at the threatened site, dominated by settlements, were lower than those at the intact site, dominated by mangroves. More fish species are discovered at the intact location with Shannon-Wiener index (H’) values of 2.17. The average fish species diversity, denoted as H’ index, decreased by 53.91% from 2.17 in intact site (95% confidence interval [CI]: 1.15–3.19) to as low as one disturbed site (95% CI: 0.018–1.98) as a consequence of anthropogenic activities and presences of settlements. Since anthropogenic activities along with settlements will discharge heavy metals then, this study attempts to address the following questions, are there any variations in the heavy metal levels in commercial fish species between coast variations ranging from settlements and mangroves? If there is a difference, what fish tissue contains the heaviest metals? The results of this study can contribute significantly to prioritizing which land should be managed due to the heavy metal contamination in fish. The specific information on which tissue contains the heaviest metals will also significantly reduce the health risk (Ahmed *et al*., 2019) due to consuming contaminated fish by coastal communities nearby. The novel aspect of this study is the development and correlation of land use changes with the magnitudes of heavy metals in fish, as well as the potential health risks of consuming these contaminated fish. This identification of land use changes and heavy metal links will contribute significantly to pollution management and heavy metal monitoring. The current study aims to elaborate and differentiate the heavy metal levels in tissues and land use types, including settlement and mangrove areas on the West Java coast of Indonesia. This study aims to assess and compare the levels of the heavy metal, including Cd, Cu, and Zn, in gills, digestive tracts, and muscles of commercial fish *Pennahia argentata* (Houttuyn, 1782) inland uses dominated by settlements and mangroves in West Java coast on 2022.

MATERIALS AND METHODS

Study area

The study area was in West Java coastal areas, Indonesia, which consists of two locations, including Jakarta in the west and Subang in the eastern parts of the West Java coast. These sites were chosen as the research areas representing land uses dominated by settlement and mangrove covers (Fig. 1). The determinations of those locations were based on literature reviews, field observations, and satellite image classification using geographical information system (GIS) analyses. The settlement location was part of Jakarta city, with a geographical location between 6.103° and 6.108° (SL) south latitude and 106.773° and 106.779°(EL) east longitude. Due to the conversion of the natural mangrove vegetation into settlements, the settlement site is recognized by the absence of natural cover, particularly mangrove forests. Driven by high population and economic growth, Jakarta has had massive residential developments (Suliman *et al*., 2022). As a result, settlement (Franjaya *et al*., 2017) has disturbed the intact mangrove forest cover in Jakarta, decreasing mangrove areas from 1998 to 2018 by up to 393 hectares (Fig. 2) (Rizal and Haykal, 2021). Traditional fishermen continue to use the water off the shore to catch some fish species despite these significant anthropogenic impacts. The mangrove land use locations followed the previous research location (Takarina *et al*., 2022). The mangrove site was in the Subang district, with coordinates of 6.241°SL and 107.667° EL. Site land uses are characterized by a matrix of fish ponds with intact mangrove forests and reforested mangroves. Lucrative mangrove covers previously characterized this site. Even though those intact mangroves were experiencing deforestation and transformed into fishponds. However, led by fishermen and community awareness, the threatened mangrove forest has been rehabilitated through mangrove plantings. As a result, now there were mangrove covers combined with fishponds. The surrounding water near the coast is known to have various fish species of commercial value that are edible or can be used as a food commodity.

Fish survey and collection

Fish survey procedures were followed and adapted from previous studies (Takarina *et al*., 2022) with additional references from Agustriani *et al*. (2020) and Araújo *et al*. (2006). The survey was conducted in the morning from 8.00 am to 2.00 pm. Gillnet, with a mesh size of 2 inches, was used to capture fish. The collected fish were preserved using ten percent (%) formaldehyde. The morphological character using the identification key provided in the guidebook of fish identification was performed to identify fish species (Kottelat and Whitten, 1993). The collected fish were adult fish with body lengths measuring more than 10 cm since adult fish contain trace elements.

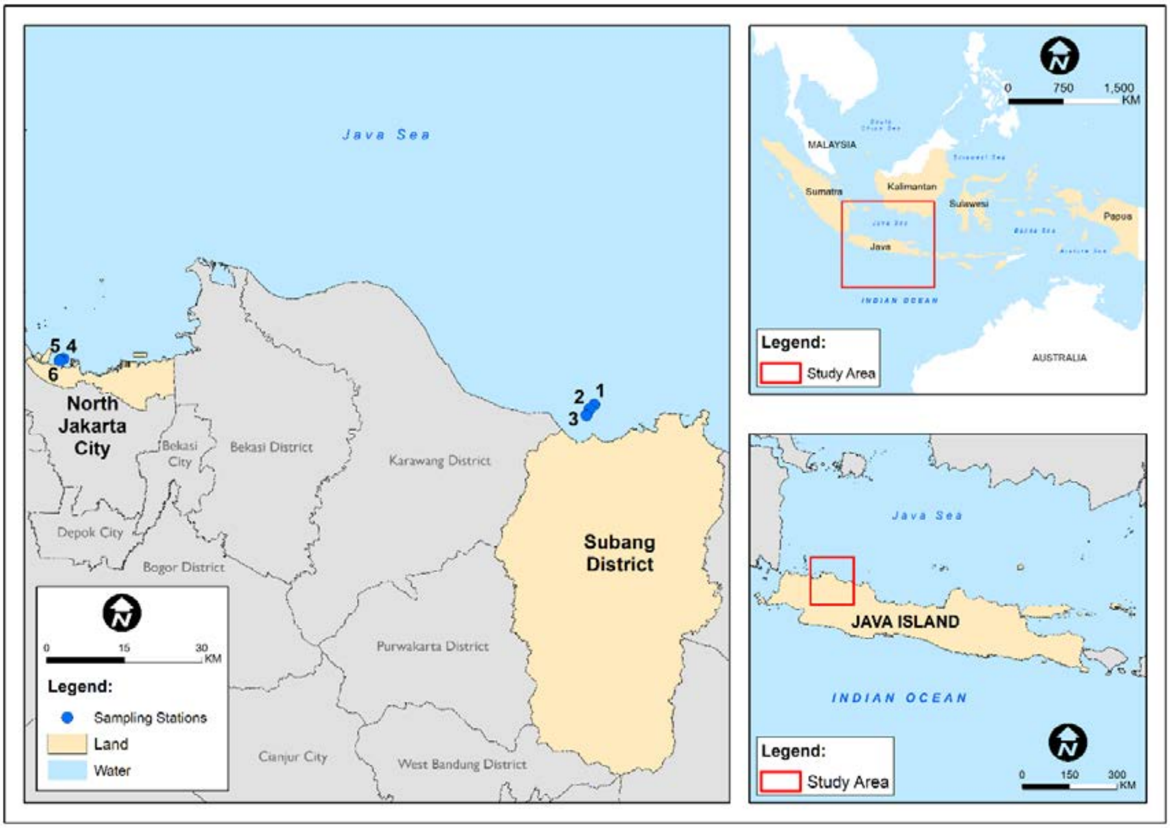

Fig. 1: Geographic location of the study area in Indonesia's West Java coast, with Subang district in the east and Jakarta city in the west dominating settlements and mangroves, respectively

Fish tissue heavy metal preparation and measurements

In each location, ten individuals of silver croakers were collected. The silver croaker samples were primarily retained in the zip-locked acid-washed polyethylene bags at −20°C to prevent deterioration and finally delivered to the laboratory for further heavy metal analysis processing. Surgical equipment was used to dissect each fish sample in the laboratory (Lakshamanasentil *et al*., 2012; Enuneku *et al*., 2018). The silver croaker's gills, digestive tract, and muscles were placed on sterile aluminum foil. Samples of silver croaker were then dried at 60 °C to eliminate water content until they had totally dried. After drying, the sample was finely powdered in a mortar. In a Teflon beaker containing 0.05g homogenized sample, 1.5 milliliter (mL) of Suprapur 65% nitric acid (HNO_3) was added to transform organometallic into an inorganic form. The sample in all Teflon bombs was heated in the oven digestive at 100°C for 8 hour (h). The sample was left to rest before the acid-digested solution was transferred into separate centrifuge tubes. Mili Q water was added until a volume of 10 ml was obtained (Poong *et al*., 2020). The resulting filtrate was submitted to inductively coupled plasma (ICP) (Nurhasanah *et al*., 2023) using a standard diluted sample solution for Cd, Cu, and Zn analyses. For each set of experiments blanks, samples were run, along with certified reference materials (CRMs), and corrections were applied where necessary. Each fish sample was examined in triplicate, and only average results were reported. The wavelengths used for the detection and measurement were as follows: Cd 214.440, Cu 324.752, and Zn 213.857 nm. The permissible limits for Cd, Cu, and Zn follow the threshold provided by WHO (Abdel-Baki *et al*., 2011).

Physico-chemical parameters measurements

Physico-chemical parameters such as the potential of hydrogen (pH), salinity, and dissolved oxygen (DO) were recorded in situ. Each parameter was noted with three replications for each sampling location. The equipment used to measure the variables was a Lutron DO meter 5510 for DO value, a Lutron pH meter 5510 for pH, and an Atago refractometer for salinity, respectively.

Data analysis

Coastal land uses

The classification of land use changes in coastal areas representing settlement and mangrove land uses was done using GIS. Image captured using Landsat eight was then supervised and reacquired to obtain the type of land use. The categories for coastal land use classifications were mangrove and fishpond, water and sea, settlement, and mangrove. Then, the compositions of each lad use type were denoted as a percentage.

Health risk assessments

The estimated daily intake (E) of metals was estimated using Eq. 1 (Zhao *et al*., 2012).

$$E = \frac{metal\,levels\; x\; consumption\,rate}{body\,weight} \quad (1)$$

Where,

Metal levels: measured in mg/kg; Body weight: body weight was estimated to be 55.9 kg for adults and 32.7 kg for children; Consumption rate: consumption rate was assumed to be 93 g/day kg for adults and 50 g/day for children; E: estimated daily intake in µg/kg/day

Statistical analysis

Statistical analysis in this study consists of Pearson correlation values (r), analysis of variance (ANOVA), and x^2-test. Pearson test was used to assess the inter-heavy metal correlations in gill, muscle, and digestive tract tissue. ANOVA was used to test the differences in heavy metal levels between locations and tissues. While the x^2-test was utilized to examine the differences in land use compositions. Data were visualized using GIS-based thematic maps and jittered box plots.

RESULTS AND DISCUSSION

Coastal land uses

One important data collected during this research is the land use characteristics, which significantly influence heavy metal concentrations in fish inhabiting coastal habitats. According to the statistical findings, a significant difference in the compositions of land uses was discovered (x^2 = 23.532, P < 0.05). The order of coastal land use in the Jakarta site was settlement > water, as can be seen in Fig. 2. From 1998 to 2018, there were land use changes due to deforestation that caused land use conversion from intact mangrove forest to fishponds and settlements, as can be seen in Jakarta. There were six locations in Jakarta where land uses changes and deforestation occurred (Fig. 2). In contrast; settlements were rarely found at the Subang. At the Subang site, the order of land use was mangrove within fishponds > intact mangroves > water.

Heavy metal levels in P. argentata

Heavy metal levels in *P. argentata* in various tissues between varied land uses are available in Fig. 3. The general patterns were Cd, Cu, and Zn were more common in digestive tracts compared to muscle and gills. The heavy metal level orders for Cd, Cu, and Zn were digestive tracts > gills > muscles. For Cd, the heavy metal levels, particularly in gill tissues in settlement sites, were higher than in gill tissues in mangrove dominance sites. While Cd levels in mangrove dominance sites were higher than in settlement sites. For Cu and Zn levels, the heavy metal level orders were digestive tracts > gills > muscles for both settlement and mangrove dominance sites. For particular Zn levels, Zn in gill was considered dominant next to the digestive tract. Cu and Zn levels were observed to be higher in all tissues in Jakarta than in Subang, as can be seen in Fig. 4. This indicates land use changes increase both the Cu and Zn levels. The highest increase in heavy metal levels was observed for Cu for muscle tissues. The changes of mangroves to the settlement have increased Cu in the muscle up to 62.69%. For Cu, heavy metals were observed to be very high in samples from Jakarta in the digestive tract, equaling 74.42 ppb. Changes in mangrove forest settlement will significantly increase the Zn in muscle (P = 0.012) to 37.18%. For Zn, heavy metals were observed to be very high in samples from Jakarta in gill, equaling 751.53 ppb (Table 1).

Intercorrelations of all trace elements in the gill, digestive tract, and muscle are available in Fig. 5 for Jakarta sites and Fig. 6 for Subang sites. Regarding the correlation (Pearson correlation) values (r), it is obvious that there is a significant positive correlation

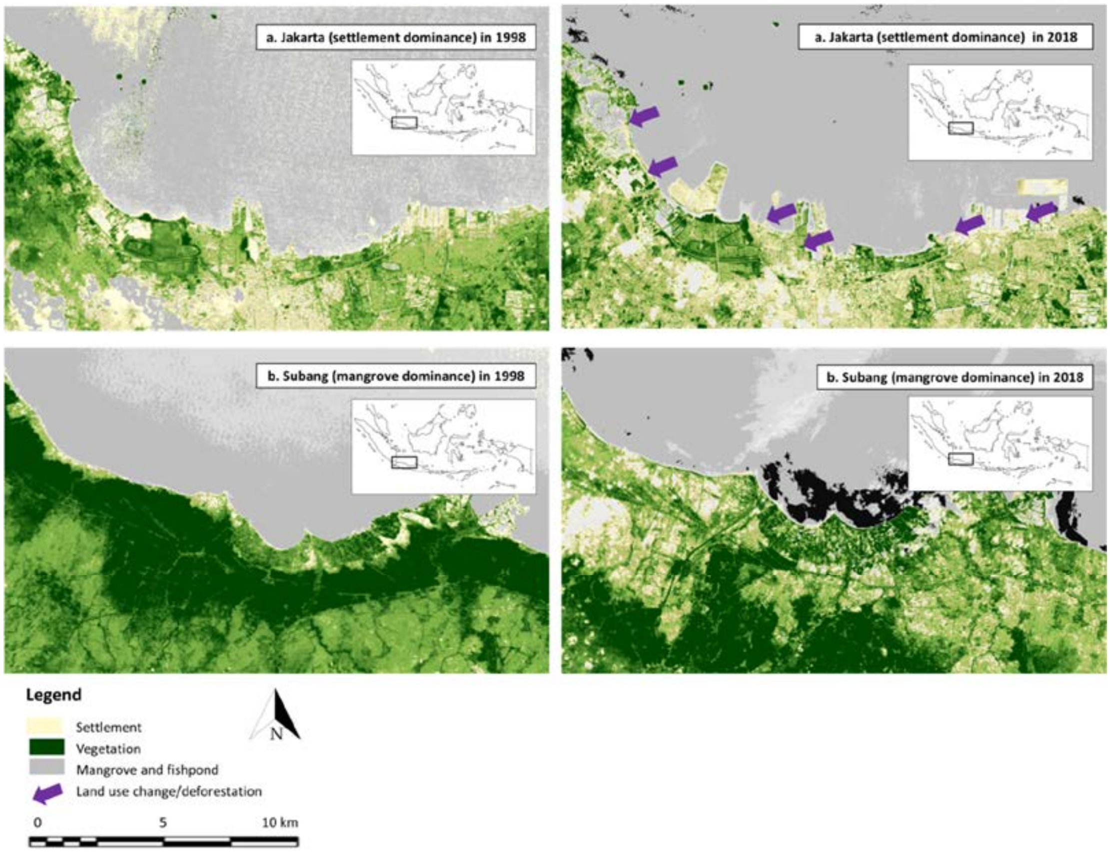

Fig. 2: Land use changes from 1998 to 2018 as indicated by arrows in Jakarta city in the west (settlement dominance) and Subang district in the east (mangrove dominance) on the West Java coast, Indonesia

between the trace elements found in the same tissues in Jakarta. The highest correlation was observed for the Cd concentration with the Cu in the digestive tracts (r = 0.87). The second significant correlation was observed for the Cd concentration with the Cu in the gills (r = 0.83). The relationships between inter-metal levels in various tissues were quite different, as observed in the Subang site. In this site with mangrove dominance, the highest inter-metal levels correlation was observed for the Cu concentration with the Zn concentration in the gills (r = 0.87). In Subang, there was an inter-metal levels correlation involving different tissues. Here, the Cd concentration in the muscle was correlated with the Zn concentration in the digestive tract (r = 0.82). Compared to mangrove dominance sites, coastal areas of Jakarta dominated by settlements had lower pH or acidic water (Table 2). The coastal waters of Jakarta were characterized by freshwater rather than high salinity.

Heavy metal estimated daily intake in consuming P. argentata muscle

Estimated daily intake (EDI) was performed only for muscle tissue and excluded the gill and digestive tract since those excluded tissues were not consumed. Gill and digestive tracts are usually not consumed and discarded. Heavy metal EDI as a consequence of consuming *P. argentata* muscle is available in Table 3. EDI was not significant for Cd levels since the EDI value was very small if the muscle of *P. argentata* was consumed. A high EDI value for Cu was observed for *P. argentata* muscle consumption from Jakarta. A similar result was also observed for Zn. The highest EDI for Zn was also observed for *P. argentata* muscle consumption from Jakarta.

Most recent studies (Powell *et al*., 2016) have

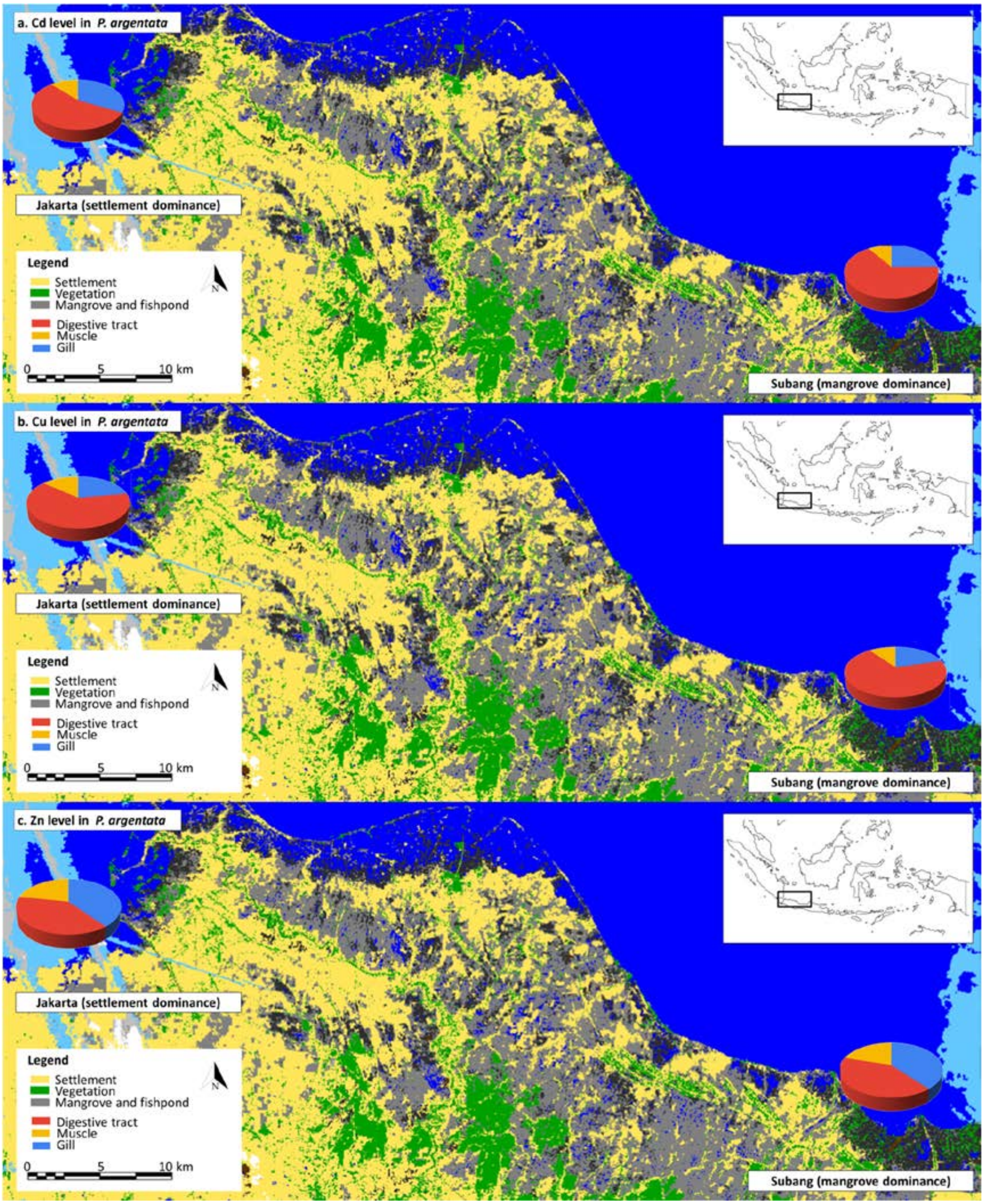

Fig. 3: Cd (a), Cu (b), and Zn (c) level compositions (pie charts) in gills, digestive tracts, and muscles of *P. argentata* related to land uses in Jakarta in the west (settlement dominance) and Subang in the east (mangrove dominance) in West Java coast, Indonesia

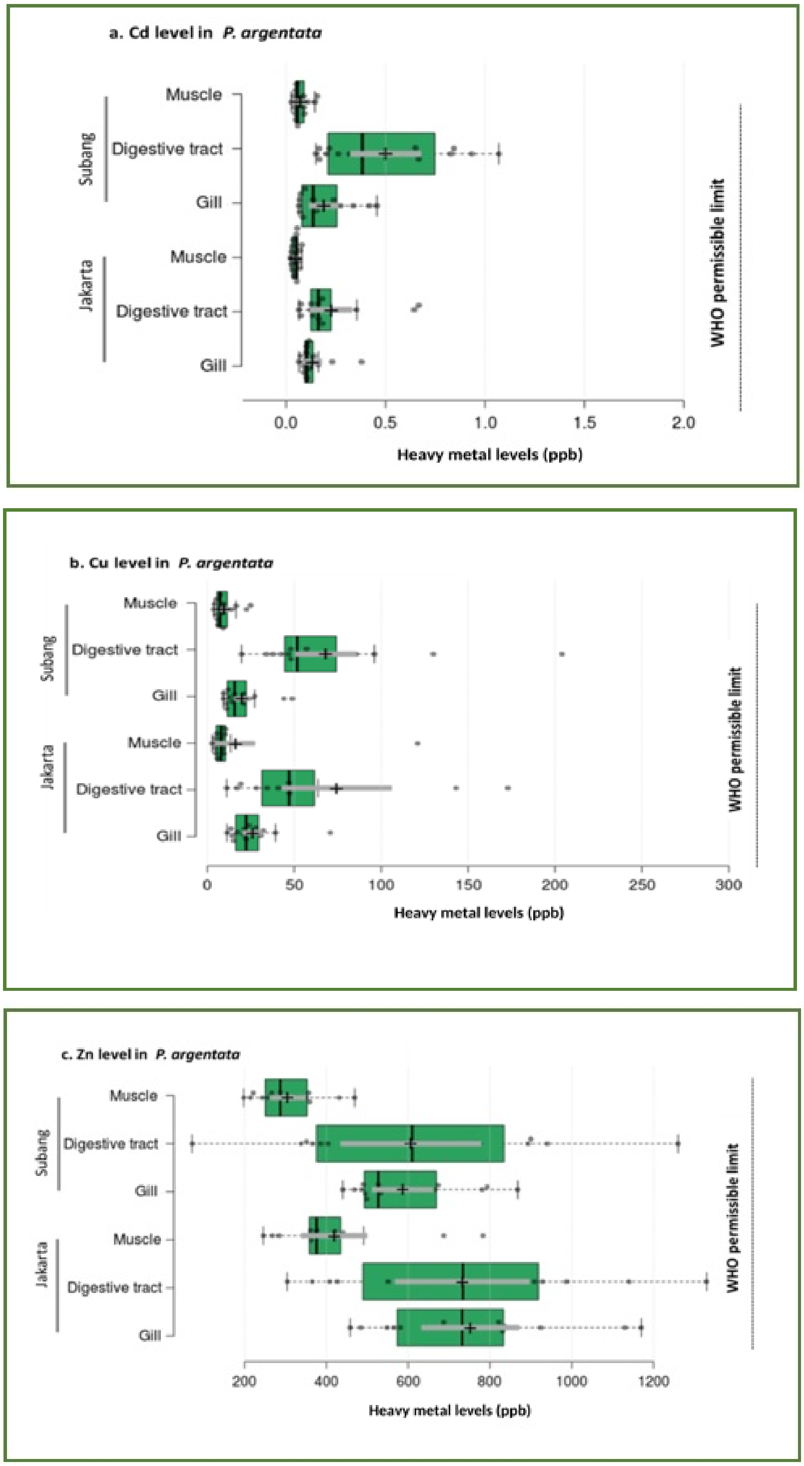

Fig. 4: Cd (a), Cu (b), and Zn (c) levels (ppb) in gills, digestive tracts, and muscle of *P. argentata* related to land use in Jakarta in the west (settlement dominance) and Subang in the east (mangrove dominance) in West Java coast, Indonesia with WHO permissible limit for Cd equals 3.0 ppb, for Cu equals 1000.0 ppb, and 100,000 ppb for Zn (Abdel-Baki *et al.,* 2011)

Table 1: Summary of the Cd, Cu, and Zn mean ± standard deviation (SD) (ppb) and ANOVA in gills, digestive tracts, and muscle *of P. argentata* related to land uses in Jakarta in the west (settlement dominance) and Subang in the east (mangrove dominance) in West Java coast, Indonesia

Heavy metals	Tissues	Mean (ppb) ± SD Jakarta (settlement dominance)	Mean (ppb) ± SD Subang (mangrove dominance)	Changes (%)	F	P
Cd	Muscle	0.04 ± 0.01	0.07 ± 0.03	0.57	5.928	0.021
	Digestive tract	0.22 ± 0.18	0.50 ± 0.31	99.99	8.229	0.007
	Gill	0.13 ± 0.07	0.18 ± 0.13	41.49	1.945	0.174
Cu	Muscle	16.10 ± 29.53	9.89 ± 6.57	62.69	0.631	0.433
	Digestive tract	74.42 ± 84.33	68 ± 46.52	9.44	0.066	0.798
	Gill	25.90 ± 14.65	20.01 ± 12.08	29.42	1.441	0.239
Zn	Muscle	419.06 ± 145.36	305.46 ± 78.36	37.18	7.097	0.012
	Digestive tract	732.26 ± 297.18	606.70 ± 310.04	20.69	1.282	0.267
	Gill	751.53 ± 214.38	586.8 ± 135.11	28.07	6.338	0.017

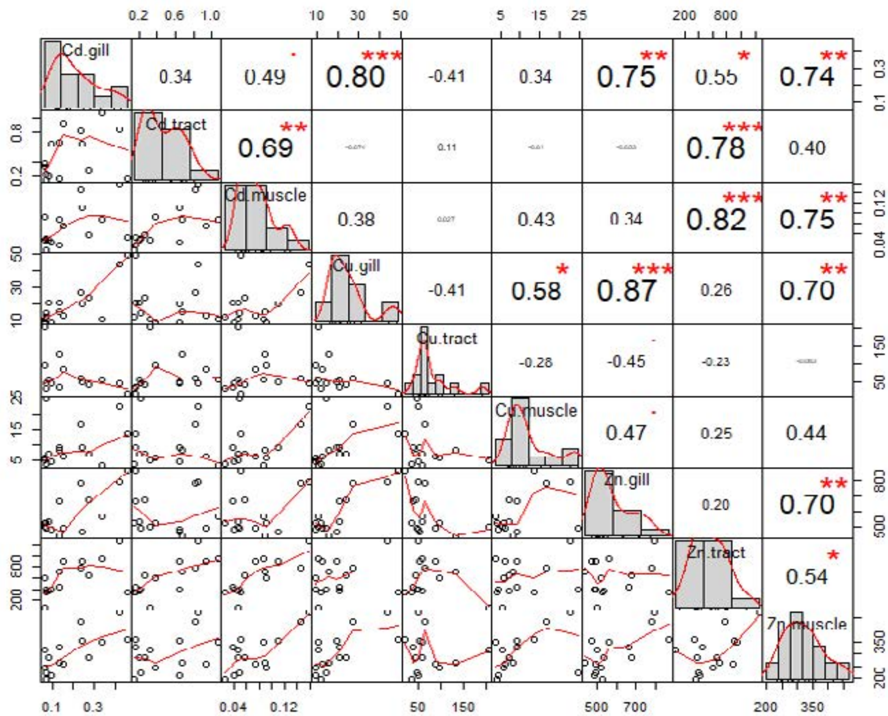

Fig. 5: Relationships between inter-metal levels (Cd, Cu, Zn) in various tissues (gill, digestive tract, muscle) in Jakarta site (***: significant at P < 0.05)

highlighted the inverse impacts of urban land use (Tóth *et al*., 2019), mangrove cover removals (Hutchison *et al*., 2014; Rogers and Mumby, 2019), land cover changes (Alam *et al*., 2021), and anthropogenic disturbances on fish community and habitat degradation (Hall-Spencer and Harvey, 2019) worldwide (Lacarella *et al.,* 2018) that include as far as Antarctic Sea (Stark *et al*., 2014), Baltic sea (Smoliński and Radtke, 2017). African continents (Britton *et al*., 2019; Castello *et al*., 2022), subtropical continents (Li

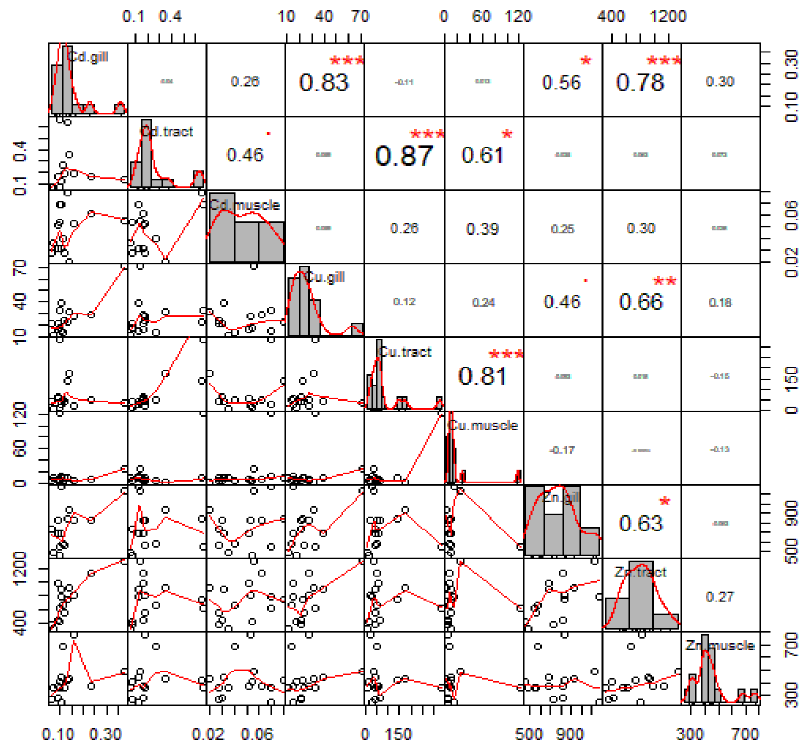

Fig. 6: Relationships between inter-metal levels (Cd, Cu, Zn) in various tissues (gill, digestive tract, muscle) in Subang site (***: significant at P < 0.05)

et al., 2018), and also tropical regions (Lo *et al*., 2020) from South America (Palacios-Sánchez *et al*., 2019; Méndez, 2021) include Brazil (Tibúrcio *et al*., 2016) to Asia. In the Asian Continent, Bella *et al.* (2021) reported impacts of land use changes in India's Western Coast, Chen *et al*. (2022) reported impacts of land use changes in Taiwan, in the China Sea (Qiao *et al*., 2022) including vast South China Sea (Rumeaida *et al*., 2014). In particular South Asian waters (Nuon *et al*., 2020) reported land use impacts on fish in the Mekong River basin in Sabah, Malaysia (Wilkinson *et al*., 2018), and Thailand waters Phinrub *et al.* (2014). In Indonesia, impacts of land use changes on the fish community have been reported in various areas, from Kalimantan waters (Haryono, 2020), to Banten (Mujiyanto *et al*., 2021; Sugiarti *et al*., 2021). Despite the rapidly growing research, there is still a scarcity of information on how land use changes can contribute to the magnitudes of contamination in the water that affect the fish community; here, this study has elaborated the impacts of coastal land use changes from intact mangrove to settlement in elevating the trace elements levels in fish tissues. From the results, it is obvious that trace elements in fish inhabiting Jakarta were consistently higher than trace elements contained in fish living in Subang. This indicates the differences in land uses that contribute to the transport of trace elements from land to coastal waters. Trace elements were elevated in the fish tissue due to the adsorption of heavy metals by fish accumulated in the sediments. High sediment rates in coastal waters are related to the upstream conditions. Massive conversion of vegetated areas from intact forests to settlements will increase the sediment discharge along with trace elements into the coastal waters and adsorbed by the fish. Then the levels of heavy metal in fish could be due to land-based discharges and surface run-off, which could have brought higher nutrients and chemicals to the surface waters that have become a major niche

Table 2: Summary of the physico-chemical parameters (DO, pH, salinity) mean ± standard deviation (SD) in Jakarta in the west (settlement dominance) and Subang in the east (mangrove dominance) on the West Java coast Indonesia

Physico-chemical parameters	Mean ± SD		F	P
	Jakarta (settlement dominance)	Subang (mangrove dominance)		
DO	19 ± 1.47	6.32 ± 0.12	220.516	0.000
pH	6.98 ± 0.20	7.7 ± 0.1	29.337	0.005
Salinity	24 ± 10.14	35.5 ± 0.00	3.851	0.121

Table 3: Summary of estimated *P. argentata* muscle daily intake (µg/kg/day) for Cd, Cu, and Zn related to land uses in Jakarta in the west (settlement dominance) and Subang in the east (mangrove dominance) in West Java coast, Indonesia

Heavy metals	Person	Estimated *P. argentata* muscle daily intake (µg/kg/day)	
		Jakarta (settlement dominance)	Subang (mangrove dominance)
Cd	Children	<0.01	<0.01
	Adult	<0.01	<0.01
Cu	Children	0.02	0.01
	Adult	0.03	0.02
Zn	Children	0.64	0.46
	Adult	0.69	0.50

Table 4: Summary of recent literature on heavy metals in *Pennahia*

Heavy metals	Tissue	Value	Location	References
Cu	Muscle	1.33 ± 0.01	Kapar coast, Malaysia	Bashir *et al*., 2015
	Gills	2.89 ± 0.03		
Cd	Muscle	0.03 ± 0.01		
	Gills	0.16 ± 0.01		
Zn	Muscle	20.62 ± 1.3		
	Gills	115.7 ± 5.5		
Cd	Muscle	0.02 ± 0.3	Mersing coast, Malaysia	Fathi, 2014
	Gills	0.05 ± 0.01		
Zn	Muscle	18.1 ± 0.79		
	Gills	66.24 ± 1.30		

habitat for fish (Yap and Al-Mutairi, 2022). *Pennahia argentata* is a benthopelagic species preferring muddy bottom. Its microhabitat explains that this fish is prone to trace elements usually accumulated in the sediments. Benthic fish are thought to have higher heavy metal concentrations than fish in the upper water column because they are in direct touch with the sediments and take in more heavy metal concentrations from zoobenthic predators. The order of trace elements in fish muscle in both sites was Zn > Cu > Cd. This trace element order is compared to the previous study (Table 4) in comparable South East Asian coasts. According to Takarina *et al*. (2021), Zn is a common trace element recorded in commercial fish on the West Java coast. In both sites, digestive tracts are the tissues that always consistently have higher heavy metal levels compared to other tissues. Heavy metals observed in digestive tracts range from titanium (Ti), vanadium (V), Cr, manganese (Mn), Fe, cobalt (Co), nickel (Ni), Cu, Zn, As, selenium (Se), bromine (Br), strontium (Sr) and Pb (Dane and Şisman, 2019). In this study, Cd, Cu, and Zn were detected in this tissue. Heavy metal levels in digestive tracts can have inverse effects on the health status of the fish species. These effects ranged from intestine swelling, infiltration, vacuolization, gastric degenerations, epithelial degenerations, fibrosis, congestion, fusion, and hyperplasia, which were more common in fish species inhabiting polluted sites influenced by anthropogenic activities. Gill is the second tissue with high heavy metal levels for all trace elements in both sites. According to Gu *et al*. (2017), heavy metal tends to be higher in gills than in other tissues. The principal site for heavy metal uptake is in the gills, which are the first target of waterborne pollutants and are extremely susceptible to heavy metal buildup because of constant exposure to the outside environment. Heavy metal accumulation in gill tissues is caused by heavy metal absorption through the gill surface, which is sometimes difficult to remove. The maximum buildup of heavy metals occurs due to the gill tissues' extremely branched form and water movement through them (Shah *et al*., 2020). Gills are the main mechanism for metal ion exchange from water, as their vast surface surfaces allow for the fast diffusion of hazardous metals. As a result, metals deposited in gills are thought to be primarily concentrated in water. Muscle is the only tissue in both sites that consistently has the lowest heavy metal levels for all trace elements. This discovery is supported by earlier research. According to Al-Najjar *et al*. (2016), trace elements found in muscle were consistently lower than heavy metal levels found in other tissues. *P. argentata* is a carnivore that feeds on small fish and invertebrates (Huh *et al*., 2018). The level of trace elements is connected to the feeding habits of the fish. Metal concentrations in fish muscles are often higher in herbivore fish than in carnivore fish (El-Moselhya *et al*., 2014). This explains the low amounts of heavy metals in *P. argentata* muscle, considering that *P. argentata* is carnivore fish (Koh *et al*., 2014). Heavy metal uptakes in fish were also related to the physicochemical parameters of water. Heavy metals in fish in settlement dominance sites were high, and at the same time, these sites were characterized by lower pH or acidic water. According to Jezierska and Witeska (2006), water acidification causes metal bioaccumulation in fish via modifying the solubility of metal compounds or directly by causing damage to the epithelia, which becomes more permeable to metals. On the other hand, the competitive uptake of H^+ ions may impede metal absorption. Besides that, the bioavailability of heavy metals was higher in waters with lower pH (Moiseenko and Gashkina, 2020).

According to this study, Cd has the lowest EDI and may pose the least risk to the community if consumed. Low EDI for Cd in fish is also reported by Djedjibegovic *et al.* (2020). High EDI was observed only for Cu and Zn in Jakarta. Because the EDI for Zn in Jakarta is high, consuming fish muscle should be done with caution. Zn, a trace element, is a common trace element that increases the risk of seafood consumption worldwide (Korkmaz *et al*., 2019). Due to consuming fish containing heavy metals, possible health risks and diseases include the risk of cancer developing over time with exposure to the chemicals at low doses (Bassey and Chukwu, 2019). Because this study confirms that heavy metal presences are linked to land use changes in coastal areas, it is strongly advised that coastal development be regulated. The conversion of intact mangrove forests to fishponds and settlements must be stopped. Besides that, it is also recommended to develop versatile bioindicators by choosing a fish species.

CONCLUSIONS

Most studies on heavy metal levels in coastal fish ignore the source and origin of heavy metals, a feature of land use. Land use changes are affected by anthropogenic activities such as agriculture, urbanization, and deforestation. This study is the first of its kind successfully describe and link the effects of different land uses on trace elements in commercial fish. In conclusion, Cu and Zn in muscle fish living along the coast near settlements were 62.69% and 37.18% higher ($P < 0.05$) than Cu and Zn in fish living on mangrove coasts. This explains the variations in land use for increasing levels of heavy metals in fish. In addition, the largest amount of Cd and Cu is found in the digestive tract, with a value of 0.22 ppb and 74.42 ppb. Meanwhile, the highest level of Zn is found in gill, with a value of 751.53 ppb in Jakarta, a densely populated coastal settlement. These results confirmed that the digestive tract consistently had the highest levels of trace elements, followed by gills and muscles, respectively. The research results prove that the digestive tract can be selected as a particular fish tissue to be used as a bioindicator for monitoring Cd, Cu, and Zn, especially on the coast of West Java, Indonesia. Based on heavy metal content and EDI calculations, Jakarta has the highest trace elements in fish. Differences in land use cause an increase in sediment discharge along the coastal waters. Zn and Cu have a greater daily intake rate than Cd at the two sampling locations. Zn metal has a very significant EDI for children and adults of 0.64 and 0.69 on the coast of Jakarta. Therefore, the consumption of fish muscle must be done with caution at the risk of considering the high Zn content, especially in Jakarta, which has the highest land use changes between the two sampling locations. As a novelty, this research has linked the associations between land use, the magnitudes of heavy metals in fish, and the potential health risks of consuming these contaminated fish. This identification of associations has made a significant contribution to environmental sciences, particularly concerning pollution management and heavy metal monitoring.

AUTHOR CONTRIBUTIONS

ND. Takarina, as the corresponding author, has contributed to funding, contributing to the proposal, and drafting the manuscript; O.M. Chuan conducted in preparation of the manuscript, reviewing proposals and data verification; T.G. Pin is the field coordinator, conducted fish sampling and helped in creating maps. I. Femnisya performed laboratory analysis for Subang fish samples and data tabulation. A. Fathinah contributed to laboratory analysis for Jakarta fish samples and data tabulation. A.N.B. Ramadhan did the Subang sample preparation and administered technical support. R. Hermawan did the Jakarta samples preparation and data tabulation. A. Adiwibowo drafted the manuscript, data analysis, and data interpretation.

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CONFLICT OF INTEREST

The author declares that there is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy, have been completely observed by the authors.

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ABBREVIATIONS

°	Degree
%	Percentage
am	Ante meridiem
ANOVA	Analysis of variance
As	Arsenic
Br	Bromine
°C	Celsius degree
Cd	Cadmium
CI	Confidence interval
Co	Cobalt
cm	centimeter
Cr	Cromium
CRMs	Certified reference materials
Cu	Copper
DO	Dissolved oxygen
EDI	Estimated daily intake
EL	East longitude
F	Means between population/ distribution
Fe	Ferro
g	Gram
g/day	Gram per day

GIS	Geographical Information System
GPS	Global positioning system
HCl	Hydrochloric acid
H'	Shannon-Wiener index
HNO_3	Nitric acid
ICP	Inductively coupled plasma
kg/km^2	Kilogram per square kilometer
mL	Milliliter
mg/kg	Miligram per kilogram
Mn	Manganese
N	North
na	Not available
NE	Not evaluated
Ni	Nickel
P	Probability / significant value
Pb	Lead
ppb	Part per billions
pH	potential of hydrogen
pm	Post meridiem
r	Pearson correlation value
SD	Standard deviation
Se	Selenium
SL	South latitude
Sr	Strontium
Ti	Titanium
V	Vanadium
WHO	World Health Organization
µg/g	Microgram per gram
µg/kg/day	Microgram per kilogram
x^2	Chi square
Zn	Zinc

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