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Species determination and heavy metal content of sailfin catfish (*Pterygoplichthys pardalis*) from Tempe Lake, South Sulawesi, Indonesia

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Abstract. *Kasmiati, Latuconsina N, Putri AA, Khasanah R, Nurfaidah, Fahrul, Syahrul, Metusalach. 2022. Species determination and heavy metal content of sailfin catfish (*Pterygoplichthys pardalis*) from Tempe Lake, South Sulawesi, Indonesia. Biodiversitas 23: 4409-4417.* Sailfin catfish is invasive alien species that has become dominant in Indonesian freshwater, including in Tempe Lake, South Sulawesi, Indonesia. Despite their abundance, these sailfin catfish are not utilized because of suspicions that they are contaminated by heavy metals that can endanger human health. The purposes of this study were to determine the sailfin catfish species present in Tempe Lake and measure the content of heavy metals Hg, Pb, and Cd in various body parts. Fish species were identified based on abdominal patterns, while heavy metal content was meaured by atomic absorption. The heaviest two body parts were the head (34.04%) and flesh (26.64%), heavy metal content detected in the liver (0.0402-0.0928 mg/kg), gut (0.0322-0.0671 mg/kg), gills (0.319-0.0865 mg/kg), dark meat (0.0268-0.0589 mg/kg), white meat (0.0221-0.0470 mg/kg), bones (0.0180-0.0519 mg/kg), and skin/scales (0.0257-0.0675 mg/kg). All of them were below the FAO/WHO 1989, US-EPA 1999, and the Indonesian National Standards. The government health and safety guidelines for fish to be safe for human consumption were Hg <0.005 mg/kg, Pb<0.10 mg/kg and Cd<0.02 mg/kg. Therefore the abundant sailfin catfish *Pterygoplichthys pardalis* in Tempe Lake could be consumed directly and as ingredients in other food products.

Keywords: Heavy metals, *Pterygoplichthys pardalis*, sailfin catfish, Tempe Lake

INTRODUCTION

The sailfin catfish species is one of the alien species living in Tempe Lake in South Sulawesi, Indonesia (Febrianti et al. 2019). Sailfin catfish is considered invasive species that compete with native species for both food and habitat (Saba et al. 2020). The sailfin catfish has come to dominate the fish population in the lake; in addition to ecosystem impacts, there has been a significant reduction in the populations of other (native) fish species, some of which are no longer found (Chaicana and Jongphadungkiet 2012). This situation has also resulted in a decrease in the income and welfare of local fishers in Tempe Lake, as 70% of the catch is dominated by sailfin catfish (Saba et al. 2020). Sailfin catfish have become dominant because, unlike most other fish species in the lake, they are not exploited either by commercial fisheries or for subsistence as a source of nutrition. In addition to its unprepossessing appearance, reasons for the lack of use of this fish include the fear that sailfin catfish in Tempe Lake may be contaminated with heavy metals. Heavy metal is one of the pollutants that can affect the quality of water and aquatic organisms that live in it. Sailfin catfish live on the substrate and eat detritus on or in the sediment; therefore, if the waters are polluted with heavy metals, they can accumulate the heavy metals present (Herawati et al. 2021). In addition to the potential for elevated heavy metal content, sailfin catfish can live and even thrive in extreme environments, such as waters with very low concentrations of dissolved oxygen, which many other organisms cannot tolerate (Rao and Sunchu 2017).

The waters of Tempe Lake are vulnerable to metal pollution, as the lake is surrounded by lands used for agriculture and plantations, industry, and residential areas, all of which produce waste, much of which ends up in the lake (Aishah and Mohamed 2022). Based on research by BLHD (2012), indications of pollution have been detected in the waters of Tempe Lake. These include changes in the temperature, pH, color, smell and taste of the water, high turbidity, as well as increases in heavy metal concentrations and radioactivity. Heavy metal inputs into Tempe Lake were confirmed by Amin and Mustafa (2000) as well as Duncan et al. (2018), with heavy metal pollution being detected in the sediment and water of rivers flowing into Tempe Lake. However, there is a lack of quantitative data on the heavy metal concentrations in the sediment and waters of Tempe Lake and in the tissues of the aquatic organisms living in the lake.

Research on the heavy metal concentrations in Tempe Lake on sailfin catfish is extremely limited (Amir et al. 2020), even though such studies have been carried out in several different areas (Munandar and Eurika 2016; Elfidasari et al. 2020; Yona et al. 2021). There is a similar lack of research to identify the sailfin catfish species present in the lake, although it is widely known that the sailfin catfish *Pterygoplichthys pardalis* has become established in some freshwater in Indonesia (Elfidasari et al. 2020). Therefore, this research aimed to identify the sailfin catfish species in Tempe Lake and measure the heavy metal concentration in certain body parts of these sailfin catfish. Heavy metal concentration measurement was focused on large individual sizes (length >36 cm, mean weight 428 g). This research provided important data as a reference for the exploitation of sailfin catfish for human consumption, animal feed, or as a raw material in any other processed products where restrictions apply with respect to safe levels of heavy metal content.

MATERIALS AND METHODS

The materials used in this study were sailfin catfish which varied in size and weight. Samples were collected from Tempe Lake in Barutancung Village, Tanasitolo Sub-district, Wajo District, South Sulawesi Province, Indonesia (Figure 1). The coordinates of the sampling sites were recorded using a Global Positioning System (GPS) unit.

Sailfin catfish samples were collected using a purposive sampling method, with the sampling site chosen based on specific considerations in order to obtain a more representative sample. The sampling site was an area commonly used as a fishing ground by local fishermen and many sailfin catfish is typically caught in their nets. This site was next to a residential area, paddy fields and agricultural lands, and to the discharge from silk weaving and tofu-making industries, all of which contribute to the heavy metal pollution in Tempe Lake.

The cold chain was maintained to ensure the specimens remained fresh. fish species were caught with a net and landed, then washed in the lake water to clean off the mud and placed in a fish crate. As soon as the fish reached the shore, they were rinsed again under running water and placed in a cool box filled with ice. The fish were divided into three groups based on size (total length TL and weight): large (30.4-42.5 cm, 206-528 g), medium (22.0-29.0 cm, 83-160 g) and small (13.5-19.8 cm, 24-50 g), with 30 fish in each group. Prior to further analysis, the fish in each group were returned to the cool box and kept cool with layers of ice between each layer of fish. Other materials used included plastic sample bags and reagents (HNO_3, H_2SO_4, V_2O_5, HCL and H_2O_2).

Sailfin catfish species identification

The sailfin catfish species present in each of the three size groups were determined based on the markings on the abdomen of each specimen (Wu et al. 2011; Bijukumar et al. 2015). Each specimen was photographed at two different magnifications and compared with the abdomen marking patterns in the references used. Three sailfin catfish abdomen marking patterns were used: the pattern for *Pterygoplichthys pardalis*, that for *Pterygoplichthys disjunctivus*, and that for an inter-grade (hybrid) type.

Determination of fish body composition

The percentage composition of sailfin catfish parts was limited to large specimens with a total length (TL) of at least 36 cm, as separating the body parts is easier in larger fish. The body parts selected were the liver, gut, gills, flesh, bones, and skin/scales. The composition or the yield of each body part was calculated as the ratio between the weights of the body part in question to the total body weight of the whole specimen.

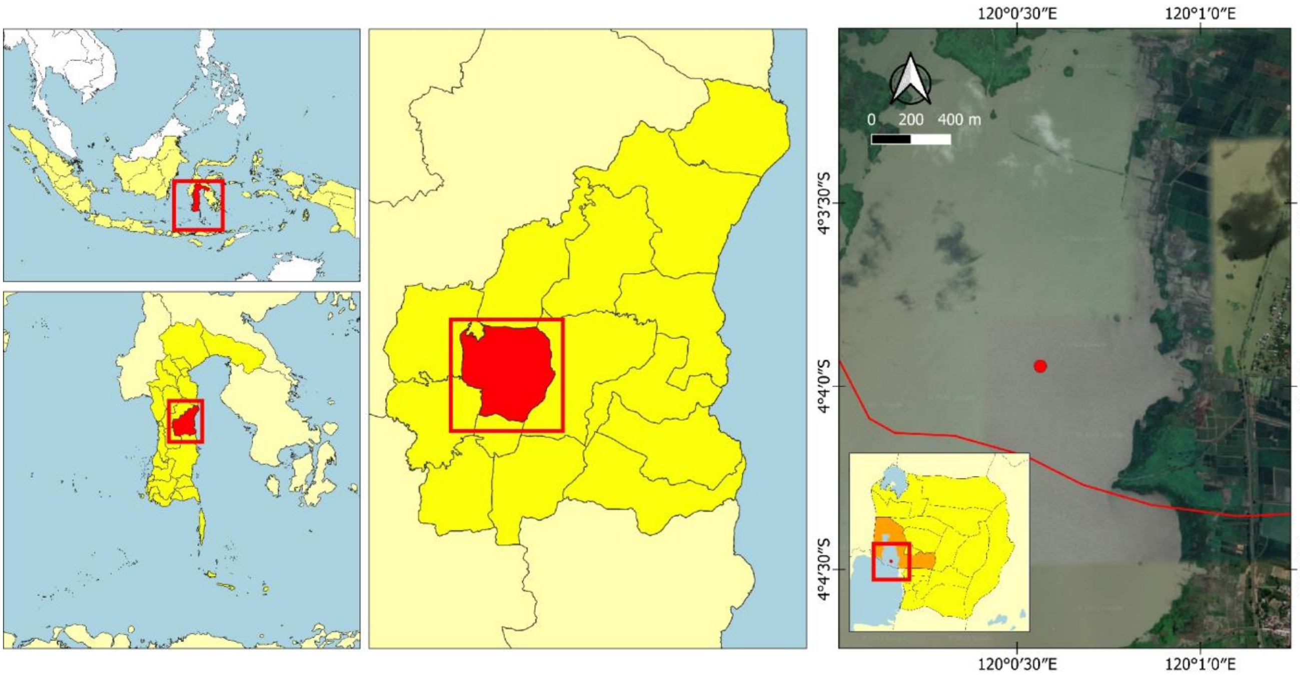

Figure 1. Map showing the Lake Tempe sailfin catfish sampling site in Barutancung Village, Tanasitolo Sub-district, Wajo District, South Sulawesi Province, Indonesia

Heavy metal concentrations

The sailfin catfish samples used were 30 big fishes with TL in the range of 36-42 cm and weighing 297-528 g, Larger fish with a higher trophic level have higher heavy metal content than small fish (Darmono 1995; Simbolon et al. 2010).

Body part/organ samples were obtained through dissection; firstly, an incision was made in the skin on the ventral side from below the operculum, along the abdomen to the anus. The liver and gut were removed using tweezers and collected separately. The head was cut off and the gills were removed by opening the head from the base of the neck to the mouth. The bones removed were the *ossa vertebrae* (backbone), from behind the operculum to the caudal peduncle by slicing through the flesh to each side of the vertebrae to separate the bones from the flesh; any flesh remaining attached to the backbone was scraped off with a knife. The white and dark meats were separated from the skin. The fins (swimming fins, dorsal fin and caudal fin) were separated from the skin and the scales remained attached to the skin using scissors. Heavy metals are important to be analyzed in every part of the fish body because the content of heavy metals in fish is different in each part of the fish body, for example, in the gonads, bones and heads, there are indications of a higher accumulation of heavy metals than in the fish meat (Yulaipi and Aunurohim 2013). This process resulted in seven separate fish body parts from which 100 g samples were taken and placed in plastic sample bags. These samples were placed in a freezer at -20ºC until the heavy metal concentration analysis was performed.

The concentration of the heavy metals mercury (Hg), lead (Pb) and cadmium (Cd) were measured were calculated using Atomic Absorption Spectrophotometry (AAS) with three replicates and compared to the Indonesia National Standards: SNI 2354.6: 2016 (Hg) and SNI 2354.5: 2011 (Pb and Cd) and FAO/WHO (1989). The atomic absorption method used referred to Muti'ah et al. (2022) with some modifications.

Determination of Hg metal is by removing the element Hg from the sample matrix through a reflux digestion step using concentrated sulfuric acid (H_2SO_4) and concentrated nitrate (HNO_3) with electric heating or destruction by microwave to obtain a positively charged element of mercury (Hg^+ or Hg^{++}). Determination of the amount of mercury with AAS without flame where the positive element mercury is then reduced with sodium borohydride to neutral Hg in the form of mercury vapor mist. The mercury vapor mist is driven by the noble gas argon into the absorption cell in the AAS and interacts with the light coming from the HDL (Hallow Cathode Lamp) or EDL (Electric Discharge Lamp) mercury cathode lamp. The interaction is in the form of light absorption, which can be seen on the AAS monitor screen. The amount of light absorption is proportional to the mercury content in the sample.

Heavy metal elements Pb and Cd were released from the sample meat tissue by means of dry digestion or ashing at a temperature of 450°C. The metal in the ash was then bonded with 6 M hydrochloric acid (HCl) and 0.1 M nitric acid (HNO_3), respectively. The resulting solution is then atomized using a graphite furnace. The atoms of the elements Pb and Cd interact with light from the Pb and Cd lamps. The interaction is in the form of light absorption, the amount of which can be seen on the AAS (Atomic Absorption Spectrophotometry) monitor.

Data analysis

Data on the proportion of sailfin catfish belonging to each species identified was presented as a percentage of the number of fish sampled. Data on the composition of the seven body parts were presented as the average of three replicates and tested using one-way analysis of variance (ANOVA) throughout SPSS 22 statistical software. Significant difference was determined at a 95% level of probability (α: 0.05). Data on heavy metal (Hg, Pb and Cd) concentrations in the seven body parts were tabulated and analyzed descriptively.

RESULTS AND DISCUSSION

This study focused on three aspects: the species identification, body part composition and the concentrations of heavy metal distributed throughout the bodies of the alien sailfin catfish that have become so abundant in Tempe Lake. The samples were divided into three size categories, as shown in Figure 2.

Sailfin catfish species identification

Within the genus *Pterygoplichthys*, each species has a distinctive pattern of markings on the abdomen with spots (that can join to form longer dashes or comma-shaped markings), chevrons or vermiculations; or with a combination of spots, chevrons and vermiculations. The species *P. pardalis* is distinguished by a pattern of black dots that can coalesce or form chevrons, although ventral spots are mostly discrete; *P. disjunctivus* is distinguished by dark dots which can coalesce to form vermiculations, while inter-grade or intermediate patterns with a mix of black dots with chevrons and vermiculations are indicative of hybridization between *P. pardalis* and *P. disjunctivus* (Wu et al. 2011; Bijukumar et al. 2015; Hussan et al. 2019). The results (Table 1) show that *P. pardalis* and inter-grade hybrids were identified in each Tempe Lake sailfin catfish size class.

In each size category, the majority of specimens (80% large, 60% medium and 70% small) were identified as *P. pardalis*, with similar abdominal patterns to those reported in individuals from the native habitat in the Amazon River, Brazil (Figure 3A). The comma and dot-shaped markings of some sailfin catfish from Tempe Lake (Figure 3B, 3C) also resemble those of introduced *P. pardalis* populations reported from Taiwan, with a mixture of dots and commas (Wu et al. 2011).

The inter-grade specimens found in this study appear to be the result of various types of hybridization, indicating that *P. disjunctivus* may also be present in Tempe Lake, as well as *P. pardalis*. According to Wu et al. (2011), *P. pardalis* and *P. disjunctivus* are commonly found together in their native habitat. This result is also in consonant with the sailfin catfish found in the Ciliwung River in West Java, i.e., *P. pardalis*, *P. disjunctivus* and inter-grade hybrids (Elfidasari et al. 2020). Page and Robins (2006) also reported that only two species of sailfin catfish had been found in Indonesia: *P. pardalis* and *P. disjunctivus*. Inter-grade sailfin catfish from the hybridization of *P. pardalis* and *P. disjunctivus* are thought to have higher adaptability to environmental conditions than either of the parent species (Wu et al. 2011). This high adaptive capacity resulted in the domination of inter-grade sailfin catfish in the Ciliwung River, which is more heavily polluted than many other freshwater bodies where sailfin catfish have been found (Elfidasari et al. 2020). The presence of relatively high numbers of these hybrids in Tempe Lake could be considered as an indicator of water pollution.

Sailfin catfish body composition

The body composition in terms of the relative weight of the various body parts varied with sample size and weight. As the fish grow, the body parts increase in size differentially, in particular the head and the internal organs (Suwandi et al. 2014). The percentage of total weight represented by each body part (mean of three replicates) for large-sized sailfin catfish is shown in Table 2.

Table 1. Sailfin catfish species identified in Tempe Lake based on abdominal markings

Size group	Total length (cm)	Weight (g)	Species
Large	30.4	206	*Pterygoplichthys pardalis*
	31.5	246	*Pterygoplichthys pardalis*
	31.5	227	*Pterygoplichthys pardalis*
	32	256	*Pterygoplichthys pardalis*
	32	266	*Pterygoplichthys pardalis*
	32	250	*Pterygoplichthys pardalis*
	32.3	234	Inter-grade (hybrid)
	33	270	*Pterygoplichthys pardalis*
	33	233	*Pterygoplichthys pardalis*
	33.2	268	*Pterygoplichthys pardalis*
	33.5	244	*Pterygoplichthys pardalis*
	34	270	Inter-grade (hybrid)
	34	274	Inter-grade (hybrid)
	34	250	*Pterygoplichthys pardalis*
	34.2	285	Inter-grade (hybrid)
	35	345	*Pterygoplichthys pardalis*
	35.5	250	*Pterygoplichthys pardalis*
	35.9	280	Inter-grade (hybrid)
	36	297	*Pterygoplichthys pardalis*
	36	357	*Pterygoplichthys pardalis*
	36	266	*Pterygoplichthys pardalis*
	36.2	320	*Pterygoplichthys pardalis*
	36.3	300	*Pterygoplichthys pardalis*
	36.5	370	Inter-grade (hybrid)
	37	398	*Pterygoplichthys pardalis*
	37.5	360	*Pterygoplichthys pardalis*
	39	437	*Pterygoplichthys pardalis*
	39.8	454	*Pterygoplichthys pardalis*
	40.5	447	*Pterygoplichthys pardalis*
	42.5	528	*Pterygoplichthys pardalis*
Medium	22	83	Inter-grade (hybrid)
	23	89	*Pterygoplichthys pardalis*
	23	81	Inter-grade (hybrid)
	23.5	104	Inter-grade (hybrid)
	23.5	80	*Pterygoplichthys pardalis*
	24	124	Inter-grade (hybrid)
	24.5	91	*Pterygoplichthys pardalis*
	25	106	Inter-grade (hybrid)
	25	124	*Pterygoplichthys pardalis*
	25	144	*Pterygoplichthys pardalis*
	25.4	165	*Pterygoplichthys pardalis*
	25.5	104	*Pterygoplichthys pardalis*
	25.5	109	*Pterygoplichthys pardalis*
	26	125	*Pterygoplichthys pardalis*
	26	112	*Pterygoplichthys pardalis*
	26.5	141	Inter-grade (hybrid)
	26.5	147	*Pterygoplichthys pardalis*
	26.5	122	*Pterygoplichthys pardalis*
	26.5	120	*Pterygoplichthys pardalis*
	26.5	123	Inter-grade (hybrid)
	27	125	*Pterygoplichthys pardalis*
	27	140	Inter-grade (hybrid)
	27.5	149	*Pterygoplichthys pardalis*
	28	155	*Pterygoplichthys pardalis*
	28	182	Inter-grade (hybrid)
	28.2	153	*Pterygoplichthys pardalis*
	28.7	133	Inter-grade (hybrid)
	29	134	Inter-grade (hybrid)
	29	158	*Pterygoplichthys pardalis*
	29	160	Inter-grade (hybrid)
Small	13.5	24	*Pterygoplichthys pardalis*
	13.7	30	*Pterygoplichthys pardalis*
	14.5	29	*Pterygoplichthys pardalis*
	15.5	24	*Pterygoplichthys pardalis*
	15.5	36	*Pterygoplichthys pardalis*
	16	27	*Pterygoplichthys pardalis*
	16	37	*Pterygoplichthys pardalis*
	16	43	*Pterygoplichthys pardalis*
	16.1	40	*Pterygoplichthys pardalis*
	16.1	30	Inter-grade (hybrid)
	16.4	29	Inter-grade (hybrid)
	17	50	Inter-grade (hybrid)
	17	44	*Pterygoplichthys pardalis*
	17	63	*Pterygoplichthys pardalis*
	17.5	38	Inter-grade (hybrid)
	17.5	46	*Pterygoplichthys pardalis*
	17.5	35	Inter-grade (hybrid)
	18	41	*Pterygoplichthys pardalis*
	18	45	*Pterygoplichthys pardalis*
	18.2	60	Inter-grade (hybrid)
	18.5	49	*Pterygoplichthys pardalis*
	18.7	41	*Pterygoplichthys pardalis*
	19	60	*Pterygoplichthys pardalis*
	19	46	*Pterygoplichthys pardalis*
	19	53	*Pterygoplichthys pardalis*
	19	66	Inter-grade (hybrid)
	19.5	46	*Pterygoplichthys pardalis*
	19.5	50	Inter-grade (hybrid)
	19.8	71	Inter-grade (hybrid)
	19.8	50	*Pterygoplichthys pardalis*

The data in Table 2 show that the head is the heaviest sailfin catfish body part, representing just over a third of total body weight. The body part with the lowest yield was the liver, contributing less than 1%. Edible body parts (white and dark meat) yielded just over a quarter (26.64%) of total body weight. These results are consonant with Purnomo et al. (2006), who found that sailfin catfish had an edible part yield of 23-25%. Significant differences ($p<0.05$) existed in the mean weight of even sailfin catfish body parts analyzed.

The yield of flesh from sailfin catfish is low compared to many other fish, with ratios of 54-59% flesh to total body weight considered typical (Suwandi et al. 2014; Hadinoto and Indrus 2018). Snakeheads (genus *Channa*) with a similar body shape to the sailfin catfish, have a flesh yield of around 54% (Suwandi et al. 2014). Tuna has a very different body shape from sailfin catfish, with an edible part (flesh or meat) yield of 59%, while the head comprises 17.5% of total body weight, the skin 3.25%, the bones 13.75% and the inner organs 6.5% (Hadinoto and Idrus 2018). Sailfishes have a body composition of 59.12% flesh, 9.26% bone, 8.24% skin, 7.63% inner organs, 5.68% head, 5.10% fins and 2.37% gills. The low proportion of edible parts in sailfin catfish is due to the large size and tough armor of the head as well as the heavy dermal plates covering the body. These are not actually true scales but tough bony plates with a sandwich-like structure (Ebenstein et al. 2015).

This low edible part yield is likely one reason why sailfin catfish are mainly exploited as ornamental fishes rather than for human consumption, even in their native habitat in South America. In general, sailfin catfish have little appeal and their fisheries potential as a food fish is low compared with many other fishes. However, the excessive abundance of sailfin catfish populations in Tempe Lake means that exploitation for human food, animal feed, or other processed products seems to be a solution that is worth considering. Developing demand for sailfin catfish would prompt fishermen to target this abundant introduced species, thereby supporting the local and national government programs to restore the balance of the aquatic communities in Tempe Lake. This in turn, would have benefits for the welfare of the local people living around the lake.

Figure 2. The sailfin catfish samples by size category: A. Large; B. Medium; C. Small

Table 2. Proportion of body weight of seven sailfin catfish body parts

Total length(cm)	Total body weight (g)	Body part	Mean weight (g)	%*
39.53	428	Liver	3.67	0.86 ± 0.13^{a}
		Gut	19	4.44 ± 1.13^{ab}
		Gills	10.33	2.41 ± 0.13^{ab}
		Dark meat	38.67	9.04 ± 1.47^{b}
		White meat	75.33	17.60 ± 1.59^{c}
		Bone	35	8.18 ± 0.37^{b}
		Skin/scales	25	5.84 ± 0.24^{ab}
		Head	143.33	33.49 ± 3.57^{d}
		Others**	77.66	18.14 ± 4.00^{c}

Note: *Values are mean ± standard deviation of triplicate determination (n: 3). Means followed by different superscript letters within the same column are signification different ($p<0.05$). ** Including fins, eggs/gonads, kidneys and ribs

Figure 3. Examples of abdominal patterns of sailfin catfish from Tempe Lake; (a) *P. pardalis* resembling specimens from the Amazon River in Brazil; (b and c) *P. pardalis* resembling specimens from Taiwan; (d, e, f, and g) inter-grade (hybrid) specimens

Heavy metal concentrations

Tempe Lake is potentially at risk from heavy metal pollution due to the land uses around the lake, including paddy fields and other forms of agriculture, industry, and residential areas. Fertilizers and pesticides used in agriculture, waste from the silk weaving and tofu-making industries, and domestic waste are all discharged into the lake at the site where the sailfin catfish samples used in this study were collected. Industrial, domestic, and other wastes can be sources of heavy metal pollution in aquatic environments (Naggar et al. 2018; Jessica et al. 2020; Kumar et al. 2012), so it is important to measure the heavy metal concentrations in the Sailfin catfish that currently dominate the ichthyofauna of Tempe Lake.

Table 3. Mean concentrations of the heavy metals Hg, Pb and Cd in sailfin catfish from Tempe Lake, South Sulawesi, Indonesia

Body part		**Heavy metal concentration (mg/kg)***		
		Hg	**Pb**	**Cd**
Liver		0.0928 ± 0.002	0.0651 ± 0.025	0.0402 ± 0,003
Gut		0.0671 ± 0.010	0.0420 ± 0.011	0.0322 ± 0.001
Gills		0.0865 ± 0.020	0.0593 ± 0.020	0.0319 ± 0.021
Dark meat		0.0589 ± 0.010	0.0424 ± 0.013	0.0268 ± 0.030
White meat		0.0470 ± 0.004	0.0356 ± 0.004	0.0221 ± 0.014
Bone		0.0519 ± 0.025	0.0327 ± 0.002	0.0180 ± 0.002
Skin/Scales		0.0675 ± 0.003	0.0337 ± 0.010	0.0257 ± 0.005
Allowable threshold (mg/kg)	SNI 7387: 2009 (BSN 2009)	0.5	0.3	0.1
	BPOM No. 5 2018 (BPOM 2018)	0.5	0.2	0.1
	FAO/WHO (1989);	-	0.5	0.5
	US-EPA (1999)	-	5	1

Note: *Values are mean ± standard deviation of triplicate determination (n: 3)

Heavy metal concentrations in sailfin catfish body parts (Table 3) were measured using Atomic Absorption Spectrophotometry (AAS) with the following detection limits: Hg: 0.005 mg/kg; Pb: 0.10 mg/kg; and Cd: 0.02 mg/kg. There was a considerable difference in the heavy metal concentrations between the seven body parts analyzed.

According to Arain et al. (2008), the rate at which heavy metals accumulate varies between various fish body parts, as do the roles these metals can play. The Hg, Pb, and Cd concentrations were highest in the liver and gills of the sailfin catfish sampled. Furthermore, the heavy metal concentrations were much higher in all other organs, especially the liver, than in the flesh or muscles. The relatively high heavy metal concentration in sailfin catfish livers can be explained by the fact that the liver is an organ that plays a key role in detoxifying the body by eliminating poisons and toxins which have been ingested or otherwise entered the body (Rajeshkumar et al. 2017). Meanwhile, the gills, as the breathing organ, are continuously in contact with the ambient water; their capacity for osmoregulation means that heavy metals present in the water will readily enter the body through the gills (Ujianti and Androva 2019). The results of this study are consonant with those of Paudanan et al. (2020), who found that heavy metal concentrations in scad body parts were highest in the spleen, followed by the liver and gills, and lowest in the flesh; and with those of Rajeshkumar and Xiaoyu (2018) who found the highest metal concentrations in the livers of Eurasian carp (*Cyprinus carpio*) and yellowhead catfish *Pelteobagrus fulvidraco*. Research on heavy metal concentrations in the skin, muscles, liver, kidneys, gills, gut, and ovaries of five boxfish species (*Takifugu oblongus*, *Lagocephalus guentheri*, *Arothron hispidus*, *Chelonodon patoca* and *Arothron immaculatus*) by Karunanidhi et al. (2017) found concentrations of Pb in the range 5.80-19.87 mg/kg and of Cd in the range 0.01-0.79 mg/kg.

Samples were collected during the dry season in October and November. At this season, the volume of water in the lake is relatively low, so heavy metal concentrations tend to be higher compared to the rainy season (Jessica et al. 2020). The results of this study are in consonant with the report of Amir et al. (2020) that concentrations of heavy metals (Pb, Hg and Ar) in the bones, dermal plates and flesh of sailfin catfish in Tempe Lake during the rainy season were below the thresholds specified in national standards (SNI). Even though the specimens were collected during the dry season, the concentrations of three heavy metals (Hg, Pb, and Cd) in seven sailfin catfish, body parts (liver, gut, gills, dark meat, white meat, bones and skin/scales/dermal plates) were all below the thresholds specified in the relevant standards issued by the Indonesian National Standards Agency BSN (*Badan Standarisasi Nasional*) SNI 7387 (BSN 2009) and the Indonesian Food and Drug Safety Agency BPOM (*Badan Pengawas Obat dan Makanan Republik Indonesia*) (BPOM 2018), FAO/WHO 1989, and US-EPA 1999. Therefore, the sailfin catfish from the study site in Tempe Lake, i.e., from Barutancung Village, Tanasitolo Sub-district in Wajo District, can be considered safe for use, including for human or animal consumption. In particular, these fish could be exploited to diversify food sources, as a source of dietary calcium, and as raw materials for the production of other processed products such as collagen and gelatine.

In conclusion, Sailfin catfish in Tempe Lake belong to two taxa: the species *Pterygoplichthys pardalis*, comprising around 70% of the population, and an inter-grade or hybrid type. For the development of further research, it is necessary to determine the species of sailfin catfish at several points in Tempe Lake to clarify the inter-grade (hybrid) species found in this study. The head is the heaviest body part, contributing the most (33.49%) to total body weight, with a relatively low yield of edible flesh (26.64%). Socialization of the use of sailfin catfish as food for the local community to increase the added value of fish. Sailfin catfish in Tempe Lake is safe for human consumption, as the heavy metal concentrations (Hg, Pb and Cd) were well below the thresholds in the relevant safety standards in vigour in Indonesia, international limits of FAO/WHO 1989, and US-EPA 1999. The local government needs to actively monitor the heavy metal content of broom fish on a regular basis along with the heavy metal content of the sediment and water of Lake Tempe.

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REFERENCE

Aishah RM, Mohamed AE. 2022. Ecological study of an artificial saline lake ecosystem in Wadi Al-Shatti, Libya. Sci J Fac Sci-Sirte Univ 2 (1): 1-8. DOI:10.37375/sjfssu.v2i1.245

Amin M, Mustafa A. 2000. Kualitas air Danau Tempe pada saat air naik dan surut. Prosiding Semiloka Nasional Pengelolaan dan Pemanfaatan Danau dan Waduk. Jurusan Perikanan Fakultas Pertanian Universitas Padjajaran, Bandung, 7 November 2000. [Indonesian]

Amir N, Syahrul, Djamaluddin N. 2020. Ikan sapu-sapu (*Pterygoplichthys pardalis*) di Kabupaten Wajo Propinsi Sulawesi Selatan: Kandungan logam berat timbal (Pb), mercuri (Hg) dan arsen (As). Jurnal Ilmiah Agribisnis Perikanan 13 (2): 168-174. [Indonesian]

Arain MB, Kazi TG, Jamali MK, Jalbani N, Alfridi HI, Shah A. 2008. Total dissolved and bioavailable element in water and sediment samples and their in *Oreochromis mossambicus* of polluted manchar lake. Chemsphere 70 (10): 1845-1856. DOI: 10.1016/j.chemosphere.2007.08.005.

Bijukumar A, Smrithy R, Sureshkumar U, George S. 2015. Invasion of South American suckermouth sailfin catfishes *Pterygoplichthys* spp. (Loricariidae) in Kerala, India - a case study. J Threat Taxa 7 (3): 6987-6995. DOI: 10.11609/jott.1897.6987-6995.

BLHD. 2012. Kajian Daya Tampung Beban Pencemaran Air Danau Tempe. [Report]. CV. Celebes Pratama Konsultan, Badan Lingkungan hidup Daerah Provinsi Sulawesi Selatan, Makassar. [Indonesian]

BPOM. 2018. Peraturan Badan Pengawas Obat dan Makanan No. 5 Tahun 2018 tentang Batas Maksimum Cemaran Logam Berat dalam Pangan Olahan. Badan Pengawas Obat dan Makanan Republik Indonesia, Jakarta. [Indonesian]

BSN. 2009. SNI 7387: 2009. Batas Maksimum Cemaran Logam Berat dalam Pangan. Badan Standarisasi Nasional, Jakarta. [Indonesian]

BSN. 2011. SNI 2354.5: 2011. Cara Uji Kimia - Bagian 5: Penentuan Kadar Logam Berat Timbal (Pb) dan Kadmium (Cd) pada Produk Perikanan. Badan Standarisasi Nasional, Jakarta. [Indonesian]

BSN. 2016. SNI 2354.6: 2016. Cara Uji Kimia-Bagian 6: Penentuan Kadar Logam Berat Merkuri (Hg) pada Produk Perikanan. Badan Standarisasi Nasional, Jakarta. [Indonesian]

Chaicana R, Jongphadungkiet S. 2012. Assesment of the invasive catfish *Pterygoplichthys pardalis* (Castelneu, 1855) in Thailand: Ecological impacts and biological control alternatives. Trop Zool 25 (4): 173-182. DOI: 10.1080/03946975.2012.738494.

Darmono. 1995. Logam dalam Sistem Biologi Makhluk Hidup. UI Press, Jakarta. [Indonesian]

Duncan AE, de Vries N, Nyarko K. 2018. Assessment of heavy metal pollution in the sediments of the river pra and its tributaries. Water Air Soil Pollut 229: 272. DOI: 10.1007/s11270-018-3899-6.

Ebenstein D, Calderon C, Troncoso OP, Torres FG. 2015. Characterization of dermal plates from armored catfish *Pterygoplichthys pardalis* reveals sandwich-like nanocomposite structure. J Mech Behav Biomed Mater 45: 175-182. DOI: 10.1016/j.jmbbm.2015.02.002.

Elfidasari D, Fahma W, Hurunin FM. 2020. Habitat characteristic of suckermouth armored catfish *Pterygoplichthys pardalis* in Ciliwung river, Indonesia. Intl J Fish Aquat Stud 8 (3): 141-147.

FAO/WHO. 1989. Evaluation of Certain Food Additives and the Contaminants Mercury, Lead and Cadmium. [Report]. WHO, Geneva.

Febrianti N, Yulianto F, Arda M, Haryani NS. 2019. Flood inundation mapping using synthetic aperture radar data dual polarization: A case study of flood in Lake Tempe, South Sulawesi, Indonesia. Intl Conf Sustain Sci Manag 572 (1): 012028. DOI: 10.1088/1755-1315/572/1/012028.

Hadinoto S, Idrus S. 2018. Proporsi dan kadar proksimat bagian tubuh ikan tuna ekor kuning (*Thunnus albacares*) dari perairan Maluku. Majalah Biam 14 (2): 51-57. [Indonesian]

Herawati EY, Diana A, Pratama DS, Karina FD, Putri A, Rahmi V. 2021. Determination of water quality status based on heavy metal contents in the rainy and dry season using the storet index in Pasuruan Sea Waters, East Java. J Fish Mar Res 5 (2): 201-207. DOI: 10.21776/ub.jfmr.2021.005.02.3.

Hussan A, Sundaray JK, Manda RN, Hoque F, Das A, Chakrabarti PP, Adhikari S. 2019. Invasion of non-indigenous suckermouth sailfin catfish of the genus *Pterygoplichtyhys* (Loricariidae) in the East Kolkata Wetland: Stakeholders perception. Indian J Fish 66 (2): 29-42. DOI: 10.21077/ijf.2019.66.2.86267-05.

Jessica B, Emmanuel S, Renald B. 2020. Heavy metal pollution in the environment and their toxicological effects on humans. Heliyon 6 (9): 1-26. DOI: 10.1016/j.heliyon.2020.e04691.

Karunanidhi K, Rajaram R, Dhinesh P, Ganeshkumar A. 2017. First report on distribution of heavy metals and proximate analysis in marine edible puffer fishes collected from Gulf of Mannar Marine Biosphere Reserve, South India. Toxicol Rep 4: 319-327. DOI: 10.1016/j.toxrep.2017.06.004.

Kumar B, Sajwan KS, Mukherjee DP. 2012. Distribution of heavy metals in valuable coastal fishes from North East Coast of India. Turk J Fish Aquat Sci 12: 81-88. DOI: 10.4194/1303-2712-v12_1_10.

Munandar K, Eurika N. 2016. Keanekaragaman ikan yang bernilai ekonomi dan kandungan logam berat Pb dan Cd pada ikan sapu-sapu di Sungai Bedadung Jember. Prosiding Seminar Nasional Pendidikan Biologi. Surakarta, Oktober 2016. [Indonesian]

Muti'ah, Siahaan J, Loka IN, Irawan J. 2022. The efficiency of heavy metal analysis method in marine fish samples by atomic absorption spectrophotometry. J Res Sci Educ 8 (2): 963-968. DOI: 10.29303/jppipa.v8i2.1489.

Naggar YA, Mohamed SK, Mohamed AG. 2018. Environmental pollution by heavy metals in the aquatic ecosystems of Egypt. J Toxicol 3 (1): 001-009. DOI: 10.19080/OAJT.2018.03.555603.

Page LM, Robins RH. 2006. Identification of sailffin catfishes (Teleostei: Loricariidae) in South-Eastern Asia. Raffles Bull Zool 54 (2): 455-457.

Paudanan M, Fajrah S, Rikwan. 2020. Kandungan logam berat (Hg, Pb) dan histopatologi (insang, daging, hati, limpa) ikan selar tetengkek (*Megalaspis cordyla* L) di Teluk Palu. Environ Sustain J 1 (1): 1-12.

Purnomo, D., Supjitah, P. & Rahmawati, D. 2006. Karakteristik fisika kimia gel ikan sapu sapu (*Hyposarcus pardalis*) dari bahan baku surimi. Prosiding Seminar Nasional Perikanan Indonesia. Sekolah Tinggi Perikanan, Jakarta.

Rajeshkumar S, Xiaoyu L. 2018. Bioaccumulation of heavy metals in fish species from the Meiliang Bay, Taihu Lake, China. Toxicol Rep 5: 288-295. DOI: 10.1016/j.toxrep.2018.01.007.

Rajeshkumar S, Liu Y, Ma J, Duan HY, Li, X. 2017. Effects of exposure to multiple heavy metals on biochemical and histopathological alterations in common carp, *Cyprinus carpio* L. Fish Shellfish Immunol 70: 461-472. DOI: 10.1016/j.fsi.2017.08.013.

Rao KR, Sunchu V. 2017. A report on *Pterygoplichthy pardalis* amazon sailfin suckermouth catfishes in freshwater tanks at telangan state, India. Intl J Fish Aquat Stud 5 (2): 249-254.

Saba AO, Nor FR, Ahmad I, Syaizwan ZZ. 2020. A report on introduced Amazon sailfin catfish, *Pterygoplichthys pardalis* in Gombak Basin, Selangor, with notes on two body patterns of the species. Pertanika 43 (4): 693-703. DOI: 10.47836/pjtas.43.4.19.

Simbolon D, Simage SM, Wulandari SY. 2010. Kandungan merkuri dan sianida pada ikan yang tertangkap dari Teluk Kao, Halmahera Utara. Ilmu Kelautan 15 (3): 126-134. DOI: 10.14710/ik.ijms.15.3.126-134. [Indonesia]

Suwandi R, Nurjanah, Winem M. 2014. Proporsi bagian tubuh dan kadar proksimat ikan gabus pada berbagai ukuran. Jurnal Pengolahan Hasil Perikanan Indonesia 17 (1): 22-28. [Indonesian]

Ujianti RMD, Androva A. 2019. Heavy metal toxicity and the influence of water quality in watershed for enhancing fisheries food security. IOP Conf Ser Mater Sci Eng 846 (1): 012049. DOI: 10.1088/1757-899X/846/1/012049.

US Environmental Protection Agency (EPA). 1999. Sediment Toxicity and Fate of Synthetic Pyrethroids. [Final Report]. Office of Pesticide Programs, US Environmental Protection Agency, Washington, DC.

Wu L, Liu C, Lin S. 2011. Identification of exotic sailfin catfish species (*Pterygoplichthys*, Loricariidae) in Taiwan based on morphology and mtDNA sequences. Zool Stud 50 (2): 235-246.

Yona D, Sartimbul A, Rahman MA, Sari SHJ, Mondal P, Hamid A, Humairoh T. 2021. Bioaccumulation and health risk assessments of heavy metals in mussels collected from Madura Strait, Indonesia. Jurnal Ilmiah Perikanan Kelautan 13 (1): 20-28. DOI: 10.20473/jipk.v13i1.24677.

Yulaipi S, Aunurohim. 2013. Bioakumulasi logam berat timbal (Pb) dan hubungannya dengan laju pertumbuhan ikan mujair (*Oreochromis mossambicus*). Jurnal Sains dan Seni Pomits 2 (2): 2337-3520. DOI: 10.12962/j23373520.v2i2.3965. [Indonesian]