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Macrozoobenthos diversity and heavy metal contamination in *Faunus ater* in the Rasian and Asahan rivers in the southern coast of Aceh, Indonesia

Vielfalt des Makrozoobenthos und Schwermetallkontamination in *Faunus ater* in den Flüssen Rasian und Asahan an der Südküste von Aceh, Indonesien

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Summary

Macrozoobenthos is a sedentary aquatic biota and is often used as a bioindicator for assessing water conditions. Therefore, this study aimed to investigate the species diversity of the macrozoobenthos and to analyze the heavy metal contamination in *Faunus ater* in the Rasian and Asahan estuaries in Aceh Province, Indonesia. The sampling was carried out in July 2022 on a squared transect of 1 m × 1 m for the collection of macrozoobenthos samples at random locations. The results showed that there were 17 macrozoobenthos species from both locations, of which 14 species were found in the Rasian River estuary and seven species in the Asahan River estuary. The diversity index of macrozoobenthos was in a moderate category. *Terebralia sulcata* had a higher density in the Asahan River, while *F. ater* had a higher density in the Rasian River. The results of the heavy metal analysis in the *F. ater* sample showed that this macrozoobenthos was contaminated by mercury, cadmium, and lead, of which the concentration of mercury exceeded the threshold limit, and they are, therefore, not safe for consumption.

Keywords: Aquatic mollusks, *Faunus ater*, *Terebralia sulcata*, heavy metal, mercury

Zusammenfassung

Makrozoobenthos sind sesshafte Wasserbiota und werden häufig als Bioindikator zur Beurteilung des Wasserzustands verwendet. Ziel dieser Studie war es daher, die Artenvielfalt des Makrozoobenthos zu untersuchen und die Schwermetallbelastung in *Faunus ater* in den Flussmündungen Rasian und Asahan in der Provinz Aceh, Indonesien, zu analysieren. Die Probenahme erfolgte im Juli 2022 auf einem quadratischen Transekt von 1 m × 1 m zur Sammlung von Makrozoobenthosproben an zufälligen Standorten. Die Ergebnisse zeigten, dass es an beiden Standorten 17 Makrozoobenthosarten gab, von denen 14 Arten im Rasian-Fluss und sieben Arten in den Flussmündungen des Asahan-Flusses gefunden wurden. Der Diversitätsindex von Makrozoobenthos lag in einer mittleren Kategorie. *Terebralia sulcata* wies im Asahan-Fluss ein größeres Vorkommen auf, während *F. ater* im Rasian-Fluss ein größeres Vorkommen aufwies. Die Ergebnisse der Schwermetallanalyse in der Probe von *F. ater* zeigten, dass dieses Makrozoobenthos mit Quecksilber, Cadmium und Blei kontaminiert waren, wobei die Quecksilberkonzentration den Schwellenwert überschritt und daher sind sie für den Verzehr nicht sicher.

Schlagwörter: Wassermollusken, *Faunus ater*, *Terebralia sulcata*, Schwermetall, Quecksilber

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1. Introduction

Macrozoobenthos are demersal organisms that are sedentary and have slow movements, making them highly susceptible to environmental conditions (Minggawati, 2013). Due to this sensitivity, macrozoobenthos are frequently used as bioindicators for assessing water quality (Dabrowska et al., 2016; Rosdatina et al., 2019; Ramadhaniaty et al., 2021). These species play an important role in the aquatic ecosystems as decomposers (Desmawati et al., 2020; Kumar et al., 2013) and transfer energy to the next trophic levels as prey for other aquatic animals such as fish and water birds (Ridwan et al., 2016; Jędruch et al., 2019).

In Indonesia, several groups of macrozoobenthos, particularly bivalves and gastropods, are used as protein sources by local communities and are traded in local markets. However, these species have been intensively harvested without regard to size, leading to overharvesting and diminishing wild stocks (Almohdar et al., 2017; Aralaha et al., 2015; Sarong et al., 2015). Overharvesting can cause population stress, leading to premature spawning to maintain their population (De Jong et al., 2015). This can affect the stability of the water ecosystem and reduce water productivity.

Studies on the diversity of macrozoobenthos have been carried out in Indonesia waters, for example, Irham et al. (2022) examined the abundance and diversity of the benthic community in Krueng Cut estuary Banda Aceh, and they recorded seven species of benthos with low diversity and moderate dominance indices. Furthermore, Octavina et al. (2018) reported seven species of macrozoobenthos in Gosong Telaga Aceh Singkil with a moderate diversity index. The biodiversity and community composition of freshwater and marine macrozoobenthos in the waters of Gonrontalo were analyzed by Kadim et al. (2022); they concluded that the diversity of macrozoobenthos in these waters was low to moderate. However, in Aceh province, specifically in the southwest coast regions, there is a lack of exploration and reports. Currently, there are only two reports available from this region. The first report was by Munandar et al. (2016) who studied macrozoobenthos diversity in the Kuala Rigaih estuary, Setia Bakti District. Aceh Jaya District recorded 10 species from this estuary. The second report by Rizka et al. (2016) examined macrozoobenthos diversity on the coast of Nagan Raya and concluded that the diversity of these species in the area tends to be moderate, indicating unstable water condition (Rizka et al., 2016). Therefore, the above studies indicate that the diversity of macrozoobenthos in Indonesian waters ranges from low to moderate. This is an indication of a general problem with the quality of water in Indonesia.

The Rasian River and the Asahan River are located in the Pasie Raja and Kluet Selatan subdistricts, Aceh Selatan District in Aceh province, Indonesia. Both traditional and illegal mining activities, such as traditional sand and gold mining, are carried out in this district and the local government has planned to develop the cement industry in this area. Therefore, in this study, we aimed to document the diversity of species and distribution of macrozoobenthos in the Rasian and Asahan rivers and to examine the heavy metal contamination in one of the dominant species of macrozoobenthos, *F. ater*. These data are crucial for monitoring the impact of development and are important information for developing a management plan for the aquatic resources in this area.

2. Materials and Methods

2.1. Site and time

Sampling was carried out in the estuary of Rasian and Asahan rivers of Aceh Selatan district, Aceh province, Indonesia, in July 2022. In each estuary location, three sampling points were determined randomly (Figure 1). The scenery of the two estuary locations is shown in Figure 2.

2.2. Sampling

Macrozoobenthos were collected on a 1 m × 1 m squared transect. At each sampling point, substrate samples from a depth of about 20 cm were taken with a shovel and then sieved with a mesh size of 0.5 mm. The macrozoobenthos samples were placed in a plastic bag, and then preserved with 10% formalin and transported to the Marine Biology Laboratory, Faculty of Marine and Fisheries, Universitas Syiah Kuala for identification based on Wye (1992) and Compagno (1998).

2.3. Ecological indices

2.3.1. Density index

The macrozoobenthos density was calculated according to Brower et al. (1977) as follows:

$D = Ni/A$,

where D = individual abundance (individuals/m^2), Ni = the total number of individuals of the species i, and A = the sampling area (m^2).

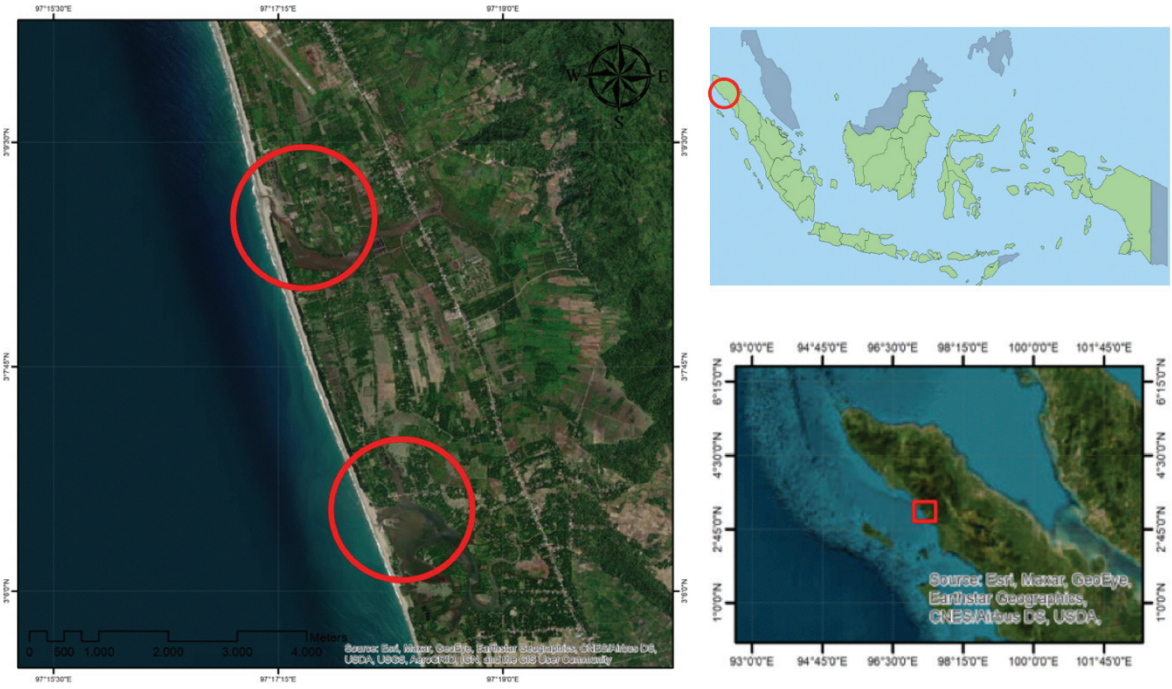


Figure 1. The map of South Aceh district showing sampling locations (red circle)
Abbildung 1. Die Karte des Probenahmebezirks Süd-Aceh zeigt Probenahmeorte (roter Kreis)

2.3.2. Diversity index

The Shannon–Wiener diversity index (H') was calculated based on Krebs (1989) as follows:

$H' = \Sigma pi \log pi$,

where H' = Shannon–Wiener diversity index, pi = ni/N, ni = total number of individual species i, and species N = total number of individuals in all species. The Shannon–Wiener diversity index criteria are H' < 1 = low diversity, 1 < H' < 3 = moderate diversity, and H' > 3 = high diversity.

2.3.3. Uniformity index

The uniformity index (E) was calculated based on Krebs (1989) as follows:

$E = H'/H_{max}$,

where E = uniformity index, H' = diversity index, $H_{max.}$ = log 2(S), and S = total species. The uniformity index criteria are as follows: low- E = 0–0.4, moderate- E = 0.4–0.6, and high- 0.6–1.0.

2.3.4. Dominance index

Simpson dominance index was calculated based on Odum (1996) as follows:

$C = \Sigma(ni/N)^2$,

where C = dominance index, ni = total number individuals in species i, and N = total number of species. The categories of dominance index are as follows: C tends to 0 (C < 0.5) = there is no predominant species and C tends to 1 (C > 0.5) = there is a predominant species.

2.4. Heavy metal contamination analysis

Analysis of heavy metals was carried out in the predominant macrozoobenthos in the two rivers, which was *F. ater* (local name *chue*). A total of 15 samples were taken randomly from every estuary. The shells were broken and the muscles were separated from the innards. Then the muscles were washed thoroughly, pooled in a sample plastic bag, and kept in an ice box (3–4 °C). Furthermore, the mercury (Hg), cadmium (Cd), and lead (Pb) contents were examined using a standard method of atomic absorption spectroscopy (AAS) (SNI, 2019). The efficiency was calculated using the equation for interpreting the AAS results RE (%) = (Ti – Tf)/Ti) × 100, where RE = removal efficiency (ppm), Tf = adsorbate concentration at equilibrium state (%), Ti = adsorbate concentration at initial state (ppm) (Logan et al., 2006). The analysis was carried out at the Center for Standardization and Industrial Services, Banda Aceh.



Figure 2. The sampling location sceneries of Rasian estuary (a) and Asahan estuary (b)
Abbildung 2. Die Szenerien der Probenahmeorte der Rasian-Mündung (a) und der Asahan-Mündung (b)

2.5. Data analysis

The data were presented in tables and figures and then analyzed descriptively by comparing them with relevant previous studies or reports.

3. Results

The Rasian River estuary contained 14 species of macrozoobenthos, while the Asahan River estuary contained seven species, resulting in a total of 17 across both rivers (Table 1). These species belonged to two phyla (Mollusk and Arthropoda) and three classes (Bivalvia, Gastropods, and Crustaceans). The external morphology of the macrozoobenthos found during the survey is presented in Figure 3. Analysis of the density of macrozoobenthos in the Rasian River showed that *F. ater* had the highest average density of 13.33 ind./m^2, followed by *Neritina turrita* (7.33 ind./m^2), and the species with a low density were *Charybdis affinis, Ocypodae kuhlii*, and *Eriphia smithii*. The diversity index values in this estuary were categorized as moderate value (H' = 2.24), high uniformity (E = 0.84), and no predominant species was present (C = 0.142) (Table 2). Meanwhile, in the Asahan River, the highest density was recorded for *Terebralia sulcata* (162 ind./m^2) followed by *F. ater* (88.3 ind./m^2), while the lowest density was recorded for *Metapaneus affinis* (0.3 ind./m^2). The diversity and uniformity indices in this estuary were also classified as moderate category (H' = 1.05 and E = 0.54, respectively) and no predominant species was present (C = 0.431) (Table 2).

Heavy metal analysis in the *F. ater* muscles showed that the species from these two rivers were contaminated with mercury (Hg) ranging from 0.0845% to 0.1115%, cadmium (Cd) 0.0002%, and lead (Pb) 0.0005%. The Hg content exceeded the tolerance threshold for aquatic animals, while the Cd and Pb contents were below the thresholds (Table 3).

4. Discussion

The species diversity index of macrozoobenthos in the Rasian and Asahan rivers was in the moderate category, but the value was lower compared to those reported in several related studies in the area, for instance, in the Peat Swamp forest in Nagan Raya and Aceh Barat Daya districts (Riska et al., 2016) and in Kuala Rigah, Setia Bakti Subdistrict, Aceh Jaya District (Munandar et al., 2016). In general, the number of macrozoobenthos species in the Rasian River was higher than in the Asahan River; this may be due to the sampling

Table 1. Composition of macrozoobenthos in the Rasian and Asahan river estuaries
Tabelle 1. Die Zusammensetzung des Makrozoobenthos in den Flussmündungen Rasian und Asahan

Phylum	Class	Family	Species	Location	
				RRE	ARE
Mollusk	Bivalvia	Donacidae	*Donax faba*	√	√
		Donacidae	*Donax denticulus*	√	-
			Donax trunculus	-	√
		Ostreidae	*Saccostrea cucullata*	√	√
	Gastropoda	Terebridae	*Hastula cinerea*	√	-
		Neritidae	*Neritina turrita*	√	√
			Nerita picea	√	-
		Pachychillidae	*Faunus ater*	√	√
		Planaxidae	*Planaxis sulcatus*	√	-
		Potaminidae	*Terebralia palustris*	√	-
			Terebralia sulcata	-	√
		Trochidae	*Umbonium vertarium*	√	-
Arthropoda	Malacostraca	Ocypodidae	*Ocypodidae kuhlii*	√	-
		Hippidae	*Emerita emeritus*	√	-
		Eriphiidae	*Eriphia smithii*	√	-
		Portunidae	*Charybdis affinis*	√	-
		Decapoda	*Metapanaeus affinis*	-	√
Total		**14**	**17**	**14**	**7**

Note: RRE = Rasian River estuary, ARE = Asahan River estuary, √ = present, - = absent

area in the Rasian River having diverse sediment characteristics and being predominantly muddy and adjacent to mangrove ecosystems dominated by nipah (*Nypa fruticans*) and *Rhyzopora* sp., while in the Asahan River, the sediment characteristics were dominated by sandy area with no mangroves. Therefore, the Rasian River estuary was richer in organic matter from mangrove litters. This finding is consistent with the findings of Nagelkerken et al. (2008), which suggested that estuarine areas with mangroves and nipa palms tend to have higher productivity levels than other aquatic ecosystems, leading to a greater variety of organisms (Fithria et al., 2022). *F. ater*, locally known as *chue*, is a biota that is present at both locations and is classified as an herbivore that feeds on plants, algae, plankton, and detritus, making its habitat the bottom of water (Agustina et al., 2017). The local population uses it as a source of protein, and it is traded in the local market. This study also examined the potential of heavy metal contamination in this biota. The results confirmed that the *chue* from these two rivers was contaminated with Hg, Cd, and Pb metals, of which the Hg concentration passed the threshold limit. Detection of Pb and Hg levels contained in foodstuffs such as *chue* indicates that biomagnification has occurred, where harmful substances accumulate in the food chain (Hilgendag et al., 2022; Murillo-Cisneros et al., 2019). The high Hg content in *chue* is probably caused by gold mining activities in Mount Manggamat, Central Kluet District, where this is the catchment area for these rivers. Mercury is commonly used by illegal miners to separate pure gold from other particles. Subsequently, mining activities must be licensed to operate prudently based on nondestructive principles for natural resources. However, it has been reported that there are a lot of illegal mining activities that do not pay attention to the impact on the surrounding ecosystem. Mount Manggamat is an upstream part that is connected to the Rasian and Asahan rivers, and therefore, this metal accumulates in the body of *F. ater* as a bioindicator, which is a filter feeder (Jedruch et al., 2019). Cd and Pb may have come from the chemical fertilizers and pesticides from the plantations and farms close to the rivers (Rumhayati et al., 2018; Atitsogbey et al., 2023). Therefore, it is necessary to carry out further intensive studies related to these initial findings to take early anticipatory action.

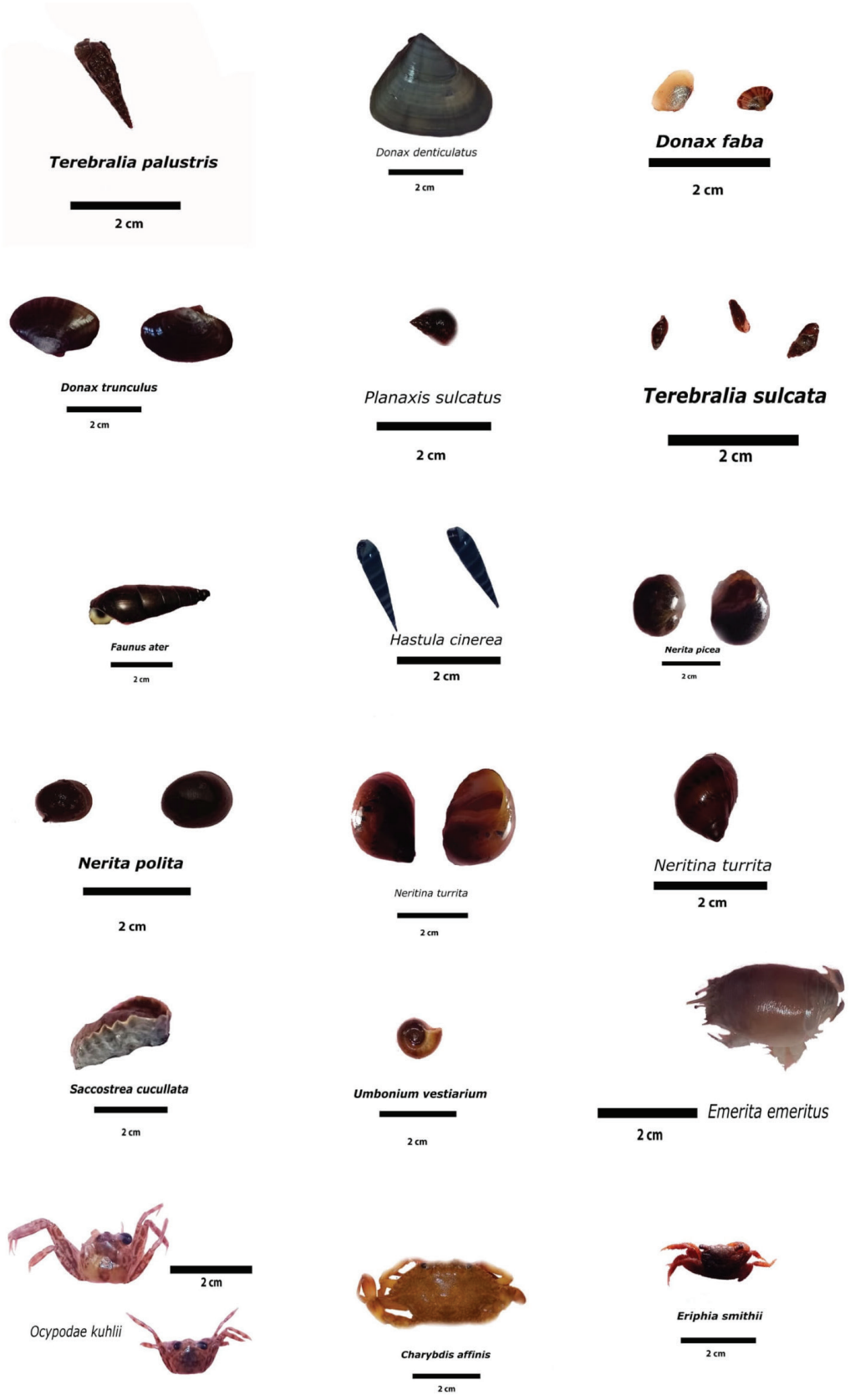


Figure 3. Photographs of the macrozoobenthos found in the Rasian River and Asahan River estuaries
Abbildung 3. Fotos des Makrozoobenthos, die in den Flussmündungen des Rasian River und des Asahan River gefunden wurden

Table 2. Density, diversity, uniformity, and dominance indices of macrozoobenthos in the Rasian and Asahan rivers
Tabelle 2. Dichte-, Diversitäts-, Uniformitäts- und Dominanzindizes von Makrozoobenthos in den Flüssen Rasian und Asahan

Location	Species	Density (ind./m²)	Diversity index (H')	Uniformity index (E)	Dominance index (C)
Rasian River estuary	*Donax faba*	3.67	2.24 (Moderate)	0.84 (High)	0.14 (No dominant species)
	Donax denticulus	5.00			
	Hastula cinerea	1.67			
	Ocypodae kuhlii	0.67			
	Emerita emeritus	2.00			
	Neritina turrita	7.33			
	Nerita picea	2.33			
	Faunus ater	13.33			
	Planaxis sulcatus	1.00			
	Eriphia smithii	0.67			
	Saccostrea cucullata	3.67			
	Charybdis affinis	0.67			
	Terebralia palustris	4.00			
	Umbonium vertarium	1.00			
Asahan River estuary	*Faunus ater*	88.3	1.05 (Moderate)	0.54 (Moderate)	0.43 (No dominant species)
	Donax trunculus	1.7			
	Saccostrea cucullata	2.3			
	Terebralia sulcata	162.0			
	Neritina turrita	9.3			
	Donax faba	18.7			
	Metapaneus affinis	0.3			

5. Conclusion

A total of 17 species of macrozoobenthos were recorded, of which 14 were found in the Rasian estuary and seven in the Asahan estuary, and therefore, the Rasian River estuary has a high diversity. However, a large number of individuals were encountered in the Asahan estuary. The diversity index of macrozoobenthos in both estuaries was in the moderate category. In addition, *F ater* was contaminated by mercury, cadmium, and lead, of which the concentration of mercury exceeded the threshold limit.

Table 3. The average concentration of heavy metals Hg, Cd, and Pb in the Funus ater sample collected from Rasian River and Asahan River estuaries
Tabelle 3. Die durchschnittliche Konzentration der Schwermetalle Hg, Cd und Pb in der Funus ater-Probe, die aus den Flussmündungen Rasian River und Asahan River entnommen wurde.

No.	Heavy metals	Unit	Method test	Tolerance threshold*	Estuary location	
					RRE	ARE
1.	Mercury (Hg)	%	AAS	0.001	0.0845	0.1115
2.	Cadmium (Cd)	%	AAS	0.001	0.0002	0.0002
3.	Lead (Pb)	%	AAS	0.008	0.0005	0.0005

Note: RRE = Rasian River estuary, ARE = Asahan River estuary
*Based on the degree of the Minister of State for the Environment, Republic of Indonesia, No. 51 of the year 2004.

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