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METALS BIOCONCENTRATION OF FRESHWATER FISHES IN CENTRAL KALIMANTAN AS AN EVALUATION CRITERIA FOR MANAGEMENT OF INLAND WATER FISHERY RESERVE

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ABSTRACT

Heavy metal bioconcentration was examined and evaluated in the muscle of several of freshwater fishes species collected from a complex of some oxbow lakes in Kahayan River and from Lake Sembuluh, Central Kalimantan. The objective of the study was to find natural background values of heavy metals in water, sediment and its biomultiplication factor related to their concentration in water and the fish position in the foodweb.

In this analysis, one to twenty-five grams of fish muscle samples was obtained from the posterior part of pectoral but anterior to anal fins. Water samples, which were taken from surface and bottom layers of the lakes, were mix and preserved with nitric acid. Sediment samples were obtained by using Ekman Grab and the interstitial waters were extracted by using wet digestion technique.

Iron concentration in fish muscle is the highest in omnivorous, followed by that of in carnivorous and detritivorous fish. Manganese, lead and mercury had different pattern of bioconcentration levels. Bioaccumulation factor for each metal and at each food habit category was also variable; the lowest value of 0.7 for iron in second consumer and 28.2 for mercury in primary consumer. Mechanism of heavy metal intrusion to fish muscle is very intricate and apparently depends upon feeding habit of each species. Concentration of mercury in water and fish muscle was far above minimum risk level, but concentrations of iron, manganese and lead in water and fish was considered still safe for environment as well as for human health. Potential utilization of these results as evaluation criteria for fishery reserve is discussed.

Keywords: Heavy metals, bioconcentration, freshwater fishes, inland water, lakes, fishery reserve management.

INTRODUCTION

The Fishery reserve or "suaka perikanan" in Indonesian Government Law term is a fishery management tool, which is legal sanctioned under the Republic Indonesia Act Number 9 on Fishery introduced in 1995. After more than ten years following its establishment, there is not yet available any criteria for evaluation of inland fishery reserve. A Strategic Integrated Research ("Riset Unggulan Terpadu") has been conducted for three years by the RDC for Limnology. The expected result of this research contract is to develop criteria for evaluation of fishery reserve, which was based on fish reproductive biology and limnology aspects. Kahayan Watershed in Central Kalimantan, which has a complex oxbow lakes and lowland lakes was chosen as the location for this study. These two types of inland water characterized as acidic black water sometime with more than three meters water level differences between dry and rainy season.

In 1996, Government of Republic Indonesia initiated a project that was aimed to invert one million hectares in peat bogs of Central Kalimantan into rice fields. Ecologically, this huge scale project means changing large amount of environmental characteristics that at the end will also change the environmental features of inland water, including the concentration of heavy metals in water. Through intricate mechanisms, significant change of heavy metals concentration in water will also change the biocoijcentration of heavy metals in freshwater fishes.

As in invertebrates, most of the mercury in fish tissues is methylated and enter the tissues at a faster rate than non-organic forms. The rate of sorption depends primarily on temperature and to lesser degree, lipid content. Organic mercury compounds are considerably more toxic than non-organic form (McLeod and Pessah, 1973). The case of mercury poisoning to human being is well known and well reported in the past. On the other hand, although currently rare in aquatic environment, organoleads are highly toxic and may therefore pose an eventual threat to fisheries resources. Hence special consideration should be given to the formulation of guidelines for total Pb and organoleads in fishery products.

Unfortunately the study on bioconcentration in Indonesian freshwater fishes, especially in inland water habitat such as black water oxbow lakes and low land lakes, are rarely conducted. In relation to that, the aim of this study is to reveal the average bioconcentration values of heavy metals on selected fish species from lakes and oxbow lakes. This study is expected to be considered a method of finding the natural background values of heavy metal bioconcentration on fish and biomultiplication factors that were related to their concentration in water, sediment and the fish position in the food web. The natural back ground level in this study is considered to be the concentration of the metals in the components of an inland water habitat that is not much disturbed yet by the human activities.

MATERIALS AND METHODS

Sampling location and method

Water sample was collected from littoral and pelagic zone in four lakes observed: Lake Takapan, Lake Rengas, Lake Lutan and Lake Sembuluh that encompassed seven sampling sites, Each sample was a composite of the surface and bottom layer Seven periods of samplings were conducted from 1995 to 1997. Each water sample from the littoral and pelagic zone was analyzed separately, however only the average data of all sampling times and sites are reported.

Fish samples were collected from the catch of experimental gill net, trap nets, hook and lines and various other fishing gears in 1995, 1996 and 1997. Fish samples were collected from three oxbow lakes in Lake Takapan Complex that consisted of Lake Lutan, Lake Takapan and Lake Rengas, which are part of Kahayan River oxbow lakes system. Some samples of fish were also collected from Lake Sembuluh. Detailed description of these sampling sites was described by Hartoto (2000).

One or more individuals from each species was selected as voucher specimen for identification, while the other samples were collected for analysis. After measurement of total Weight, total length, standard length and body height, fish specimen was dissected for sex examination, sampling of digestive system for food habit study and judgment of gonad developments status as well as ovary sampling for fish fecundity study for bioaccumulation study, 39 samples of 20 .fish species from L. Takapan, 12 samples of 8 species from L. Rengas and 11 samples of 10 species from L. Sembuluh were prepared. These fish samples did not represent fish community of Lake Takapan Complex since Hartoto (2000) reported that the fish inhabiting Lake Takapan was more than 60 species.

Estimation of fish species position in the food web in similar location followed method that was described by study of Hartoto *et al.* (2000). In this study the fish is classified into first or primary consumer, secondary consumer and third or top predator and the fish food web of Lake Takapan indicate a profile of predatory food chain started with the detritivorus fishes as the first consumers of organic materials.

Analysis of heavy metals content in water, sediment and fish muscle

Two to twenty-five grams fish muscle from body part between pectoral and anal fin were taken from randomly selected individuals. These sampled muscles were preserved in metal free formaldehyde to be analyzed their heavy metals content in the laboratory. Analyses of iron, manganese, lead and mercury in fish were done by using wet and dry ashing method (Cantle, 1982). The method was followed by digestion before the samples were measured by Atomic Absorption Spectrophotometer (Greenberg *et al,* 1994). One to twenty five grams of dry sample burnt until scorched, and grind until fine. Five-mL concentrated nitric acid (HNO_3) was added to the sample before it was heated on a hot plate until brownish nitrate vapour was disappeared. After this step, five mL 30 percent hydrogen peroxide (H_2O_2) was added to the samples before heating continued up to two hours. The black brownish sludge resulted was diluted with five percents HNO_3 (v/v). The slurry was then poured into Kjehldahl flask fitted with reflux condenser. The samples were distilled for 3-4 hours and the vapor phase was condensed and collected in metal free polyethylene vials. This step was to ensure that no acid accumulates in the sample and contamination is minimized. The distillate was later analyzed by Atomic Absorption Spectrophotometer. Dilution up to ten times was performed if necessary. The analysis for Hg used Cold Vapor Flameless Atomic Absorption Spectrophotometry method as described by Cantle (1982).

Analysis of data

The $A_{s\cdot w}$ is the index of ratio of particular metal concentration in sediment compared to its concentration in water column.

RESULTS AND DISCUSSION

Concentration of heavy metals in water

As shown on Table 1, the average of concentration of dissolved iron (1.845 mg/1) and manganese (0.073 mg/1) in Lake Lutan water was the highest. Iron and manganese concentrations in Lake Takapan, which were 1.260 mg Fe/1 and 0.029 mg Mn/1 respectively, were the second highest followed with that of in Lake Rengas (1.199 mg Fe/1 and 0.027 mg Mn/1). From these facts, the average concentrations of this metal ion in Lake Lutan were still within natural range. Boyd (1990) stated that the concentration of these metal ions found in the natural water were 1 to 5 mg Fe/1 and 0.2 to 0.5 mg Mn/1.

Regarding to suspended matter, among all of them, Lake Lutan (164.0 mg/1) was the most turbid. It was then followed by Lake Rengas (147.1 mg/1), Lake Takapan (105.6 mg/1), and Lake Sembuluh (27.6 mg/1). It is probably that these heavy metals were adsorbed by clay particles and chelated by aquatic humic substances. Boyd (1990) stated that some heavy metals also form complexes with oxides, hydroxides, and carbonates in water

Table 1. The heavy metals concentration and other parameter values in water column of oxbow lakes in Central Kalimantan

No	Name of location	Parameter						
		Fe mg/1	Mn mg/1	Pb mg/1	Hg mg/1	pH*	SS* mg/1	HA** mg/1
1	Lake Takapan	1.260	0.029	0.024	0.057	4.22	105.6	74.6
2	Lake Rengas	1.199	0.027	0.056	0.008	4.38	147.1	118.7
3	Lake Lutan	1.845	0.073	0.051	0.010	5.41	164.0	74.4
4	Lake Sembuluh	0.455	0.047	0.173	0.057	4.47	27.6	86.7

* SS= Suspended Solid, data from Hartoto (in publication)
** HA = Humic Acid, data from Hartoto & Yustiawati, (in publication)

Lead concentration in all four aquatic systems which were 0.024 mg/1 (Lake Takapan), 0.056 mg/1 (Lake Rengas), 0.051 mg/1 (Lake Lutan), 0.173 mg/1 (Lake Sembuluh) is still within the range of safe concentration (0.1 mg Pb/1). According to Boyd (1990), safe concentration of mercury and lead are 0.0001 mg Hg/1 and 0.1 mg Pb/L respectively.

The behavior of lead in natural waters is a combination of precipitation equilibria and complexing with inorganic and organic ligands. The degree of mobility of lead depends on the physicochemical state of the complexes formed. In acidic media, humic acid sorbs lead less stronger than clays, but the trend reverses at pH $\geq$ 6.5 where soluble Pb-humates change for retention on the solid phase. Sorption of lead by river sediments correlated to organic content and grain size (Ramamoorthy and Kushner, 1975; Wilson, 1976). Table 1 also indicates that there was a positive correlation between concentration of Pb and SS, as observed in Lake Takapan, Lake Lutan and Lake Rengas. Most of all of the lakes under studied indicate a high concentration of humic acid, low pH and significant concentration of suspended solid that suspected also contain some clays (diameter<0.45 um). In relation to that, presumably the lead which is dissolved in the water column tend to precipitated by the suspended solid particles to the lake bottom. Consequently the concentration in the water is low as indicate by the results of the study.

On the other hand, total mercury concentration in all lakes (0.008-0.108 mg Hg/1) exceeded the safe concentration. The concentration of mercury in Lake Takapan and Lake Sembuluh was very high in this both lakes. These might be in part caused by the input of mercury used by unlicensed gold mines occurring in the upper segment of River Kahayan and its tributary.

Heavy metals in sediment

As shown in Table *2,* in the oxbow lakes, the concentrations of iron in sediment are range from 1700 to 2700 times higher than in the water. For manganese, the $A_{s\text{-}w}$ values ranged from 2100 to 4100, but for lead the $A_{s\text{-}w}$ value ranged from 37 to 532. Mercury was also retained in the sediihent of oxbow lakes, in which the sediments in Lake Lutan tended to retain the metals the most, while Lake Takapan sediment the retained the metal the least. This pattern probably due to the facts that Lake Lutan is the oxbow lake that receives water from river Kahayan that was observed more turbid and contained higher suspended solid, which is suspected to coagulate the dissolved mercury.

Sediment of Lake Lutan was also extremely high on iron and manganese that were 4952.4 and 153.7 mg/kg dry weights respectively. Table 2 showed different values of $A_{s\text{-}w}$ values for all heavy metals examined in this study. $A_{s\text{-}w}$ value of iron in Lake Sembuluh was the highest but lowest in Lake Rengas. These data indicated that in Lake Sembuluh iron tended to be deposited but in Lake Rengas tended to be more in solution. On the contrary, the $A_{s\text{-}w}$ value of manganese in Lake Sembuluh was the lowest, while in Lake Rengas the $A_{s\text{-}w}$ value of this metal was the highest.

Lead showed a very different pattern. In Lake Takapan this metal tended to settle in the sediment, but in Lake Sembuluh it was retained in solution. There was a possibility that lead in Lake Takapan was bound to organic matter and enriched in the humic acid fraction. However this explanation needs further study. For comparison Nriagu and Coker (1980) stated that in Lake Ontario about five to ten percent of lead in sediments bound to organic matter and enriched in the humic acid fraction. Humic and fulvic acids accounted for 9 % and 1-4 % of the organic matter, respectively.

Mercury tended to be deposited in Lake Lutan and Lake Rengas, but it tended to remain in solution in Lake Takapan and Lake Sembuluh (Table 2). The mercury concentration in Lake Lutan was three times higher. For Lake Takapan (0.424 mg Hg/kg dry weight), Lake Rengal (0.887 mg Hg/kg dry weight) and Lake Sefnbuluh (0.799 mg Hg/kg dry weight) was still within the range. Concentration of dissolved mercury in unpolluted fresh water varies among 0.00002 to 0.0001 mg/1 (Salanki and Licsko,1991). A significant fraction of mercury in natural waters associated with suspended solids and accounts for a substantial portion (next to the water column) of the transported mercury in the aquatic environment.

In Table 2, it was found that the sediment samples from all lakes are contaminated by mercury up to more than 1600 times to 10000 times the concentration in the sediment of uncontaminated natural waters. According to Moore and Ramamoorthy (1983) the level of dissolved Hg in sediment is 0.00026 mg/kg dry weight. As stated by Ramamoorthy and Rust (1976) the rate of absorption of Hg depends largely on the physical-chemical characteristics of the sediment such as surface area, organic content, cation exchange capacity, grain size and its bonding constant. Visual examination on upper most sediment layer in Lake Takapan, Lake Lutan and Lake Rengas indicated that the composition mainly consisted of organic material, but for Lake Sembuluh mostly consisted of quartz sand.

Unlicensed gold mining operation is nearly everywhere in Central Kalimantan river segment, and the miners used pumps to withdraw the river sediment suspected of containing unpurified gold nugget. The purification process of the gold nugget are conducted using approximately 1 g of liquid mercury to extract each gram of gold. This used mercury usually discarded nearby the mining location. On the other side, the pumped sediment in most cases is mixed in flowing water of the column, which at the end will reach more stagnant condition of the lake and settle down as contaminated lake sediment. It is important to be noted here that Lake Lutan, Lake Rengas, Lake Takapan is the oxbow lakes that received water from River Kahayan, River Rungan or both. On the other hand Lake Sembuluh is the fiuviatilic lake that received water from River Seruyan. The area around these lake is the location of this unlicensed gold mining.

Bioaccumulation of Pb, Hg, Mn and Fe in fish muscle

The results of iron, manganese, lead and mercury analysis in fish muscles were presented in Table 3, Table 4, Table 5 and Table 6. The fish inhabiting Lake Sembuluh already contaminated by organic mercury as well as in oxbow lake system. These were indicated by average value of this metal as much as 0.933 mg/kg wet basis in lakes (Table 7) and as much as 0.096 mg/kg wet basis in oxbow lakes (Table 8). According to US Public Health Service (1989) minimal risk level for mercury in food for greater than 14 days exposure to human is 0.063 mg/kg (wet basis) of inorganic mercury. Therefore most of the fish muscles in oxbow lakes systems were already contaminated by organic mercury above the safety level, except for most of the first fish consumer. This fact was in conformity with the statement of mercury pollution in all lakes mention before. :

Table 3 showed that there were 21 fish species that were consisted of six species of primary consumers, fourteen species of second consumers and one species of third consumer. It was found that , the highest bioaccumulation of iron was in the "Seluang batang" *(Rasbora argyrotaenia).* In which its food source were remnant fragments plant or animal (detritus.* This fish is always swimming at the edge of any water body, either when water was rising or descending, that can be associated with the seeking of food. This foraging behavior might explain why this primary consumer had highest iron, as well as manganese and mercury concentration in their muscle.

Lead bioconcentration in fish muscle in oxbow lakes was lower (Table 8) than the report on that in lake and river in USA that was 7.9 mg/kg wet weight in invertebrates, 0.2-0.5 mg/kg wet weight primary carnivores, and 0.3-0.4 in secondary carnivores (Wilson, 1976). However, first consumer in Lake Sembuluh had lead concentration that was more than above report.

In our observation, the potential non point source of lead as pollutant was only the leaded gasoline and small amount of oil used as fuel and lubricants for small boats for used as water transportation. However, since most of the boat was a small and only 30 percent of them used gasoline as fuel, the other use kerosene and diesel fuel, this might explain why lead concentration in water is still within the range of safe concentration. With this fact, it is acceptable to consider the concentration of lead in water as the back ground level. Moreover the concentrations of lead in fish muscle are range from 0.150 to 0.420 mg/kg (wet basis).

Table 8 indicates that the highest value of Fe, Mn, Pb and Hg in fishes were in second consumer or in third consumer. For iron, second consumers show the highest average bioconcentration, follow by the third consumer and the least is the first consumer. For lead the highest concentration were similarly found on the second consumer but the lead concentration in primary and third consumer is similar. For manganese and mercury, highest concentration was similarly found in the top predator, but the lowest concentration is found the primary consumer for mercury and in second consumer for manganese. There is not enough information to explain this variable pattern, so more detailed study in concentration of these metals in other natural diets type is required.

CONCLUSION

In relation to the four elements of heavy metal examined in this study, only mercury could be regarded as pollutants in the sampling stations. The other metals concentration in the water observed could be considered as the background levels of each metal in nature. Based on this results, the average of background levels of heavy metals in the oxbow lake receiving water from tributary rivers or main rivers represented by the sampling stations ranged from 1.100 to 1.900 mgFe/1, 0.020 to 0.070 mgMn/1 and 0.020 to 0.050 mgPb/1.

Furthermore the back ground fish bioconcentration are 4.167 to 5.337 mg Fe/kg (wet basis), 0.110 to 0.167 mg Mn/kg (wet basis) and 0.157 to 0.415 mg Pb/kg. Back ground levels of these three heavy metals are suggested to be used as a base of criteria for evaluation on inland water fishery reserve. From human health point of view the concentration of mercury in water and fish muscle was far above minimum risk level, therefore it posses a potential threat to human health. The other heavy metal is still at below the acceptable limit for natural waters.

Table 2. Partitioning of some heavy metals in the environmental pools of oxbow lakes and arger low land lakes in Central Kalimantan

No.	Name of Location	Concentration in water mg/L				Concentration in sediment mg/kg (dry weight)				A,.w			
		Fe	Mn	Pb	Hg	Fe	Mn	Pb	Hg	Fe	Mn	Pb	Hg
1	Lake Takapan	1.260	0.029	0.024	0.057	2184.20	61.64	12.76	0.424	1733.5	2125.7	531.8	7.4
2	Lake Rengas	1.199	0.027	0.056	0.008	2045.65	110.48	10.74	0.887	1706.1	4091.8	191.8	110.9
3	Lake Lutan	1.845	0.073	0.051	0.010	4952.39	153.73	16.54	2.643	2684.2	2105.9	324.4	264.3
4	Lake Sembuluh	0.455	0.047	0.173	0.057	1449.63	13.22	6.46	0.799	3186.0	281.2	37.3	14.0

As-w: Sediment Accumulation Factor, that is a number calculated by dividing the concentration in the sediment pool with the concentration in the water pool

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Table 3. The bioconcentration of heavy metal in some fish species from Lake Takapan

No	Name of Fish		Number of	Bioconcentration (mg/kg dry weight)				Estimated position in
	Local name	Scientific name	Samples	Fe	Mn	Pb	Hg	me iooo weo
1	Sepatung	*Pristolepis fasciata*	1	17.625	1.277	0.164	0.639	Primary consumer
2	Kalabao	*Osteochilus kelabau*	1	lg.766	0.226	0.462	0.113	Primary consumer
g	Sanggang	*Puntius waandersi*	2	24.044	0.370	0.389	1.045	Primary consumer
4	Puyau masau	*Osteochillus hasselti*	1	20.515	0.701	5.667	1.709	Primary consumer
5	Kohing	*Cyclocheilichthys apogon*	3	17.072	0.169	5.667	1.709	Primary consumer
6	Gandaria	*Dangilla ocellata*	1	25.195	0.277	0.102	0.000	Primary consumer
7	Seluang batang	*Rasbora argyrotaenia*	2	49.863	0.266	23.740	9.0g9	First consumer
g	Lais bamban	*Cryptopterus apogon*	4	9.488	0.208	3.981	0.673	Second consumer
9	Lais biasa	*Pterocryptis furnessi*	2	3.405	0.730	2.629	1.135	Second consumer
10	Lais bulu	*Cryptopterus cryptopterus*	3	15.049	<0.005	6.781	1.690	Second consumer
11	Adungan	*Hampala macrolepidota*	1	13.468	0.146	1.103	1.041	Second consumer
12	Singaringan	*Mystus nigriceps*	3	9.243	0.151	5.245	0.4gg	Second consumer
13	Lais benihis	*Cryptopterus limpok*	3	10.423	0.302	1.495	0.408	Second consumer
14	Lawang	*Pangasius spt*	1	22.884	0.467	0.000	0.117	Second consumer
15	Jelawat	*Leplobarbus hoeveni*	2	29.174	0.543	2.121	0.497	Second consumer
16	Lais bulu	*Cryptopterus cryptopterus*	1	2.406	0.197	6.701	0.872	Second consumer
17	Lais bantut	*Cryptopterus bicirhis*	2	5.411	0.267	6.613	1.798	Second consumer
lg	Lais timah	*Cryptopterus sp*	1	2.570	0.851	2.3g0	6.818	Second consumer
19	Puyau	*Osteochillus triporos*	1	5.492	0.013	6.953	3.158	Second consumer
20	Baung	*Mystus nemurus*	3	12.716	0.220	4.219	0.638	Second consumer
21	Tapah	*Wallago leeri*	1	24.775	0.409	0.338	0.154	Third consumer

Table 4. The bioconcentration of heavy metals in some fish from Lake Rengas

No	Name of fish		Number of	Bioconcentration (mg/kg dry weight)				Estimated position
	Local name	Scientific name	Samples	Fe	Mn	Pb	Hg	in thp fnnH wph
1	Seluang batang	*Rasbora argyrotaenia*	2	35.310	2.148	2.734	1.171	Primary consumer
2	Lais bamban	*Cryptopterus apogon*	1	25.5gO	0.778	2.309	0.468	Second consumer
3	Baung	*Mystus nemurus*	2	25.043	0.122	2.989	1.517	Second consumer
4	Lele	*Clarias leiacanthus*	2	14.462	0.261	5.106	1.029	Second consumer
5	Bilis /benangin	*Thynnichthys thynnoides*	1	24.551	0.957	4.820	2.229	Second consumer
6	Lais biasa	*Cryptopterus lais*	1	4.339	<0.005	2.031	0.858	Second consumer
7	Lais bulu	*Crytopterus cryptopterus*	1	10.119	<0.005	7.508	1.187	Second consumer
g	Tapah	*Wallago leeri*	2	22.320	<0.005	0.944	0.901	Top consumer

Table 5. The bioconcentration of heavy metals in siome fish from Lake Lutan

No	i\ame oi iisn		Number offish	Bioaccumulation (mg/kg dry weight)				Estimated position in
	Local name	Scientific name	samples	Fe:	Mn	Pb	Hg	the food web
1	Lais biasa	*Cryptopterus lais*	1	6.712	0.263	0.395	0.099	Second consumer
2	Betet/Semumul	*Amblyrinchichthys truncatus*	1	2.773	0.682	0.977	0.341	First consumer
3	Seluang tipis	*Oxygaster anomalura*	1	10.846	0.552	3.456	0.138	First consumer

Table 6. The bioaccumulation of heavy metals in some fish from Lake Sembuluh

'Mo	Name ot tisn		Number of	Bioconcentration (mg/kg dry weight)				Estimated position
	Local name	Scientific name	fish samples	Fe	Mn	Pb	Hg	in the food web
1	Biis	*Thynnichthys thynnoides*	1	4.574	<0.005	10.005	0.740	First consumer
2	Salap (Betutung)	*Puntius schwanefeldi*	1	2.242	O.005	3.57g	0.902	First consumer
3	Selusur batu	*Botia hymenophysa*	1	15.507	0.000	1.206	1.048	First consumer
4	Patung	*Pristolepis fasciata*	1	9.209	0.649	1.712	0.521	First consumer
5	Penganten	*Botia macracantha*	1	2.817	<0.005	1.024	0.297	Second consumer
6	Kakamban	*Cryptopterus lais*	1	15.300	O.005	14.867	1.121	Second consumer
7	Baung	*Mystus nemurus*	2	42.561	0.547	1.268	0.782	Second consumer
8	Senggiringan	*Mystus nigriceps*	1	20.296	0.000	8.866	2.144	Second consumer
9	Tapah	*Wallago leeri*	1	20.956	0.197	0.014	2.813	Top consumer
10	Toman	*Channa micropeltes*	1	35.162	3.513	3.686	1.429	Top consumer

Table 7. Average bioconcentration of fishes of four heavy metals at various positions in the fish community food web in the oxbow lakes

No	Name of Lake	Type of consumer	n of species	n of sam pie	Bioconcentration mg/kg (dry weight)				Bioconcentration mg/kg (wet basis)				BAF (wet basis)			
					Fe	Mn	Pb	Hg	Fe	Mn	Pb	Hg	Fe	Mn	Pb	Hg
1	Lake Takapan	Primary	7	11	13.691	0.336	1.383	0.579	2.634	0.065	0.266	0.111	2.09	2.24	11.0	1.97
		Second	13	27	7.369	0.189	2.845	1.093	1.418	0.036	0.547	0.210	1.13	1.24	22.8	3.69
		Third	1	1	24.775	0.409	0.338	0.154	4.767	0.079	0.065	0.030	3.78	2.71	2.71	3.76
2	L. Rengas	Primary	1	2	35.310	2.148	2.734	1.171	6.794	0.413	0.526	0.225	5.67	15.31	4.29	28.20
		Second	6	8	13.012	0.265	3.095	0.911	2.504	0.051	0.595	0.175	2.09	1.89	0.91	21.91
		Third	1	2	22.320	<0.005	0.944	0.901	4.294	<0.001	0.182	0.174	3.58	-	2.24	21.67
3	L. Lutan	Primary	2	2	6.809	0.617	2.217	0.239	1.310	0.119	0.427	0.046	0.71	1.63	8.36	4.60
		Second	1	1	6.712	0.263	0.395	0.099	1.291	0.051	0.076	0.019	0.70	0.69	1.99	1.90
		Third	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	L. Sembuluh	Primary	4	4	7.883	0.428	4.125	0.803	3.468	0.188	1.815	0.353	7.62	4.00	10.5	6.20
		Second	4	5	16.195	0.109	5.205	0.809	7.125	0.048	0.437	0.356	15.67	1.02	13.2	6.24
		Third	1	1	28.059	1.855	1.850	2.121	12.349	0.816	0.814	0.933	27.13	17.39	4.70	16.37

Table 8. Average bioconcentration of some heavy metals in fishes from oxbow type inland water*

No	Feeding habit	Average bioconcentration in mg/kg (wet basis)			
		Fe	Mn	Pb	Hg
1	Primary consumer	4.167	0.131	0.157	0.035
2	Second consumer	5.337	0.110	0.415	0.076
3	Third consumer	4.945	0.167	0.157	0.096

• average from the data from Lake Lutan, Lake Rengas and Lake Takapan