Parasites and Macroinvertebrates as Indicators of Environmental Stress: The Case of Mindu Catchment Area

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Abstract: *A total of 42 fish belonging to ten different species were sampled from the Mindu Dam and analysed for parasites. Oreochromis urolepis were infected by four parasite species, while Brycinus lateralis was infected by one parasite species. The macroinvertebrates were sampled from four sites in the Mindu catchment area, sorted and classified into three ecological categories; 19 families of macroinvertebrates were classified as pollution tolerant and most of these species were collected from the tail race of the dam. 15 families were intermediate in terms of pollution tolerability and three families belonged to a pollution sensitive group. Most of the metallic ions were detected from the sediments. Zink, Chromium and Lead were detected in all the samples from all the sampling localities except in Ngerengere river (Zn- water sample) and the dam's tail race (Cr-water sample). Mindu dam is under strong anthropogenic pressure due the increase in human settlements around its catchment area. In addition people cultivate in the nearby surroundings and use pesticides and fertilizers to nourish their crops, the residues of which are constantly being washed into the dam. All these contribute to undermine the health of Mindu as a habitat and as such disturb biological diversity in the dam.*

Key words: Parasites, Macroinvertebrates, Environment, Pollution, Biodiversity

INTRODUCTION

Healthier, less degraded ecosystems tend to have more parasites with complex life cycles than do altered systems, because these parasites depend on functioning natural systems. For example, most trematodes must infect three different host animals—first, intermediate, and final—to develop into egg-producing adults. If one of the host animals /commonly the macroinvertebrates is missing, as it may be in a degraded ecosystem, the parasite cannot complete its life cycle (Williams & Jones, 1994).

Changes to natural systems can profoundly alter the parasite communities. Changes most likely to affect parasite communities are alterations in the communities of the parasites' hosts, the animals/macroinvertebrates that the parasites use to complete their life cycles (Esch et al., 1990). Today, these changes are most likely to occur because of climate change and massive environmental degradation, including habitat fragmentation, pollution, overharvesting of aquatic species, and introduction of nonnative species (Turcekova et al., 2002).

A measure of the trematode community, gathered from dissecting snails (macroinvertebrate) that act as the first host of these worms, provides a single, integrated snapshot of host species that have been in an estuary over the average lifespan of the snails that occur in an environment. Intact trematode communities are assurances of the healthy integrity and diversity of species within the aquatic environment (Williams & Jones, 1994).

Trematode infection begins as a snail grazing on algae incidentally ingests worm eggs, perhaps from a bird dropping. The eggs hatch into worms that prevent the snail's own reproduction. Instead, the infected snail nourishes the growing larval worms, which eventually develop into a free-swimming stage and leave the snails to seek their second, or intermediate, host (Esch & Fernandez, 1993).

Depending on the worm species, the intermediate host might be a crab, fish, bird, or another species of snail. For instance, Diplostomum species infect the catfish, Clarias gariepinus as the second intermediate hosts. By travelling to the fish's brain, the worm causes the fish to behave differently from other catfish. An infected fish will sometimes move about jerkily near the water's surface, turning on its side and flashing its light-coloured belly. This behavior attracts predators like herons; capturing infected fish is 10 to 30 times easier for the heron than capturing healthy fish (Chappell et al., 1994).

The heron, in turn, becomes the host to the adult worm. The adult trematode takes up final residence in the bird's gut, releasing thousands of eggs that are deposited by way of bird droppings back into the aquatic environment, completing the life cycle of the parasite (Chappell et al., 1994).

The presence of such trematodes in an ecosystem is a clear indication of its healthiness and the possible numbers of animals/macroinvertebrate available in the area. Parasites therefore are good indicators of biodiversity. The current study was geared towards understanding the role of parasites and their macroinvertebrate host as indicators of environmental health and biological diversity using the Mindu Dam, Morogoro region as a case study.

Study area

The study was conducted at Mindu Dam (Fig. 1) found in Morogoro region, 60 51' South, 310 41' East and 530 m ASL. The dam covers an area of about 10 km2 and is surrounded by Uluguru Mountains from which several rivers including Ngerengere, Mzinga and Mgera feed the dam. The dam was constructed primarily to provide water for Morogoro municipality and currently supplies water to about 70% of its water requirements. The dam is also a source of fish, several species including Oreochromis karomo, Oreochromis urolepis, Oreochromis niloticus and Clarias gariepinus occur in the dam. About twelve snail species and other macroinvertebrates have also been documented from the dam (Kigadya, 1998).

Apart from serving as a source of water for the urban population, horticultural farming also takes place in the nearby surroundings (southern parts of the dam along river banks). Peasants use pesticides and fertilizers for crop nourishments, the residues of which spills into the Dam. These pause a serious threat to the health of the Mindu Dam. Streams from the Uluguru Mountain, with possible chemical pollutants from the weapon manufacturing plant (Mzinga) located a few kilometres, empties into the Dam to make the problem worse. The study therefore was designed to investigate the use of parasites and macroinvertebrates as indicators of water contamination in the Mindu Dam possibly from the sources stipulated.

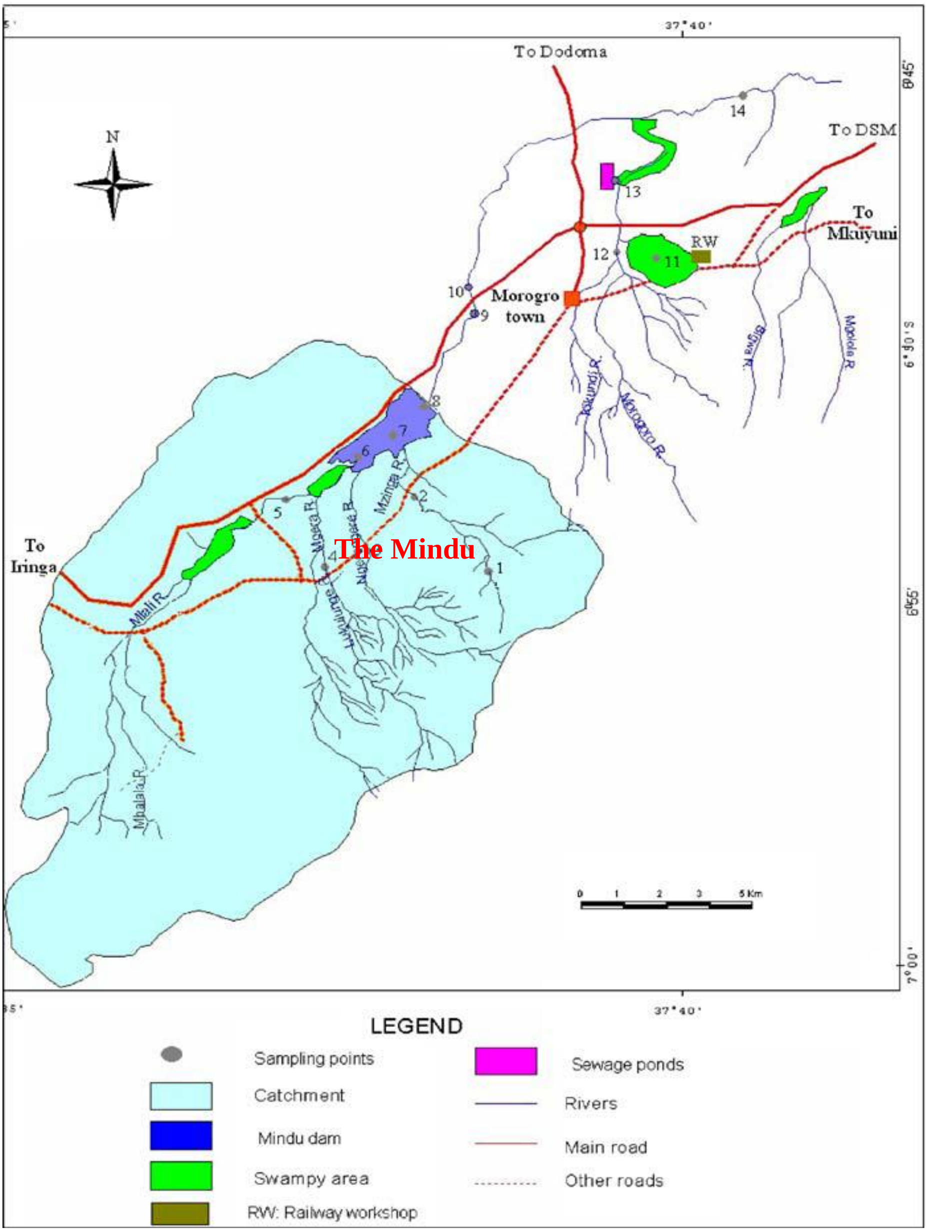

Figure 1: The Mindu Dam and its catchment area

Sampling methodology

Fish and parasites samples

Fish samples were directly fished from the dam by using gill nets. Samples of fish from different species were later opened by mid-ventral incision using stainless steel scissors and examined for parasites. When found, the parasites were picked by a stainless steel forceps and transferred into clean 1.0 ml plastic vials and stored frozen until needed for analysis. Fish and parasites species richness were determined by counting. In addition a portion of muscle tissue from a subsample of fish was collected and stored the same way for chemical pollutant analysis. All care was taken during handling to avoid possible metallic contamination.

Macroinvertebrate samples

At each sampling location, using a Surber sampler (a 500 ìm mesh bag connected to a 1 foot square sampling frame), a composite of three independent macroinvertebrate samples were collected and preserved in 70% ethanol. Sub-samples of macroinvertebrates were stored frozen as above for later heavy metal analysis. Soil sediments and water from the dam, nearby streams and horticultural farms were also collected for heavy metal analysis.

Laboratory analysis

Analysis of soil sediments and water for heavy metal contamination

Each frozen sample was thawed separately and sub-sampled for dry weight determination at 105 ^{o}C. The other portions of the samples was lyophilised, freeze-dried, finely crushed and homogenized in agate mortar and pestle. About 1 g of the homogenized tissue was digested in 1 ml conc. HNO_3 in a culture test tube incubated at 80 ^{o}C in a water bath. After total digestion and subsequent cooling, the solution was diluted to 20 ml and analysed for chemical pollutants in a closed system by atomic absorption spectrophotometry. Data obtained were analysed using appropriate statistical tests.

Analysis of macroinvertebrates

In the laboratory, a random-subsampling technique was used to isolate from the original composite from each site a subsample of at least 200 individuals. These animals were sorted, enumerated and identified. Animals remaining in the composite sample were surveyed, and single individuals representing species not already included in the 200+ individual-subsample were added to it. This step allowed us to note the presence of potentially important indicator species in the sample that otherwise would be omitted. Consequently, specimens were identified in the laboratory to family level, using dissecting and compound microscopy.

Metrics and statistical treatments of macroinvertebrates

Metrics are quantitative representations of single (simple metric) or combined (multi-metric) characteristics of a sampled biological community. Using methods widely employed in the study of stream communities, Beck's Index, was calculated. Ultimately, substantial changes in biotic characteristics at a particular site can indicate stressful conditions. Such changes may be the result of site-specific environmental characteristics, or they may reflect region-wide features (e.g., rainfall patterns).

RESULTS

Fish and Parasite species richness

A total of 42 fish belonging to ten different species were sampled from the Mindu Dam and analysed for parasites. The total length of the fish ranged from 10.2 to 17.6 cm, the minimum weight was 13.1 gm while the maximum weight was 129.6 gm found in *Astatotilapia* sp1. The mean condition factor (CF) ranged between 0.7±0.05 to 1.9±0.08 (Table 1). Five parasite species were recovered infecting six species of fish, *Oreochromis urolepis* were infected by four parasite species, four fish species were infected by two parasites, *Brycinus lateralis* was infected by one parasite species while four fish species were not infected. A minimum number of parasites per host fish were one whereas *Oreochromis karomo* and *Astatotilapia* sp2 were infected by a maximum of eight parasite species (Table 1).

Table 1: Fish's total length (TL), weight, condition factor (CF) and the number of parasites recovered from a total of 42 fish specimens examined (Values are presented as means)

	Fish Characteristics					Parasites species				
Fish species	**#Ex**	**TL**	**Weight**	**MxL***	**CF**	**Dactylo**	**Cest 1**	**Cest 2**	**Trema (eye)**	**Acantho**
Brycinus lateralis	6	11.7	18.2	14.0	1.1±0.06	1	0	0	0	0
Oreochromis urolepis	6	16.7	92.3	44.0	1.9±0.08	6	1	4	1	0
Marcusenius macrolepidotus	6	17.6	50.0	32.0	0.9±0.1	0	0	0	0	0
Petrocephalus catastoma	6	10.2	14.8	15.0	1.4±0.2	0	0	0	0	0
Labeo victorianus	6	11.6	14.9	41.0	0.9±0.07	0	0	0	0	0
Barbus paludinosus	2	11.0	13.1	15.0	1.0±0.1	0	0	0	0	0
Oreochromis karomo	2	16.5	111.3	28.0	1.4±0.1	7	0	0	0	8
Astatotilapia sp1	3	17.1	129.6	-	1.6±0.1	7	0	0	0	6
Astatotilapia sp2	3	10.7	32.8	-	1.5±0.09	8	0	0	0	4
Clarias gariepinus	2	16.3	78.4	170.0	0.7±0.05	4	0	0	0	4

***MxL** – Maximum total length of fish according to FishBase 2000.
#Ex – Number of fish examined

The Macroinvertebrates

The macroinvertebrates were sampled from four sites in the Mindu catchment area, sorted and classified into three ecological categories; 19 families of macroinvertebrates were classified as pollution tolerant and most of these species were collected from the tail race of the dam. 15 families were intermediate in terms of pollution tolerability and three families belonged to a pollution sensitive group (Table 2). The tolerant group are those that withstand different levels of pollution in the environment, while the sensitive ones do not withstand the minimum level of pollutants in the environment.

Table 2: Different groups of macroinvertebrates identified across the Mindu dam

	MGELA			MZINGA			NGERENGERE			TAIL RACE		
Family Name	I	II	III	I	II	III	I	II	III	I	II	III
Class I: TOLERANT												
Baetidae	27	3	45	33	43	27	38	23	12	2		1
Potamonautidae	2	2	2							3		
Chironomidae	36	10	40	31	36	35	55	58	51	658	832	1018
Simuliidae	8	3	11		19	3						7
Tipulidae	2	1										
Oligochaeta	2					1	3	1		13	7	7
Coenagrionidae	6	1	8	3	1	3		2				
Hydropsychidae	2	4		7	15	9	3		1			2
Mellaniidae			2								9	36
Lymnacidae			1									
Ephydridae				1								
Nepidae					1							
Belostomatidae					1							
Corixidae							2					
Dytiscidae larvae								1				
Ceratopogonidae										6	12	2
Tabanidae											1	
Psychodidae											3	
Hirudinae											2	5
Class II: INTERMEDIATE												
Aeshnidae	1											
Gomphidae	7	8	6	1	8	3	8	1	3			
Calopterygidae	1			2								
Leptoceridae	2	7	2			7		5	2			
Hydrophilidae larvae			1									
Caenidae				7			21	64	44			
Corduliidae				4								
Elmidae larvae				1	2	6		1	1			
Psephanidae					6	1						
Ancylidae							2	1				
Planorhidae (Bulinus)							1					
Ostracoda										255		
Copepoda										12		
Atyidae										4	4	5
Ecnomidae										3	5	9
Class III: SENSITIVE												

Family Name	MGELA I	MGELA II	MGELA III	MZINGA I	MZINGA II	MZINGA III	NGERENGERE I	NGERENGERE II	NGERENGERE III	TAIL RACE I	TAIL RACE II	TAIL RACE III
Notonemounidae			1	2								
Perlidae			1		19	14						
Teloganodidae					21	24	4					

Metrics and statistical treatments of macroinvertebrates

Beck's Biotic Index

$BI = 2n_I / n_{II}$

Where; BI = Beck's biotic index

n_I = number of class I species identified from the samples

n_{II} = number of class II species identified from the samples

	General	Mgela	Mzinga	Ngerengere	Tail race
Class I	19	10	9	7	11
Class II	15	5	7	6	4
$BI = 2n_I / n_{II}$	2.53	4.0	2.57	2.33	5.5

Interpretation:

Index value	**Description**
0	Stream grossly polluted
1 to 5	Stream moderately polluted
6 to 9	Stream clean, but with a monotonous habitat and in stream velocity
10 or greater	Stream clean

Inference: The Mindu dam is moderately polluted, but progressing towards a gross pollution.

Trace metal analysis:

Distribution of trace metals in water, sediments and fish of the Mindu Dam are as shown in Table 3 below. Most of the metallic ions were detected from the sediments and fish muscles as opposed to the water. Zink, Chromium and Lead were detected in all the samples from all the sampling localities except in Ngerengere river (Zn- water sample) and the dam's tail race (Cr-water sample).

Table 3: Comparison of levels of trace metals analyzed in water, sediments and fish in Mindu dam

	Water Samples (µg/L)				Sediment Samples (µg/kg)			Fish (µg/g)
Analyte	**Mzinga**	**Tail race**	**Ngerengere**	**Mgela**	**Mzinga**	**Ngerengere**	**Mgela**	
Zn	12.85	2.91	BDL	1.65	92.56	74.09	94.39	244.40
Cu	0.64	BDL	BDL	BDL	399.9	488.6	383	4.46
Cd	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Fe	BDL	BDL	BDL	BDL	2052	1623	94.39	348.07
Cr	3.73	BDL	0.66	1.69	5.76	75.74	98.6	3.43
Pb	0.01	0.87	0.63	1.57	5.30	75.02	4.014	3.37

BDL= below detection limit

DISCUSSION

The results of this study indicated a highly reduced parasites population infecting fish in the dam as compared to what used to be in previous years. Kibebe (1994) found high prevalence of nematodes and cestodes from the alimentary tract of catfish, from Mindu Dam. Kibebe's study was, however, limited in scope, as parasites residing in sites other than the gut were not investigated. Nkwengulila (1995) reported the occurrence of the Digenea *Diplostomum mashonense* Beverley-Burton, 1963, in the cranial cavity of *C. gariepinus* from Mindu Dam. Furthermore, Nkwengulila (1998) reported the occurrence of about 30 species of helminthes in *C. gariepinus* from the same area. This was not the case in this study. In addition, the types of parasites found in the current investigation were those that tolerate different types of pollutants, which, further correlates with their corresponding invertebrate intermediate hosts isolated from the dam.

Though the prevalence of the isolated parasites infecting fishes in the Mindu Dam was low compared to previous studies, the information delivered by the presence of these parasites in the dam and its catchment area is of paramount importance. For instance, two species of cestodes were isolated from the gut of *Oreochromis urolepis* and a trematode was found infecting the eye of the same fish species. In addition, a number of acanthocephalans were isolated from *Oreochromis karomo*, Astatotilapia sp. and *Clarias gariepinus*. Each of the four parasites species required not less than three different invertebrate intermediate hosts in order to complete its life cycle.

Thirty six families of macroinvertebrates were identified in the current study, the majority of which belonged to a class I of environmental integrity according to Beck’s Biotic Index (BBI). These types of macroinvertebrates are those that tolerants different forms of pollutants and thus indicative of the same. Among the families of macroinvertebrates identified in the dam, belongs that that support the life of the four fish parasites found from the Mindu in this study. It is therefore postulated that the parasites found in this study are also tolerant to moderate form of pollution. The BBI results indicated that the Mindu and its catchment area are moderately polluted. The findings are in line with what Mdegela et al. (2009; 2013) found from the same environment using a different technique.

The above findings are further supported by the results of trace metal analysis from water and sediment samples collected from the Mindu Dam. The samples of water from the Mindu catchments area had trace metal concentrations within levels acceptable by WHO (2007) for drinking water quality standard. On the other hand, higher levels of Fe and Cu were detected in all sediment samples, whereas concentration of Cr and Pb were high in Ngerengere and Mgela sediment samples. The current findings are against those reported by Mdegela et al. (2009). Cadmium and chromium are used in weapon manufacturing to provide a hard layer in the inner barrel surface that control corrosion, and Pb is used in bullet manufacturing (Gagan et al., 2012). The Mzinga weapon manufacturing plant could be a possible source of the discharge of these metallic pollutants into the Mindu catchments area. Wastewater from the plant is discharged into a treatment pond located within the Mindu catchments with possibilities of overflow in heavy rainy season. However, low levels of trace metals concentration detected in the area could be due to the absorption/adsorption effect of the wetland plants. The papyrus plants abundantly present in the area are known for their adsorption potential of trace metals from the environment (Nabulo et al., 2008). Yet to be documented nevertheless, are the levels of trace metal concentration in the wetland and various horticultural plants found in the catchments. These will further shed light as to why levels of trace metals concentration is relatively low when compared to what is found in the sediments from rivers draining into the Mindu dam.

Cadmium is a material with high toxicity, even at low exposure levels, with both chronic and acute effects on the environment and individual health (Susan et al., 2014). Exposure to Cd is linked to liver and kidney damage and is associated with lung cancer (Susan et al., opp. Cit.). Chromium is a health hazard; its exposure leads to increased risk of lung cancer, asthma and damage to nasal lining. Oral ingestion of Cr in drinking water may also cause cancer. Both Cr and Cd are water soluble and can migrate to accumulate in the environment. Determination of these elements in plants and invertebrate animals found in the vicinity of the Mindu catchments area is thus imperative if their present and effects are to be monitored and control measures taken in the earliest time possible.

CONCLUSION

Mindu dam is under strong anthropogenic pressure due the increase in human settlements around its catchment area. In addition people cultivate in the nearby surroundings and use pesticides and fertilizers to nourish their crops, the residues of which are constantly being washed into the dam, motor vehicle fuels from Dar-Iringa-Mbeya highway are also being washed into the dam. Chemicals from Weapon manufacturing plants also diffuse into the Dam. All these could contribute to undermine the health of Mindu as a habitat and as such disturb biological diversity in the dam.

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References

Chappell, L.H., Hardie, L.J., and Secombes, C.J. (1994) Diplostomiasis: the disease and host-parasite interactions. In Parasitic diseases of fish. Edited by A.W. Pike and J.W. Lewis. Samara Publishing Ltd., Tresaith, Dyfed, U.K. 59-86 pp.

Esch, G., Bush, A. and Aho, J. (1990) Parasite communities: Pattern and processes. Chapman and Hall. London. 335 pp.

Esch, G.W. and Fernandez, J.C. (1993) A functional biology of parasitism. Ecology and evolutionary implications. Chapman and Hall. London. 337 pp.

Gagan F., Deepesh G., Archana T. (2012) Toxicity of lead: A review with recent updates. Interdiscip Toxicol. 2012; Vol. 5 (2): 47–58. doi: 10.2478/v10102-012-0009-2.

Kibebe, J.D.N. (1994) Preliminary observations on the helminths of the alimentary tract and associated structures of the catfish, *Clarias gariepinus*. Third year project report, Department of Zoology and Marine Biology, University of Dar-es-salaam.

Kigadye, E.S.P. (1998) Parasites of the Mindu Dam. MSc. Thesis, UDSM.

Mdegela, R.H., Braathen, M., Pereka, A.E., Mosha, R.D., Sandvik, M. and Skaare, J.U. (2009) Heavy Metals and Organochlorine Residues in Water, Sediments, and Fish in Aquatic Ecosystems in Urban and Peri-Urban Areas in Tanzania. Water air and Soil pollution, 1: 369-379.

Mdegela, R.H., Mosha, R.D., Ngowi, H.A. and Nonga, H. (2013) Environmental and Health Impacts Associated with Usage of Agrochemicals in Mindu Dam Catchment Area, Morogoro, Tanzania. Huria journal, 15: 18-33.

Nabulo, G., Oryem O.H., Nasinyama, G.W., and Cole, D. (2008) Assessment of Zn, Cu, Pb and Ni contamination in wetland soils and plants in the Lake Victoria basin. Int. J. Environ. Sci. Tech., 5(1), 65-74.

Nkwengulila, G. (1995) Epidemiology and Taxonomy of *Diplostomum* species (Trematoda: Diplostomatidae) infecting fish of Llyn tegid, North Wales and Ruvu basin-Tanzania. Ph.D. Thesis, University of Liverpool. 321pp.

Nkwengulila, G. (1998) Taxonomy and Biology of the helminth fauna of the catfish, *C. gariepinus,* (Burchell, 1822) (Clariidae) and Tilapia (Cichlidae). Unpublished report.

Susan M.H., Jesse D., Collin, E-S., Jeanne, M.F., Jennifer G., Garth H., James W.R. and John H. S. (2014) The persistent problem of lead poisoning in birds from ammunition and fishing tackle. The Condor: Ornithological Applications 116:408–428. DOI: 10.1650/CONDOR-14-36.1

Turcekova, L., Hanzelova, V., and Spakulova, M. (2002) Concentration of heavy metals fish and its endoparasites in the polluted water reservoir in Eastern Slovakia. *Helminthologia*, 39:1-23.

Williams, H. and Jones, A. (1994) Parasitic worms of fish. Taylor and Francis Publishers Ltd. London. 443 pp.

WHO., 2007. Health Risks of Heavy Metals from Long-Range Transboundary Air Pollution. Joint Task Force on the Health Aspects of Long-range Transboundary Air Pollution, Geneva.