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FISH AVOIDANCE RESPONSE TO HEAVY METALS AND THEIR MIXTURES

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Abstract. Experimental data concerning avoidance response of fishes to heavy metals obtained by the author during the last decade are presented. It has been found that avoidance response is a significant species-specific form of adaptive fish behaviour occurring at sublethal concentration levels, its intensity being directly proportional to the logarithm of concentration and independent from the toxicity of the substance studied.

Comparative laboratory and field tests were performed on anadromous fish – vimba *(Vimba vimba)*. Adult fish under field conditions avoided solutions of heavy metals rather intensively. The threshold avoidance concentrations were: 0.005 mg/l for copper and 0.026 mg/l for zinc. A higher intensity of avoidance response under field conditions depended on a higher locomotor activity of the test fish as well as on the absence of migration and spawning motivation. Rainbow trout *(Oncorhynchus mykiss)* significantly exceeded vimba by its sensitivity to heavy metals: avoidance thresholds being 0.001 mg/l for copper and 0.0001 mg/l for zinc.

It has been established that the olfactory system of fish is involved in forming the avoidance response to heavy metals. Adult individuals of vimba under experimental anosmia lost their capability to avoid preliminary avoidable concentrations of copper – 0.5 and 1 mg/l and zinc – 2 and 4 mg/l, which caused mortality of test fish in some cases. Studies of avoidance response of equivalent groups (10 individuals each) of four dominant fish species, from the Neris river coastal zone communities, simultaneously to solutions of the five heavy metal (Cu, Zn, Ni, Cr, Fe) model mixture as well as a separate test carried out on rainbow trout showed that by the sensitivity to the mixture under study, the fishes can be arranged into the following decreasing sequence: rainbow trout > three-spined stickleback > roach > dace > perch. The responses of fishes to heavy metal mixture solutions were rather different. Interspecific schooling did not occur.

The acclimation of fish to heavy metals has been proved. Rainbow trout was pre-exposed for 3 months to sublethal concentrations of copper (0.15 and 0.30 of 96-hour LC50) and to the solutions of two kinds of five heavy metal mixtures of different combinations (0.16 and 0.19 of 96-hour LC50). Intact and control fish significantly avoided copper and heavy metal mixtures in all cases. Pre-exposed fish demonstrated preference response to heavy metals of maximal intensity.

Key words: fish, avoidance response, heavy metals, heavy metal mixtures

Introduction

Avoidance of polluted waters is one of the most significant sublethal responses of fish (Sprague, Drury, 1969). Fish populations can be affected by aquatic pollutants not only directly. Their active retreat from polluted areas can result in disturbances in their migration and distribution. Therefore, a reduction of their normal area of habitat, as well as their resources, can occur. From another point of view, the avoidance response by fishes is one form of phenotypic adaptation allowing fishes to survive in altered environment (Flerov, 1989).

Great attention has been given to the study of avoidance response to pollutants by fishes during recent decades, and a considerable amount of experimental data based on laboratory tests are available (Giattina, Garton, 1983; Beitinger, Freeman, 1983). The literary data, however, are often fragmental, contradictory, and difficult to compare. Although avoidance of pollutants by fishes has been observed in nature, it is supposed that the threshold avoidance concentrations in nature are much higher and more variable than those under laboratory conditions where direct or masking factors capable of affecting fish behaviour are absent (Sprague, 1971; Beitinger, Magnuson, 1976; Weber et al., 1981; Giattina et al., 1981; Sprague, Korver, 1987). That is why it is necessary to conduct field studies and com-

pare their results with those of laboratory tests.
The majority of avoidance tests have been carried out on the level of a single individual and only the minority on the groups of individuals of the same species. However, fish populations exist not separately but are connected with other fish populations by many relations, i.e. set up a community. Under the effect of pollution, rapid quantitative and qualitative changes in a community structure occur. Conditions for existance of several or only one eurytopic species can be formed. Community succession mechanisms are still unclear and not investigated experimentally. That is why it is necessary to conduct tests on the level of a model community, i.e. to determine the responses of several fish species simultaneously.
The investigations concerning the mechanisms by means of which fishes detect and avoid pollutants are still scarce, however. Information on how the responses are modified by acclimation of fish to pollutants is almost totally lacking. This kind of information could throw light on the effects of pollution on the distribution of fish in the natural environment.
In the present account the results of the above mentioned problems investigated during the past ten years are presented.

Material and methods

The tests were conducted on one-year-old rainbow trout (*Oncorhynchus mykiss)* of 7-9 cm total length, obtained from the Žeimena Fish Farm, adult vimba *(Vimba vimba)* of 23-30 cm total length, collected in the Širvinta river by means of electrofishing during the spawning season (May-June), juvenile vimba of 7.5-10 cm total length as well as other small dominant fish species of coastal zone communities, such as three-spined stickleback *(Gasterosteus aculeatus)*, roach *(Rutilus rutilus)*, perch *(Perca fluviatilis)*, and dace *(Leuciscus leuciscus)* of 6-8 cm total length collected in the Neris River 15 km above Vilnius during experimental fishing with a drag-net with 6 mm meshes. The fishes were acclimated in the laboratory for at least one week until they started feeding. They were kept in tanks supplied with aerated artesian water of good quality with total hardness of approximately 248 mg/l as $CaCO_3$, alkalinity approximately 244 mg/l as $H\bar{CO}_3$, pH = 8.0 and temperature 10 ± 0.2°C.
Fish responses in the laboratory were examined by means of a flow-through gradient chamber (Fig. 1) with two parallel water streams (Svecevičius, 1994). The chamber was 1500 x 600 x 300 mm in size and the total flowing capacity was 6 litre/minute. Fifteen minutes after the introduction of the test solution into one of the sections of the chamber, two zones were formed: zone **a** (pure water) and zone **b** (solution).
The nature and intensity of response were estimated during 2.5-hour tests by means of multiply momentary recordings of fish in polluted and unpolluted water zones by use of rapid separation or a filming camera by the Response Index through formula:
Response Index = 50 (2 - N_T/N_C)
where N_C is the average number of fish in polluted zone during the control period (water is pure) and N_T is the average number of fish in the same zone during the test period (pollutant is introduced). The value of index 100 denoted maximal avoidance, while 0 denoted maximal preference and 50 denoted indifference. Significance of behavioural response was verified by Student's t-test at $p \leq 0.05$.
The field experiments were performed on groups of adult vimba consisting of ten individuals, half male and half female, in a creek where a working area with a gravel bottom of about 12 m^2 was arranged (Fig. 2); the depth being 15-20 cm with a flow rate of 16-17 litres/second. The water quality was similar to the characteristics of non-polluted rivers of Lithuania with total hardness of approximately 120 mg/l as $CaCO_3$, alkalinity approximately 153 mg/l as $H\bar{CO}_3$, pH = 7.3 ± 0.6 and temperature = 17.3 ± 0.8°C. The ecological characteristics of the test area, such as temperature, substratum, and flowing rate, were close to

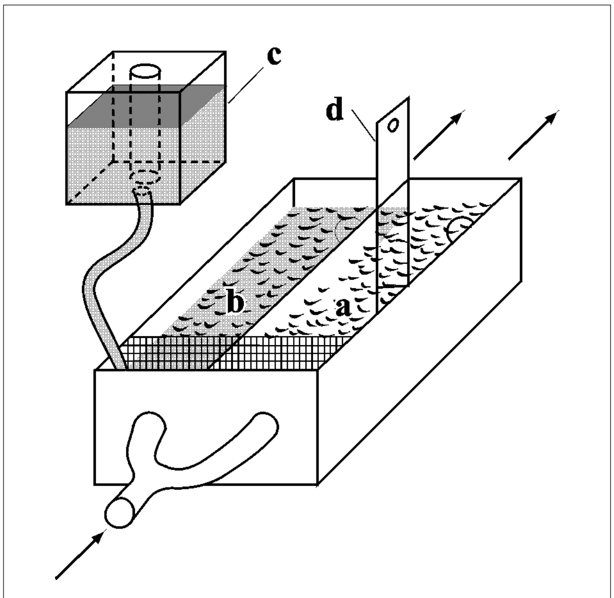

Figure 1. Gradient chamber: a – pure water zone; b – polluted water zone; c – toxicant supply tank; d – slipping bolt

those natural for vimba at migratory/spawning season (Svecevičius, 1989).

The following chemically pure substances were used in making stock solutions of separate heavy metals and their mixtures $CuSO_4$, $ZnSO_4$, $NiSO_4$, $K_2Cr_20_7$ and $FeSO_4$.

In order to determine the role of olfaction in detecting and avoiding heavy metals by fish, anosmia tests were carried out by means of treating adult vimba olfactory organs with a 0.5% solution of detergent Triton X-100 prepared in standard Ringer solution for cold-blooded animals (Svecevičius, 1991). The responses of fish under anosmia to copper and zinc solutions were compared with those of intact fish.

To evaluate fish community behaviour regularities, 2.5-hour tests were performed on four fish species (three-spined stickleback, roach, perch and dace) simultaneously. The species were tested in groups of 10 individuals. A choice was given to the fish in a gradient chamber to discriminate between pure and polluted water with a five heavy metal model mixture of different concentrations. The 100% concentration of a model mixture was formed according to their Maximal Permissible Discharges (MPD) into municipal sewage waste-waters: Cu – 0.5; Zn – 1.0; Ni – 0.5; Cr – 2.5; Fe – 5 mg/l, correspondingly. Separate tests were carried out on rainbow trout (Svecevičius, 1998).

In order to determine fish behavioural adaptation capabilities to heavy metals, rainbow trout in groups of 16 individuals were pre-exposed for 3 months to sublethal concentrations of two different heavy metal model mixtures and two copper sublethal concentrations of 0.1 and 0.2 mg/l, which were equal to 0.15 and 0.3 parts, respectively, of a 96-hour LC50 value determined in acute toxicity tests (Svecevičius, Vosylienė, 1996). The formation of model mixtures was carried out basing on available analytical data of the discharges of average annual amounts of five representative heavy metals in waste-waters receiving effluent from the cities of Vilnius and Kaunas into the Nemunas and Neris rivers during 1990-1991 (Vosylienė et al., 1994):

The fish were kept in 120-l aquaria in groups and test

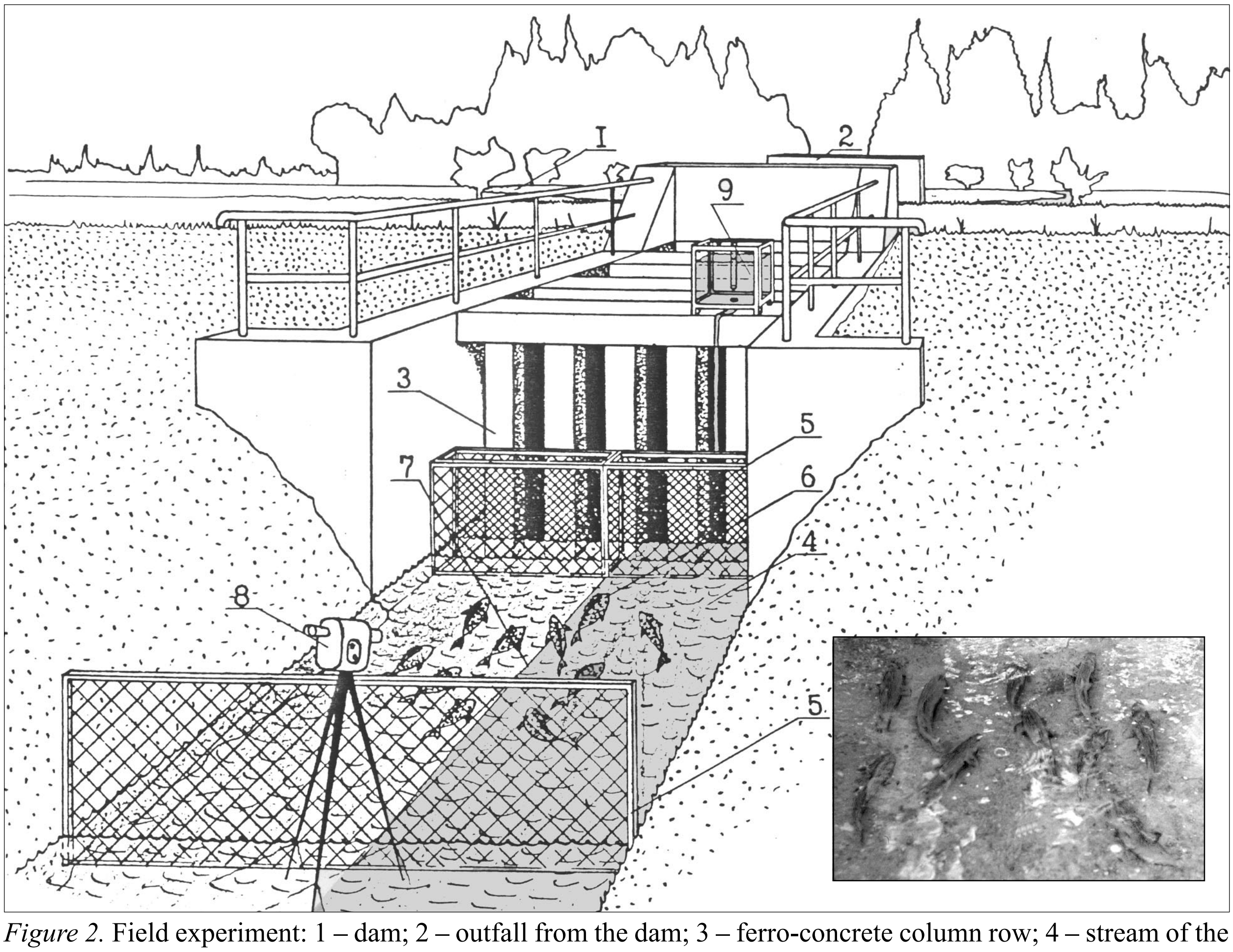

Figure 2. Field experiment: 1 – dam; 2 – outfall from the dam; 3 – ferro-concrete column row; 4 – stream of the creek; 5 – net fences; 6 – test fish; 7 – pure and polluted zone separation mark; 8 – filming camera; 9 – toxicant supply tank

	Mean concentration (mg/l)					Ratio to 96-hour LC50
Heavy metal	**Cu**	**Ni**	**Cr**	**Zn**	**Fe**	
Vilnius variant	0.11	0.12	0.15	0.25	2.9	0.16
Kaunas variant	0.13	0.13	0.23	0.38	2.4	0.19

solutions were renewed three times a week (on Monday, Wednesday and Friday). During the 3-month test period every month, the fish were investigated behaviourally. Responses of the pre-exposed fish were compared with those in control and intact fish responses.

Results and discussion

Comparative laboratory and field tests. Juvenile and adult vimba avoided copper and zinc solutions both under laboratory and field conditions (Table 1). As it was mentioned above, the fish were tested in groups of 10 individuals. Copper was avoided by vimba more intensively than zinc. Avoidance response in juvenile vimba reached significant level at a copper concentration of 0.1 mg/l then adult fish avoided this copper concentration with almost maximal intensity. Similarly, adult fish under field conditions avoided zinc solutions much more intensively than juvenile vimba. In order to compare the data obtained, separate laboratory tests were carried out on rainbow trout – the fish species commonly used in toxicity tests (Table 2). Contrary to vimba, rainbow trout avoided zinc more intensively than copper. The general intensity of avoidance re-

Table 1. Avoidance response of vimba to copper and zinc solutions under laboratory and field conditions

Heavy metal concentration (mg/l)	Response indices (mean ± SE)	
	Juveniles in the laboratory (N = 10)	Adults in the field (N = 5)
Copper		
0.001	50 ± 5.5	48 ± 4.0
0.01	47 ± 5.7	61 ± 2.8*
0.05	-	84 ± 2.0*
0.1	61 ± 4.4*	95 ± 1.2*
0.5	73 ± 5.6*	95 ± 1.7*
1	89 ± 3.3*	-
Zinc		
0.004	49 ± 5.8	54 ± 3.0
0.04	53 ± 5.6	52 ± 3.3
0.22	-	72 ± 3.2*
0.4	61 ± 3.1*	77 ± 3.0*
2	74 ± 3.3*	94 ± 1.9*
4	88 ± 3.5*	-

** significantly different from 50 (P ≤ 0.05)*

Table 2. Avoidance response of rainbow trout to copper and zinc solutions

Heavy metal concentration (mg/l)	Response indices (mean ± SE, N = 10)	
	Copper	Zinc
0.001	51 ± 6.3	59 ± 6.1
0.05	60 ± 5.9*	-
0.01	80 ± 7.4*	79 ± 4.3*
0.1	89 ± 4.5*	87 ± 6.2*
1	-	97 ± 0.8*

** significantly different from 50 (P ≤ 0.05)* sponses to zinc and copper were much higher in comparison to vimba responses.

The intensity of avoidance responses in all cases was found to be directly proportional to heavy metal concentration logarithm (Fig. 3). Regression analysis confirmed that a linearly proportional interdependence exists between heavy metal concentration logarithm and avoidance concentration response intensity. The threshold avoidance concentration was defined by estimating the concentration equivalent to the point were regression line intersects theoretically neutral response level (Response Index is equal to 50) (Höglund, 1961; Fava, Tsai, 1976; Anestis, Neufeld, 1986).

According to the avoidance thresholds data rainbow trout showed the highest sensitivity to copper and zinc solutions. Rainbow trout was found to be 5 times more sensitive to copper than adult vimba and 44 times more sensitive than juvenile vimba. It was 260 times more sensitive to zinc than adult vimba and 1,600 times more sensitive than juvenile vimba.

Data on acute toxicity of copper and zinc in juvenile vimba and rainbow trout were compared to threshold

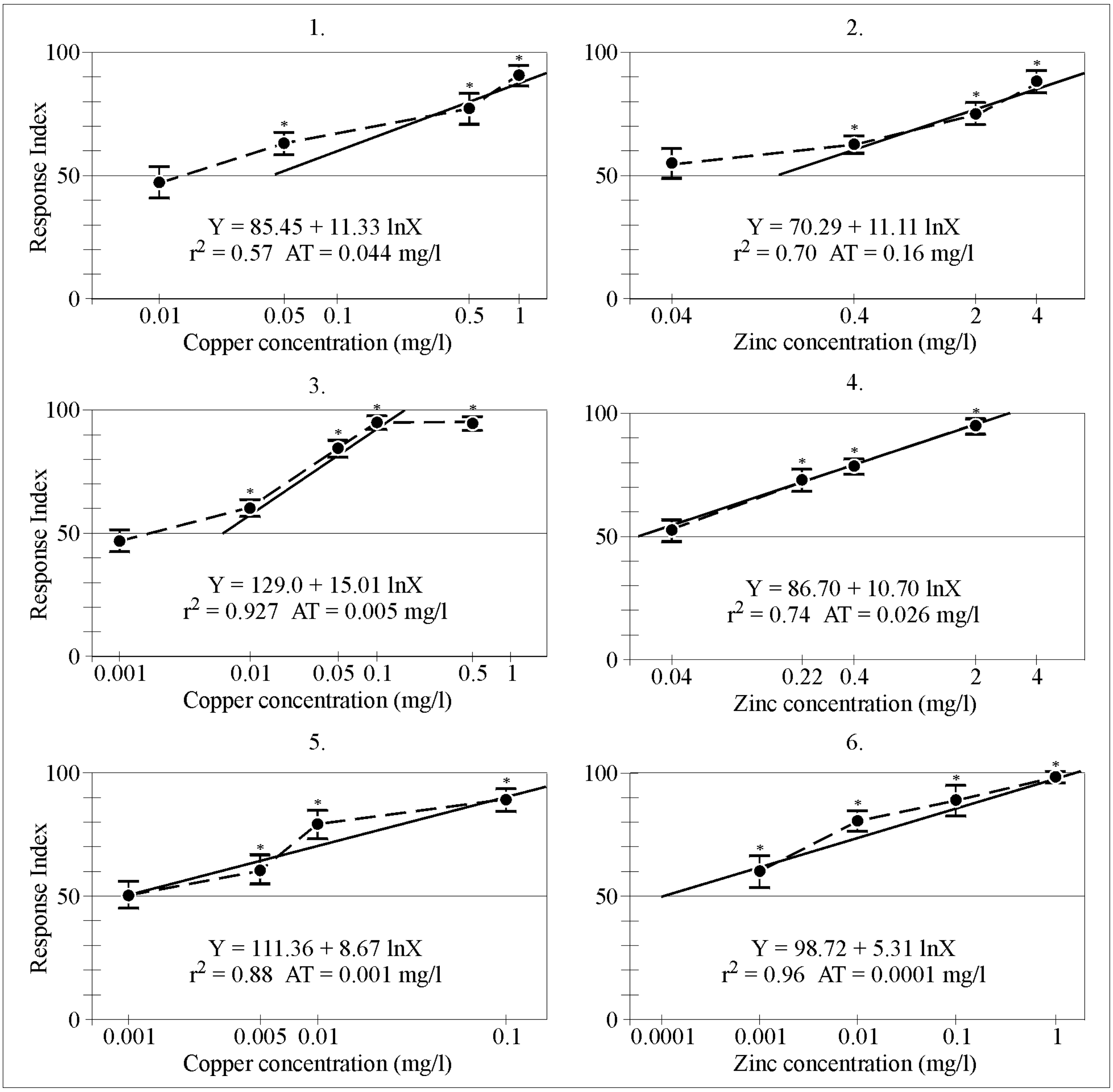

Figure 3. Fish response diagrams: juvenile vimba (1, 2), adult vimba (3, 4), rainbow trout (5, 6). X axis corresponds to heavy metal concentration in mg/l (logarithmic scale), Y axis corresponds to Response Index, dots indicate mean values, vertical lines denote SE.

** significant differences from 50 (P ≤ 0.05); AT – avoidance threshold* avoidance concentrations (Table 3). The data show that in all cases avoidance response occur at a very low sublethal concentration of copper and zinc. Evidently, there is no correlation between heavy metal toxicity and its avoidance intensity.

Our data obtained on the avoidance response of vimba to zinc and copper do not agree with data reported by other authors for Atlantic salmon (*Salmo salar)* (Sprague et al., 1965; Saunders, Sprague, 1967). These authors have reported that in the laboratory salmon parr have a median avoidance concentration of 0.0024 mg/l for copper and 0.054 mg/l for zinc. Simultaneously, abnormal slopes of adult salmon migrating for spawning are 0.017-0.021 mg/l for copper and 0.21-0.258 mg/l for zinc. The authors mentioned above have also reported that spawning migration is completely stopped at concentrations of copper of over 0.038 mg/l and zinc at 0.48 mg/l. Consequently, under natural conditions the Atlantic salmon is less restrained by these metals, and this phenomenon has been explained by the authors as a lack of strong motivation in the laboratory. The motivation to migrate was probably absent in our test fish, although the stretch of the stream used for field experiments corresponded in all ecological parameters (substratum, depth, and flowing rate) to the biotope, attractive for adult vimba during migratory/spawning season.

Another factor that might influence the intensity of avoidance could be temperature. In field tests temperature reached 16-18°C, while in laboratory tests it did not exceed 10°C. Probably the higher temperature induced the higher locomotor activity in test fish and considerably affected the intensity of avoidance response.

The role of locomotor activity in fish avoidance behaviour has been proved experimentally: under the same testing conditions median avoidance concentrations of zinc in two ecologically close salmonid fish species rainbow trout and Atlantic salmon but very diverse in locomotor activity, differed ten times (Sprague, 1964; Sprague, 1968).

Determination of the role of olfaction in avoidance responses of fish to heavy metals. 2-hour duration tests were conducted on adult individuals of vimba in order to determine the role of olfaction in the formation of their avoidance response to copper and zinc solutions. The test fish were experimentally anosmated by means of treatment of their olfactory organs with detergent Triton X-100 as mentioned above. The responses of the fish under anosmia were compared with those of intact fish.

Experimental results obtained on avoidance responses to preliminary avoidable solutions of copper and zinc by vimba under anosmia and those intact are presented in Table 4.

Table 3. Comparison of threshold avoidance concentrations to 96-hour acute lethal concentrations of copper and zinc in juvenile vimba and rainbow trout (values reported in mg/l)

Heavy metal	Threshold avoidance concentration	96-hour LC50	Ratio to 96-hour LC50
Vimba			
Copper	0.044	0.55	0.08
Zinc	0.16	15.5	0.01
Rainbow trout			
Copper	0.001	0.65	0.0015
Zinc	0.0001	3.79	0.00003

Table 4. Avoidance responses of intact adult vimba and fish under anosmia to copper and zinc solutions

Heavy metal concentration (mg/l)	Response indices (mean ± SE, N = 7)	
	Intact fish	Fish under anosmia
	Copper	
0.5	59 ± 2.7*	52 ± 3.8
1	62 ± 3.0*	50 ± 3.7
	Zinc	
2	59 ± 3.7*	51 ± 3.9
4	64 ± 3.5*	51 ± 3.5

** significantly different from 50 (P ≤ 0.05)*

The data obtained have shown that adult vimba under anosmia totally lost the capability to avoid heavy metals. In copper solutions of l mg/l the fish became intoxicated. Their locomotor activity increased and "coughing" became very intensive. In zinc solutions of 2-4 mg/l vimba distinctly changed its colouring, it became dark.

During the next 24 hours after the experiment, 2 death cases out of 7 individuals of the fish tested with a copper concentration of 1 mg/l were registered.

The results obtained in the present research are in agreement with some literary data concerning the role of the olfactory system of fishes in developing their behavioural responses to heavy metals.

Thus, in a steep gradient, intact individuals of lake whitefish (*Coregonus clupeaformis)* were given a chance to choose between pure water and copper solution in the range of concentrations from 0.032 mg/l to 32 mg/l (Brown et al., 1982). It was at 0.032 mg/l that the fish showed a significant response of avoidance, its maximal value being reached at 1.6 mg/l. Further increase in the concentration gave rise to the preference response in the range of concentrations 1.6-6.4 mg/l. Anosmia of fishes by means of treatment of their olfactory sacks with nitric acid had caused their indifference to any copper concentrations. Preference response occurred only at the highest copper concentration of 32 mg/l, which, from the author's point of view, was due to incomplete cauterisation of the test fish. Conclusion may be drawn that, like in the vimba under study, olfaction is involved in developing avoidance-preference responses to copper in lake whitefish as well.

The data are presented concerning the capacity of heavy metals to block or disturb the olfactory system in fishes (Brown et al., 1982; Little et al., 1985; Rehnberg, Schreck, 1986; Baatrup, 1991; Blaxter, Hallers, 1992; Bjerselius et al., 1993). From the experiments with copper, it can be seen that this fact may result in the death of the animals. Consequently, the olfactory system proves itself to be a link of ecological importance in developing defensive behavioural responses to toxicants in fishes.

Fish community responses. Four fish species tested simultaneously as well as rainbow trout tested separately were capable to avoid heavy metal model mixture solutions (Table 5). Since the intensity of avoidance response was found to be directly proportional to heavy metal mixture concentration, avoidance thresholds estimation were performed by use of regression analysis (Fig. 4). Rainbow trout showed the highest sensitivity to heavy metal solutions. Avoidance response intensity reached significant level at the concentration of model mixture equal to 1%, and a 10% concentration was avoided with almost maximal intensity. Three-spined stickleback responded to heavy metal solutions sufficiently intensively, and the response index reached significant level starting with a 5% concentration. The avoidance response of roach was biphasic: significant level of avoidance response was reached at the interval of mixture concentrations between 5 and 25%. With an increase in concentration response intensity decreased and stabilised at the indifference level. Dace significantly preferred very high concentration (25%) of metal mixture, but higher concentrations were significantly avoided. Perch did not show any response within a very large interval of mixture concentrations (1-50%). Significant avoidance response was determined only at the mixture concentration equal to 100%.

24 hours later all the test fishes looked healthy.

According to the threshold values the fish species can be arranged into the following decreasing sequence:

Species:	Rainbow trout	Three-spined stickleback	Roach	Dace	Perch
Relative sensitivity index	1	0.5	0.24	0.01	0.008

Since a fish community is a live system of interacting species populations, behavioural relations among groups of different fish species are probable. Less sensitive fish can imitate behaviour of more sensitive ones. In the given case, no interspecific schooling was found. Though being in the same group, the species showed great divergence by their sensitivity to heavy metal mixture. Evidently, that avoidance response to heavy metals in fishes is species-specific. Perhaps it depends on ecological status of the fish or different chemoreception sensitivity.

Theoretically the present investigation provides an experimentally confirmed model of a retrogressive succession, i.e. the sequence of species elimination in fish community in the case of biotope pollution by heavy metals.

Pre-exposure tests. The data obtained in the previous study have shown that intact rainbow trout individuals are capable to avoid copper spontaneously (Table 2). Avoidance response sensitivity was very high and its intensity reached a significant level at 0.005 mg/l copper concentration, though 0.1 mg/l copper concentra-

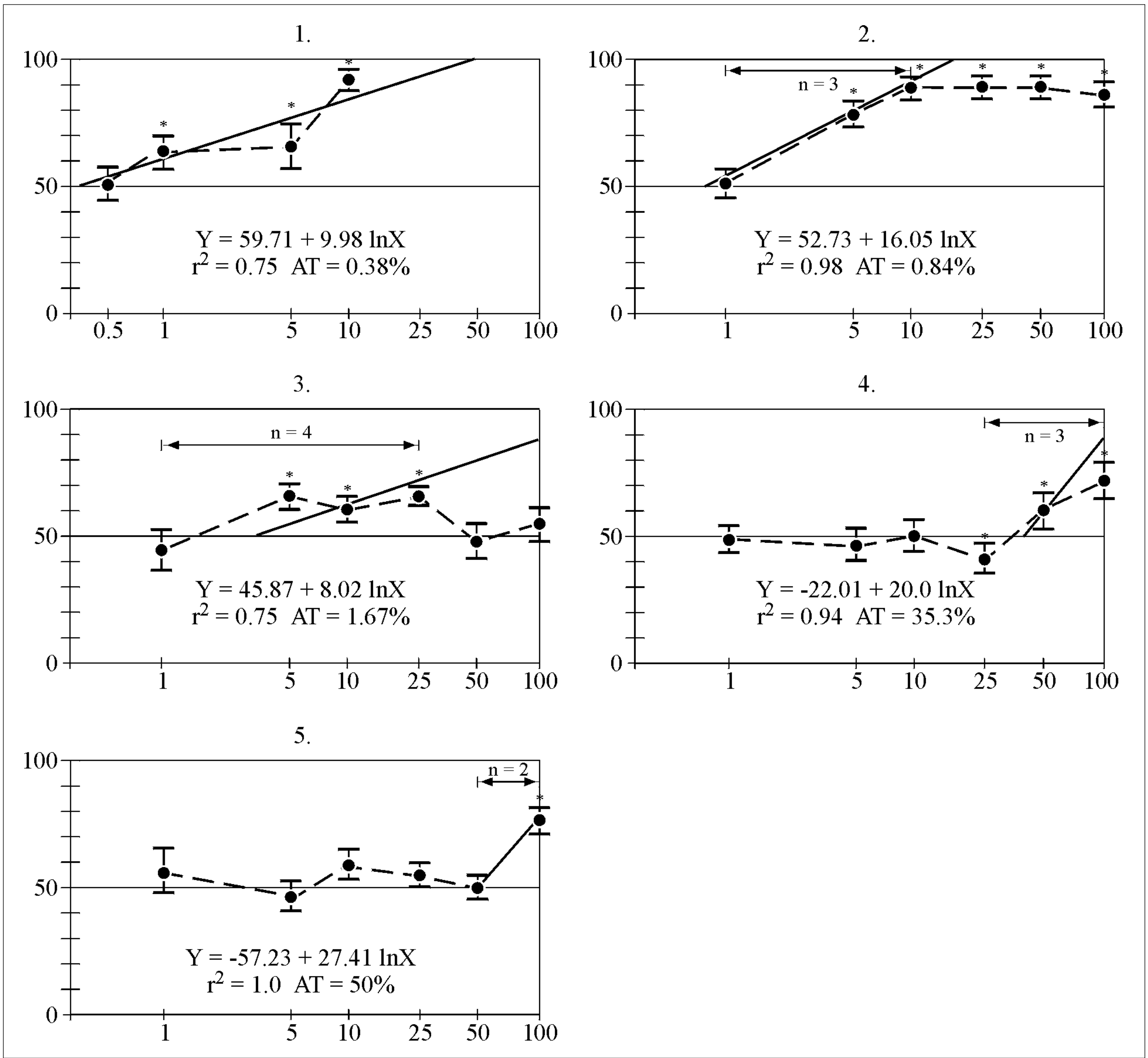

Figure 4. Fish response diagrams: rainbow trout (1), three-spined stickleback (2), roach (3), dace (4), perch (5). X axis corresponds to heavy metal mixture concentration in % (logarithmic scale), Y axis corresponds to Response Index, dots indicate mean values, vertical lines denote SE, * significant differences from 50 ($P \leq 0.05$). AT – avoidance threshold

Table 5. Avoidance responses of fishes to heavy metal model mixture solutions

Heavy metal mixture concentration (%)	Response indices (mean ± SE, N = 10)				
	Rainbow trout	Three-spined stickleback	Roach	Dace	Perch
0.5	52 ± 7.8	-	-	-	-
1	64 ± 6.8*	52 ± 5.1	44 ± 5.1	47 ± 5.2	54 ± 5.4
5	65 ± 7.2*	81 ± 4.2*	65 ± 4.8*	44 ± 5.5	44 ± 5.3
10	90 ± 3.4*	88 ± 2.6*	60 ± 5.2*	49 ± 6.0	58 ± 4.4
25	-	88 ± 2.5*	65 ± 3.1*	41 ± 3.3*	53 ± 3.0
50	-	87 ± 2.7*	47 ± 6.1	61 ± 5.5*	50 ± 2.8
100	-	86 ± 3.1*	56 ± 5.4	69 ± 6.7*	69 ± 3.8*

** significantly different from 50 ($P \leq 0.05$)*

tion was avoided with almost maximal intensity. The avoidance threshold value (0.001 mg/l) estimated by use of the regression analysis (Fig. 3) appeared to be in close agreement with experimental data of other researches (Black, Birge, 1980; Giattina et al., 1982).
The control group of fish significantly avoided copper at a concentration of 0.1 and 0.2 g/l (Table 6), and the intensity of response was the same as in intact trouts. However, pre-exposed fish significantly preferred those concentrations of copper. Besides, the intensity of preference response was very high.
Very similarly, the control fish significantly avoided both kinds of heavy metal model mixtures (Table 7), contrary to pre-exposed fish, which preferred them with high intensity.
The data obtained in the present study are in agreement with some literary data concerning behavioural responses of fish pre-exposed to pollutants. Thus, rainbow trout pre-exposed to sublethal concentrations of chromium for 7-20 weeks demonstrated much higher avoidance thresholds of chromium than the control fish (Anestis, Neufeld, 1986). Similarly, vendace (*Coregonus albula)* avoided bleached kraft mill effluent (BKME), although fish pre-exposed to BKME for 1 week preferred contaminated water (Myllyvirta, Vuorinen, 1989). Lake whitefish (*Coregonus clupeaformis)* pre-exposed to cadmium for 3 weeks showed significant attraction to water containing sequentially increasing sublethal cadmium concentration (McNicol, Scherer, 1993).
The mechanism of such fish behaviour is not clear. However, there is no doubt that such fish responses are directly connected with changes in fish chemoreceptor sensitivity to pollutants. In natural environments such fish behaviour could be determined as a “physiological trap” and could affect fish migrations and distribution if fish were pre-exposed to specific substances early in their development. Thus, the study of avoidance-preference responses of intact fish may not fully reflect how natural fish populations respond

Table 6. Avoidance-preference responses of control and pre-exposed rainbow trout to copper (Response indices, mean ± SE, N = 10)

Exposition (days)	Fish test group	Copper concentration (mg/l)	
		0.1	0.2
30	Control	89 ± 4.5	90 ± 3.4
	Pre-exposed	15 ± 6.1	11 ± 5.2
60	Control	85 ± 3.8	95 ± 1.3
	Pre-exposed	9 ± 3.5	10 ± 3.6
90	Control	96 ± 1.8	98 ± 0.8
	Pre-exposed	14 ± 4.3	12 ± 3.9

All values are significantly different from 50 (P ≤ 0.05)

Table 7. Avoidance-preference responses of control and pre-exposed rainbow trout to heavy metal model mixtures (Response indices, mean ± SE, N = 10)

Exposition (days)	Fish test group	Heavy metal model mixtures	
		Vilnius variant	Kaunas variant
30	Control	98 ± 0.3	99 ± 0.2
	Pre-exposed	14 ± 3.6	11 ± 4.2
60	Control	95 ± 1.3	98 ± 0.2
	Pre-exposed	17 ± 5.5	15 ± 4.4
90	Control	94 ± 0.8	95 ± 0.2
	Pre-exposed	16 ± 5.0	10 ± 6.6

All values are significantly different from 50 (P ≤ 0.05) to the presence of pollutants. Furthermore, exhaustive studies concerning the mechanisms by means of which fish can adapt to pollutants are needed.

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Žuvų vengimo reakcija į sunkiuosius metalus ir jų mišinius

G. Svecevičius

Santrauka

Apibendrinti per pastaruosius 10 metų autoriaus atlikti žuvų vengimo reakcijos į sunkiuosius metalus tyrimų rezultatai. Nustatyta, kad vengimo reakcija yra svarbi, specifinė žuvų rūšies adaptacinės elgsenos forma, pasireiškianti subletalinių koncentracijų lygyje, jos intensyvumas tiesiog proporcingas koncentracijos logaritmui ir nepriklauso nuo tiriamos medžiagos toksiškumo. Lyginamieji laboratoriniai ir lauko bandymai buvo atlikti su praeive žuvimi – žiobriu (*Vimba vimba).* Suaugusios žuvys lauko sąlygomis pakankamai intensyviai vengė sunkiųjų metalų tirpalų. Slenkstinės koncentracijos tuo metu sudarė: 0,005 mg/l vario ir 0,026 mg/l cinko. Juvenilinio žiobrio vengimo reakcija į juos laboratorinėmis sąlygomis buvo mažiau intensyvi, vengimo slenksčiai sudarė 0,044 mg/l vario ir 0,16 mg/l cinko. Aukštesnį šios reakcijos intensyvumą lauko sąlygomis lėmė didesnis bandymo žuvų lokomotorinis aktyvumas, taip pat ir tai, kad nebuvo migracijos ir neršto motyvacijos. Vaivorykštinis upėtakis *(Oncorhynchus mykiss)* buvo daug jautresnis sunkiesiems metalams negu žiobrys: vengimo slenksčiai sudarė 0,001 mg/l vario ir 0,0001 mg/l cinko.

Žuvų vengimo reakciją į sunkiuosius metalus formuoja žuvų uoslės sistema. Eksperimentiškai anosmuoti suaugusio žiobrio individai prarasdavo įgytą sugebėjimą išvengti vario – 0,5 ir 1 mg/l ir cinko 2 ir 4 mg/l koncentracijų, nuo kurių atskirais atvejais bandymo žuvys krisdavo.

Keturių dominantinių Neries up. priekrančių bendrijų žuvų rūšių ekvivalentinių grupių (po 10 individų) vengimo reakcija į penkių sunkiųjų metalų (Cu, Zn, Ni, Cr, Fe) modelinį mišinį vienu metu ir atskiri bandymai, atlikti su vaivorykštiniu upėtakiu, taip pat parodė, kaip žuvis būtų galima suskirstyti pagal jautrumą tiriamam mišiniui: vaivorykštinis upėtakis > trispyglė dyglė > kuoja > strepetys > ešerys. Žuvų reakcijos į sunkiųjų metalų mišinio tirpalus buvo labai skirtingos. Vidurūšinio apsimokymo nebuvo.

Įrodyta žuvų aklimacijos galimybė prie sunkiųjų metalų. Vaivorykštinis upėtakis buvo 3 mėnesius iš anksto eksponuojamas subletalinėse vario koncentracijose (0,15 ir 0,30 nuo 96 val. LC50) bei dviejų skirtingų kombinacijų penkių sunkiųjų metalų modelinių mišinių (0,16 ir 0,19 nuo 96 val. LC50) tirpaluose. Intaktinės ir kontrolinės žuvys visais atvejais patikimai vengė vario ir metalų mišinių. Iš anksto eksponuotos žuvys parodė maksimalaus intensyvumo preferencijos reakciją į sunkiuosius metalus.