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Fluctuating asymmetry of zebra mussel (*Dreissena polymorpha* Pall.) and floating pondweed (*Potamogeton natans* L.) in water bodies within the Chernobyl accident Exclusion Zone

A.A. Yavnyuk[1], N.N. Efremova[1], O.N. Protsenko[1], D.I. Gudkov[2] and A.B. Nazarov[3]

[1]*Ecological Safety Department, National Aviation University, Kosmonavta Komarova Ave. 1, 03058 Kiev, Ukraine*
[2]*Department of Radioecology, Institute of Hydrobiology of the National Academy of Sciences of Ukraine, Geroyev Stalingrada Ave. 12, 04210 Kiev, Ukraine*
[3]*State Specialised Scientific and Production Enterprise "Chernobyl Radioecological Centre" of the Ministry of Emergency Situations of Ukraine, Shkol'naya Str. 6, 07270 Chernobyl, Ukraine*

Abstract. The main purpose of the study is establishment how radioactive contamination with different exposures affect aquatic living organisms by means of the fluctuating asymmetry determination. Studies are also aimed for the assessment of relative contamination of the water bodies by man-made radionuclides taking into account biological aspects. Represented results of studies are the pilot researches towards to the estimation of bilateral asymmetry of aquatic organisms in conditions of long-term radioactive impact and can be the part of complex radioecological monitoring of aquatic ecosystems within the Chernobyl accident Exclusion Zone in future.

1. INTRODUCTION

Among the most accessible methods of estimating the stability of living organisms' development is the determination of fluctuating asymmetry value of bilateral morphological features, and significance of this parameter as the response of living organism on unfavorable impact may be used as the integral estimation of habitat quality. The level of morphological deviations in living organisms during ontogenesis is a sensitive indicator of natural populations' state, which allows estimating of general impact of unfavorable environmental factors on biota including a human-caused impact.

2. MATERIALS AND METHODS

The main objects of studies were the bivalve mollusk zebra mussel (*Dreissena polymorpha* Pall.) from the Chernobyl NPP cooling pond and the higher aquatic plant floating pondweed (*Potamogeton natans* L.) form Glubokoye Lake, located within the most contaminated area of the Exclusion Zone. The following morphometric parameters of mollusk's shell were analyzed: total length, protuberance of left and right valves and also mass. The results of measurements were compared with analogous ones for mollusks from Zaporozhye NPP cooling pond and from the southern part of Kakhovka reservoir of the Dnieper River. For floating pondweed, we have measured the following parameters of leaves: widths of left and right half, quantity of the major and minor veins on the different half. The results were compared with leafs of plants from conditionally "clean" Kiev and Kanev reservoirs of the Dnieper River.

From the Chernobyl NPP cooling pond there were investigated 101, from the different places of Kakhovka reservoir – 181, from Zaporozhye NPP – 35 individuals of zebra mussel. All collected

molluscs were prepared with the use of 5% formalin solution. There also were taken 130 samples of floating pondweed's leafs from Glubokoe Lake and 65 ones from Kiev reservoir.

Zebra mussels (*Dreissena polymorpha* Pall.) are small shellfish of the family *Dreissenidae* named for the striped pattern of their shells. Colour patterns can vary to the point of having only dark or light coloured shells and no stripes. Threads underneath the shells typically find them attached to objects, surfaces, or each other. The valve of adult individuals is about 2–4 cm length and has a triangle form (Fig. 1). Mantle has only three openings: for the foot motion with byssus, for the water and for excrement extraction. It habitats on the depth up to 10 m. Zebra mussels are native to the Black, Caspian, and Azov Seas. In certain places the quantity of molluscs is very large – up to 7 kg biomass and about 10,000 molluscs per sq. m. Zebra mussels are the obligate filter feeders and can accumulate in high concentrations all radionuclides which can find in water.

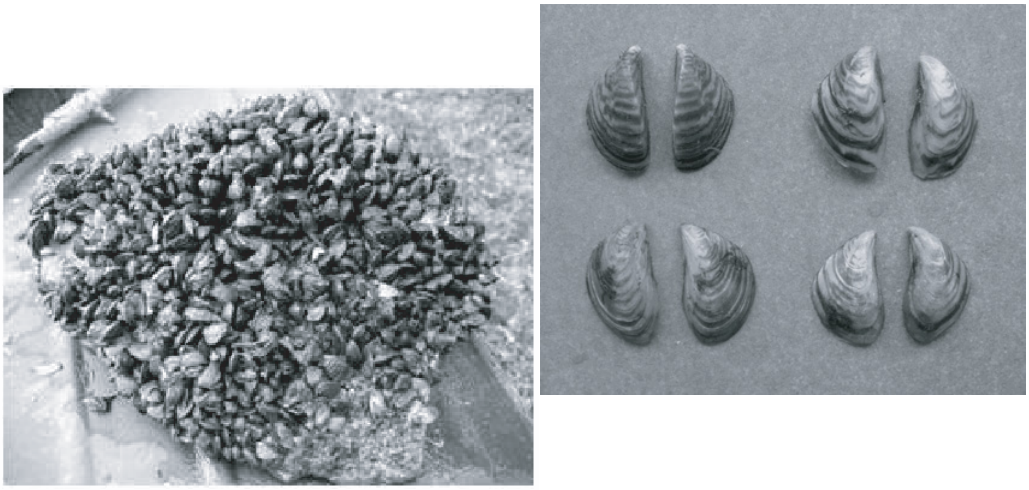

Figure 1. General view of the zebra mussel's colony and valves, prepared for the comparative measurements.

Floating pondweed (*Potamogeton natans* L.) is higher aquatic plant of the family *Potamogetonaceae* is one of the commonest of the pondweeds. It grows in still freshwater, rooted in the bottom mud. Submerged leaves are grass-like, but higher up the shoot it produces oval floating leaves about four inches long (Fig. 2). The ribbon-like underwater leaves have a broad light green central stripe, and the floating leaves are often oppositely arranged. The underwater leaves of floating pondweed are so narrow they appear to be stiff leafless stalks, and the floating leaves often have slightly heart-shaped bases. Species of genus *Potamogeton* has a relatively high ability to accumulate isotopes of strontium. This is connected with this plant's ability to accumulate large quantities of calcium (which is not washed off during standard sampling) on its surface during photosynthesis. At that calcium carbonate that is removed from the plant surface could contain 7–20 times more radioactive strontium than the plant tissue (Laynerte and Seysuma, 1977). Thus, *Potamogeton* species makes a good prospective radioecological monitoring object as a specific accumulator of ^{90}Sr.

3. CALCULATIONS

Two formulas were used for the estimation of fluctuating asymmetry phenomenon. Formulas were selected after the checking of directional asymmetry presence, than there were compared the average values of height and mass of the valves.

Figure 2. General view of the floating leaves of *Potamogeton natans*.

At first, it was necessary to calculate the directionality of the asymmetry by the valve height and mass with use of the following formula:

$$Md_1 = \overline{X}_r - \overline{X}_l, \qquad Md_2 = \overline{W}_r - \overline{W}_l, \tag{1}$$

where: $\overline{X}_r$ is the average height value of the right valve; $\overline{X}_l$ – of the left one; $\overline{W}_r$ is the average mass value of the right valve; W_l – of the left one.

Expression of the asymmetry was calculated by the following formulas:

$$A_1 = \frac{\sum |X_{ri} - X_{li}| - Md_1}{n}, \qquad A_2 = \frac{\sum |W_{ri} - W_{li}| - Md_2}{n}, \tag{2}$$

where: n is the number of specimens in the sample.

By the same way there was measured expression of the fluctuating asymmetry for the parameters of the floating pondweed's leaves.

4. RESULTS AND CONCLUSIONS

Obtained results testify that the highest evidence of fluctuating asymmetry of valves protuberance is observed in mollusks from Chernobyl NPP cooling pond. This value equals 0.8192 (Fig. 3). Mollusks from Zaporozhye NPP cooling pond and Kakhovka reservoir are characterized by considerably less value of this attribute evidence (0.0547 and 0.0328 correspondingly).

High content of radionuclides in the main components of Chernobyl NPP cooling pond ecosystem and in mollusks tissue (Table 1) can set conditions for chronic impact of radiation exposure on zebra mussel population allow assuming that the radiation factor may be considered as determinative one, which affects the significance of asymmetry of mollusks' valves height. Higher level of bilateral asymmetry in zebra mussel from Zaporozhye NPP, in comparison with mollusks from relatively "clean" parts of Kakhovka reservoir, also pays attention to itself.

Table 1. Specific activity of radionuclides in molluscs (body and shell) from sampling points, Bq/kg wet weight.

Water body	^{90}Sr			^{137}Cs		
	min	max	average	min	max	average
Cooling pond of the Chernobyl NPP	1100	2400	1711	130	1500	871
Cooling pond of the Zaporozhye NPP	85	110	100	143	181	164
Kakhovka reservoir	62	98	70	84	132	117

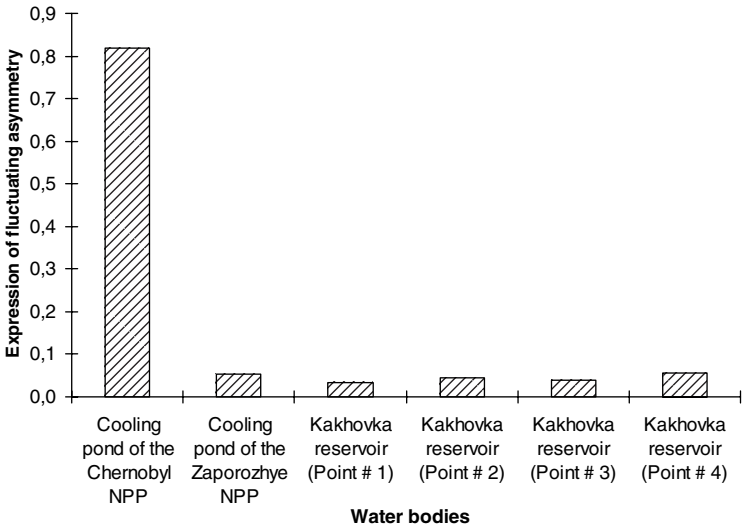

Figure 3. Diagram representing the fluctuating asymmetry expression by valve height.

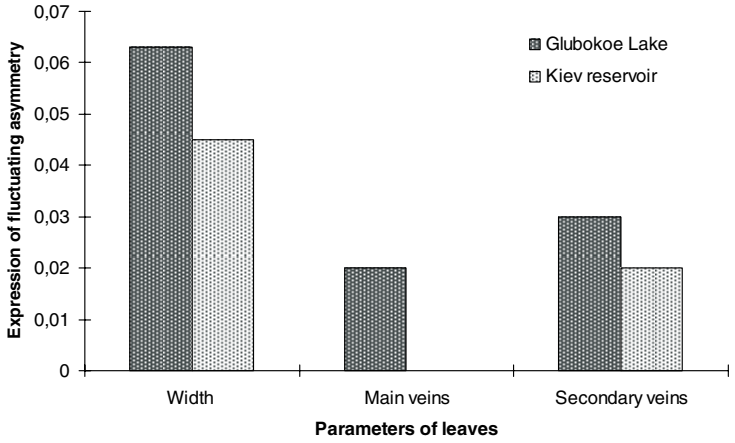

Figure 4. Expression of the fluctuating asymmetry in floating pondweed's left and right half of leaves.

The leaves of floating pondweed from Glubokoye Lake characterized by the value of asymmetry 0.063 for widths of left and right half and 0.02 and 0.03 for major and minor veins. The analogous parameters of plant leaves from the Dnieper reservoir were 0.045, 0.00 and 0.02 respectively (Fig. 4). Glubokoe Lake is one of the most contaminated water body within the Chernobyl accident Exclusion Zone with high specific activity of main radionuclides in biotic components including higher aquatic plants (Table 2). But in spite of the established difference between asymmetry value of leafs from contaminated and conditionally "clean" water bodies it is suppose that floating pondweed is less sensitive object for analysis of fluctuating asymmetry value in radioactive contaminated aquatic ecosystems.

As we can see from the tables and diagrams, in case of bivalve mollusks fluctuating asymmetry is expressed by the best way in the case of valves height. There was not established expression of asymmetry by valves mass. In accordance with calculations expression of the fluctuating asymmetry by valve height corresponds average exposure in every water body, from which specimens were taken.

Table 2. Specific activity of radionuclides and expression of fluctuating asymmetry in floating pondweeds from Glubokoe Lake and Kiev reservoir.

	Specific activity, Bq/kg w.w.		Fluctuating asymmetry		
Water body	^{90}Sr	^{137}Cs	left and right leaves width	main veins	secondary veins
Glubokoe Lake	12800	560	0.063	0.02	0.03
Kiev reservoir	26	11	0.045	0.00	0.02

Significant amount of radionuclides in the main components of the Chernobyl NPP cooling pond ecosystems and chronic character of the impact of irradiation on zebra mussels population allow assuming that determinative factor, which effects asymmetry by valve height, is radioactive influence. In case of higher aquatic plant for three parameters of fluctuating asymmetry expression is higher in Glubokoe Lake, which is relatively more contaminated by radionuclides than Kiev reservoir.

Analysis of expression of fluctuating asymmetry for hydrobionts from water bodies with different levels of radioactive contamination within the Chernobyl accident Exclusion Zone can be an accessible, perspective and sensitive method of radiation impact registration.

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