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V. G. Tsytsugina, PhD, Leading sci.

The A.O. Kovalevsky's Institute of Biology of the Southern Seas, NAS Ukraine, Sevastopol, Ukraine
e-mail vtsy@ibss.iuf.net

ASSESSMENT OF ECOLOGICAL RISK TO POPULATIONS OF AQUATIC INVERTEBRATES

On the base of experimental data and cytogenetic studies of marine and freshwater invertebrates natural populations it was shown that different species had approximately equal part (%) of full value posterity at the same average level of chromosome mutagenesis for populations, independing on deleterious factors and females fecundity. This phenomenon made it possible to calculate specimens reproductive contribution for species with different females fecundity and to assess expected reduction of population adaptive potential and the increase of ecological risk at different levels of population damage. It is suggested that the adaptation to pollution will be more effective in populations with high female fecundity.

Key words: aquatic invertebrates, pollution, fecundity, adaptation, ecological risk assessment.

Approaches to ecological risk assessment are based mainly on "dose (concentration) – effect" dependencies [3]. But the most constructive and adequate approach to ecological risk assessment is the study of adaptive potential of natural populations. It is known that genetic variability and adaptive possibility are connected with effective population size (i.e. the number of specimens which breed and determine genetic structure of next posterities). Effective population size depends on the dispersion of reproductive contribution of specimens. Increasing of reproductive contribution dispersion leads to decreasing of effective population size and adaptive potential [1]. For the assessment of specimens reproductive contribution a number (%) of posterity with spontaneous mutagenesis (up to 2% cells with chromosome aberrations [6]) may be used as the criterion of full value posterity because one with higher number of cells with chromosome aberrations is less viable [8]. Proceeding from data on the number (%) of full value posterity in population and the mean fecundity of females it is possible to calculate the number of full value posterity per a female (i. e. reproductive contribution). Obviously the increase of ecological risk may be expected if there is less than one full value embryo (or larva) per a female.

Experimental data on separate and combined effect of ionizing radiation and chemical mutagens on the posterity of *Chaetogammarus olivii* (Amphipoda) and *Idothea baltica* (Isopoda) females with different fecundity (5,20 and 40 eggs) have shown that approximately equal part (%) of full value embryos at the same average level of chromosome mutagenesis for populations was observed, independently of the eggs number and a type of injure factors (Table 1) [8].

This data were compared with the results of cytogenetic studies of embryos and larvas in natural invertebrates populations (20 marine and freshwater species from 11 taxons of coelenterates, annelids, mollusks, arthropods) from different biotopes in 1975 – 2003 [4, 6, 9] (Table 2). These species have the fecundity from several eggs to hundreds ones. In Table 2 it can be seen that (such as in experiments) different species had approximately equal part (%) of full value posterity at the same average level of chromosome mutagenesis for populations.

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Table 1 Part (%) of full value crustacean posterity at the same average level of chromosome mutagenesis (experimental data)
Табл. 1 Доля (%) полноценных потомков ракообразных при одинаковом среднем уровне хромосомного мутагенеза (экспериментальные данные)

Mutagen	Mean number of cells with chromosome aberrations, %	Species	Mean fecundity of females (number of eggs)	Number of embrios with spontaneous mutagenesis (%)
^{90}Sr		*Chaetogammarus olivii*	40	19
^{137}Cs		*Ch. olivii*	5	20
$Pb^{(2+)}$		*Ch. olivii*	40	28
$Pb^{(2+)}$	5.0 ± 0.6	*Ch. olivii*	5	18
Chlorphene		*Ch. olivii*	40	30
$Pb^{(2+)}$ +chlorphene		*Ch. olivii*	40	30
^{137}Cs + chlorphene		*Ch. olivii*	5	22
^{90}Sr		*Idothea baltica*	20	20
^{90}Sr		*Chaetogammarus olivii*	40	5
^{90}Sr		*Ch. olivii*	5	5
^{90}Sr+^{137}Cs+$Pb^{(2+)}$+ +chlorphene	8.0 ± 08	*Chaetogammarus olivii*	40	5
^{90}Sr		*Idothea baltica*	40	8

The observed phenomenon makes it possible to calculate reproductive contribution of specimens for species with different fecundity as well as to assess expected reduction of population adaptive potential and the increase of ecological risk at different levels of environmental pollution.

Table 3 presents the results of such calculation for females with different fecundity (5, 20, 50, 100 eggs) at the mean number cells with chromosome aberrations from 1.5 to 8.5%.

It can be seen that the reduction of adaptive possibility may be expected in populations with low fecundity of females (5 eggs) already at environmental pollution inducing in the mean 6% cells with chromosome aberrations (less than one full value embryo per a female). Obviously the adaptation to pollution will be more effective in populations with higher female fecundity (20 – 100 eggs) even at higher mean level of damage.

On the other hand, it was shown on *Chaetogammarus olivii* (as an example) that the posterity of females with high fecundity is less resistant to deleterious effect [7]. Populations of the Black Sea Amphipoda produce 3-4 generations a year [2]. The 1st and the most numerous generation appears in spring, the 2nd – in summer, the 3rd – in autumn and the 4th one – at the end of a year. The life span of these crustaceans is 6 – 10 months. Crustaceans of the 1st and the 2nd generations breed in summer and autumn, the 3rd, the 4th and partly the 2nd generations – in winter and spring. Depending on water temperature the time needed for maturation varies from 1.5 to 3 months. Maturation of these crustaceans is faster in summer and autumn; therefore the size of females during reproduction is always smaller than in winter and spring. Big individuals of the 3rd and 4th generations with the length of 6–10 mm dominate in the population in winter and spring months. They are the main reproduction fund for the spring breeding. They are going to die in May after finishing reproduction. Radical change of age and size composition of the population happens in this period. Females of 4 – 5 mm length dominate in the population of the crustaceans at the end of May and the beginning of June. They are crustaceans of the 1st generation of the current year. Already bigger females of the 2nd and the 3rd generations of 5 – 6 mm size dominate in late autumn.

Table 2 Part (%) of full value posterity in natural hydrobionts populations
Табл. 2 Доля (%) полноценных потомков в природных популяциях гидробионтов

Species	Habitat	Mean number of cells with chromosome aberrations, %	Number of embryos (larvae) with spontaneous chromosome mutagenesis, %
Polydora ciliata	Black Sea	1.5 ± 0.5	95
Glaucus sp.	Indian Ocean		91
Mytilus galloprovincialis	Black Sea		88
Chaetogammarus olivii	Black Sea		76
Idothea baltica	Black Sea		82
I. metallica	Atlantic Ocean		80
Melita palmata	Aegean Sea		85
Mysidacea gen. sp.	Black Sea		83
Decapoda gen. sp.	Atlantic Ocean		85
Pterocuma pectinata	Black Sea	2.5 ± 0.5	65
Dikerogammarus haemobaphes	Dnieper River, Kakhovsky reservoir		60
Pontogammarus crassus	Dnieper River, Kiev reservoir		56
P. robustoides	Dnieper River, Kremenchug reservoir		56
Decapoda gen. sp.	Atlantic Ocean		65
Glaucus sp.	Indian Ocean	4.0 ± 0.6	40
Melaraphe neritoides	Black Sea		43
Anchylomera Brossevilei	Indian Ocean		50
Chaetogammarus olivii	Black Sea		44
Idothea baltica	Black Sea		45
Pontogammarus crassus	Dnieper River, Kakhovsky reservoir		40
P. crassus	Dnieper, Kiev reservoir		45
Pontogammarus crassus	Dnieper River, Kremenchug reservoir	6.0 ± 0.8	18
P. robustoides	Dnieper River, Kremenchug reservoir		13
P. robustoides	Dnieper River, Kakhovsky reservoir		11
Podon polyphaemoides	Black Sea		15
Velella velella	Pacific Ocean	8.3 ± 1.3	5
Monodacna caspia	Black Sea		6
Gammarus lacustris	10-km Ch NPP zone		3

Experiments with acute γ-irradiation were carried out in different seasons: in spring (April) when females producing large amount of eggs breed and in summer (June) when in population there are only females with low fecundity [7].

In Table 4 it can be seen that the posterity of females with high fecundity demonstrates less resistance to the irradiation. It is possible that age physiological peculiarities of parents contribute to definite extent into this difference. However, the main cause apparently is as follows. As it was shown in the work [2], fecundity of females depends on their size. The relation is expressed by the power function with the index of extent, equaled to 3, and the constant to 0.0409. Small females with the size of 3 – 4 mm produce averagely three eggs, bigger females (5 – 6 mm) – 12 eggs and the biggest females (7 – 10 mm) – 40 – 50 eggs. The relation between sizes of females and their fecundity is observed for other groups of Crustacea, specifically, for Cumacea, Mysidacea and some others.

Table 3 Reproductive contribution calculated for females with different fecundity

Табл. 3 Репродуктивный вклад, рассчитанный для самок с разной плодовитостью

Mean level of chromosome mutagenesis,%	Number of posterity with spontaneous mutagenesis, %	Mean fecundity of females (number of eggs)	Number of posterity with spontaneous mutagenesis per a female
		5	4
		20	16
1.5 ± 0.5	80	50	40
		100	80
		5	3
2.5 ± 0.5	60	20	12
		50	30
		100	60
		5	2
4.0 ± 0.6	40	20	8
		50	20
		100	40
		5	0.75
6.0 ± 0.8	15	20	3
		50	7.5
		100	15.0
		5	0.25
8.5 ± 0.5	5	20	1.0
		50	2.5
		100	5.0

Table 4 Cytogenetic effect of acute γ- irradiation (5 Gy) on posterity of *Chaetogammarus olivii* females with different fecundity

Табл. 4 Цитогенетическое действие острого γ- излучения (5 Гр) на потомство самок *Chaetogammarus olivii* с разной плодовитостью

Mean fecundity of females (number of eggs)	Mean number of cells with chromosome aberrations, %	Lim
40	35.7 ± 2.0	20.0 - 53.6
5	15.5 ± 1.0	3.6 - 30.0

Radioresistance of posterity depends, apparently, on fecundity of females and is decreased significantly for big females, producing large amounts of eggs. It is obvious, that fecundity of females and resistance of posterity compensate each other. Maximum adaptation of each generation is reached in such a way. The alternative (number of embryos – embryos' resistance) is solved differently in different seasons. In spring, in a decisive time for a population, when a radical change of its composition occurs, the winter big crustaceans of older age groups, making up the base of the population and its main reproductive fund for spring reproduction, completely realize their biotic potential before their mass death, producing a numerous, though less resistant posterity. In May – June young females of the 1st generation produce a small number of eggs, significantly more resistant ones. The alternative is solved in this case for the benefit of greater life ability of a small number of individuals.

From the data obtained it might be inferred that obviously higher resistance posterity in populations with low females fecundity and more wide adaptive possibility of populations with high females fecundity can be considered as a alternative properties of populations with different females fecundity.

As a model of such alternative the analysis of cytogenetic study of *Ch. olivii* population in the sewage region may be discussed. The adaptation of this population to pollution is accompanied by growing of non-specific resistance to high damage by incorporated ^{90}Sr (22 MBq/l) [7].

In order to assess adaptive possibility of this population in different seasons when females with high or low fecundity breed calculations of specimen reproductive contribution were made (Table 5).

Table 5 Reproductive contribution of *Chaetogammarus olivii* specimens under the action of ^{90}Sr
Табл. 5 Репродуктивный вклад особей *Chaetogammarus olivii* при действии ^{90}Sr

Mean fecundity of females (number of eggs)	Mean number of cells with chromosome aberrations, %	Number of embryos with spontaneous mutagenesis, %	Number of embryos with spontaneous mutagenesis per a female
5	8.7 ± 1.0	15	0.75
40	9.2 ± 1.2	10	4.0

The results show that the posterity of females with high fecundity (40 eggs) is less resistant but amount of full value embryos per a female is 5 times more than this in females with low fecundity. This example clearly demonstrates that though the resistance of the posterity in populations with low fecundity of females may be high but chances on the adaptation in populations with high females fecundity will be obviously greater.

Conclusion. On the basis of experimental data and the results of cytogenetic studies of 20 marine and freshwater invertebrates species (coelenterates, annelids, mollusks, crustaceans) with different females fecundity it was shown that approximately equal part (%) of full value posterity at the same average level of chromosome mutagenesis for populations in different species was observed. This phenomenon allows specimen reproductive contribution for different species to be calculated as well as expected reduction of population adaptive potential and the increase of ecological risk to be assessed. Calculations make it possible to suggest that the adaptation to pollution in populations with high females fecundity will be more effective.

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Оцінка екологічного ризику для популяцій водних безхребетних. В. Г. Цицугіна. На базі експериментальних даних та цитогенетічних досліджень природних популяцій морських й прісноводних безхребетних показано, що різні види, незалежно від плодовитості самок та типу пошкоджуючоі дії мають приблизно однакову долю (%) повноцінних потомків при однаковому середньому для популяцій рівні хромосомного мутагенеза. Цей феномен дозволив розрахувати репродуктивний вклад особин для видів із різною плодючістю самок та оцінити очікуване зниження адаптивного потенціалу популяцій і змішення екологічного ризику при різному рівні пошкодження популяцій. Припускається, що адаптація до забруднення буде більш ефективною у популяціях із високою плодючістю самок.

Ключові слова: водні безхребетні, забруднення, плодючість, адаптація, оцінка екологічного ризику.

Оценка экологического риска для популяций водных беспозвоночных. В. Г. Цыцугина. На базе экспериментальных данных и цитогенетических исследований природных популяций морских и пресноводных беспозвоночных показано, что разные виды, независимо от плодовитости самок и типа повреждающего воздействия, имеют приблизительно одинаковую долю (%) полноценных потомков при одинаковом среднем для популяций уровне хромосомного мутагенеза. Этот феномен позволил рассчитать репродуктивный вклад особей для видов с разной плодовитостью самок и оценить ожидаемое снижение адаптивного потенциала популяций и увеличение экологического риска при разном уровне повреждения популяций. Предполагается, что адаптация к загрязнению будет более эффективна в популяциях с высокой плодовитостью самок.

Ключевые слова: водные беспозвоночные, загрязнение, плодовитость, адаптация, оценка экологического риска.