Ecotoxicology & ERA

Stochastic processes in populations and effects of toxicants

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Problems for the discussion

- What does it mean "ecological risk"?
- What do standard ecotoxicological assays tell about ecological risk?
- The meaning of stochastic demographic processes
- natural population processes are per se dangerous
- Life in nature nature is changeable and dynamic!
 Can random phenomena be included in the
- ecological risk assessment?

Ecological risk: What does it mean?

- Ecological risk can only be defined in terms of ecology, not toxicology!
- Ecology is the study of populations, communities, and ecosystems.
 - \rightarrow Ecological risk can therefore be defined as:
 - for populations: probability of extinction (or time to extinction)
 - for communities: decline in species richness, changes in diversity, etc.
 - for ecosystems: changes in functioning (e.g. decrease in productivity, decrease in decomposition rate).













Stochastic processes

Demographic

- random fluctuations in the number of survivors and newborns (p_x and f_x remain unchanged)
- important in populations smaller than about 100 individuals
 Environmental
 - random fluctuations in fertility and survival due to variability of environmental conditions (variable p_x and f_x values)
 - impact on population dynamics independent of population size

Genetic

- random fluctuations in fertility and survival due to genetic heterogeneity of the population (variable p_x and f_x values)
 impact on population dynamics independent of population
- size

Where does the demographic stochasticity come from?

- The population size is finite → very rarely are the long-term fertility averages and survival probabilities actually realized:
 - If f_i = 2.15 and N = 50, then the actual number of newborns could be 107 or 108 but NEVER 107.5
 - If p_i = 0.13 and N = 50, then the actual number of survivors may be 6 or 7, but NEVER 6.5
- → The smaller the population, the more important random demographic phenomena

How to study stochastic processes?

Monte Carlo simulations

- invented in the 1930s, later used, e.g., in the Manhattan Project
- among the creators: Stanisław Ulam
- a class of calculation algorithm methods based on the use of random or pseudo-random numbers



Studying stochastic processes in populations

- •What kind of stochasticity is to be simulated?
 - **demographic**: number of newborns from the Poisson distribution; number of survivors of the binomial distribution
 - environmental: f_x from log-normal distribution; p_x from the beta distribution.
 - genetic stochasticity is indistinguishable from environmental













Conclusions

- The importance of demographic stochasticity depends on the population size;
- Toxicants affect the population size:
- → the effects of toxic substances under field conditions are not independent, but depend on the interaction between the direct toxic effects and stochastic phenomena.
- Interaction is probably most important at moderate contamination levels and in low to medium size populations (high contamination will outweigh random effects, and in large populations demographic randomness is of little importance).









The influence of temperature on the fertility of grasshoppers

Species	Temeperature (°C)	Cocoons per female	Eggs per cocoon	Total reproductive output
Chorthippus	25	1.6	8.3	13.28
brunneus	30	8.2	9.7	79.54
	35	22.6	10.1	228.26
Stenobothrus	30	0.5	-	0
lienatus	35	2.2	3.2	7.04













Conclusions

- Stochastic processes can significantly change the ecological risk caused by contamination;
- Although in non-polluted environments, demographic stochasticity is important only in small populations, toxicants decrease the population size and, consequently, increase the importance of demographic stochasticity;
- Environmental stochasticity can also be important in large populations (e.g., at N₀ = 1000, p_{ext} increased from ca. 0.2 at RSD = 0 to 0.7 at RSD = 50%)

Conclusions for risk assessment

- The following data are necessary for a meaningful assessment of the extinction risk:
 - the life history of the organism;
 - population size;
 - variability of environmental conditions.
- However, facts contradict the high risk of extinction at moderate contamination levels: risk assessment models should take into account the density dependence.



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A farewell message: Living in an unpredictable world is dangerous!

