5.6: Metapopulations

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Learning objectives

You should be able to

- explain the relevance of meta-population dynamics for environmental risks of chemicals
- name the important mechanisms linking meta-populations to chemical risks

Implications of meta-population dynamics on risks of environmental chemicals

Populations can be defined as a group of organisms from the same species which live in a specific geographical area. These organisms interact and breed with each other. At a higher level, one can define meta-populations which can be described as a set of spatially separated populations which interact to a certain extent. The populations may function separately, but organisms can migrate between the populations. Generally the individual populations occur in more or less favourable habitat patches which may be separated by less favourable areas. However, in between populations, good habitats may also occur, where populations have not yet established , or the local populations may have gone extinct. Exchange between populations within a meta-population depends on i) the distances between the individual populations, ii) the quality of the habitat between the populations, e.g. the availability of so-called stepping stones, areas where organisms may survive for a while but which are too small or of too low habitat quality to support a local population and iii) the dispersal potential of the species. Due to the interactions between the different populations within a meta-population, chemicals may affect species at levels higher than the (local) population, also at non-contaminated sites.

An important effect of chemicals at meta-population scale is that local populations may act as a source or sink for other populations within the meta-population. When a chemical affects the survival of organisms in a local population, the local population densities decline. This may increase the immigration of organisms from neighbouring populations within the meta-population. Decrease of local densities would decrease emigration, resulting in a net-influx of organisms into the contaminated site. This is the case when organisms do not sense the contaminants, or that the contaminants do not alter the habitat quality for the organisms. In case the immigration rate at the delivering/source population to replace the populations is too high to replace the leaving organisms, population densities in neighbouring populations may decline, even at the non-contaminated **source** sites. Consequently, local populations at contaminated sites may act as a **sink** for other populations within the meta-population, so chemicals may have a much broader impact than just local.

On the contrary, when the local population is relatively small, or the chemical stress is not chronic, meta-population dynamics may also mitigate local chemical stress. Population level impacts of chemicals may be minimised by influx of organisms of neighbouring populations, potentially **recovering** the population densities prior to the chemical stress. Such recovery depends on the extent and duration of the chemical impact on the local populations and the capacity of the other populations to replenish the loss of the organisms in the affected population.

Meta-population dynamics may thus alter the extent to which contaminants may affect *local* populations _ through migration between populations. However, chemicals may affect the total carrying capacity of the meta-population as a whole. This can be illustrated by the modelling approach developed by Levins in the late 1960s (Levins 1969). A first assumption in this model is that not all patches that can potentially carry a local population are actually occupied, so let F be the fraction of occupied patches (1-F being the fraction not occupied). Populations have an average change of extinction being *e* (day^{-1} when calculating on a daily base), while non-occupied patches have a change of *c* of being populated (day^{-1}) from the populated patches. The daily change in numbers of occupied patches is therefore:

Formule

In this formula *c**F*(1-F) equals the number of non-occupied patches that are being occupied from the occupied patches, while *e* * F equals the fraction of patches that go extinct during the day. This can be recalculated to a carrying capacity (CC) of

$$CC = 1 - \frac{e}{c}$$

while the growth rate (GR) of the meta-population can be calculated by

$GR = c - e$

In case chemicals increase extinction risk (*e*), or decrease the chance on establishment in a new patch (*c*) this will affect the CC (which will decrease because *e*/*c* will increase) as well as the GR (will decrease, may even go below 0). However, this model uses average coefficients, which may not be directly applicable to individual contaminated sites within a meta-population. More (complex) recent approaches include the possibility to use local-population specific parameters and even more, such model include stochasticity, increasing their environmental relevance.

Besides affecting populations directly in their habitats, chemicals may also affect the areas between habitat patches. This may affect the potential of organisms to migrate between patches. This may decrease the chances of organisms to repopulate non-occupied patches, i.e. decrease *c*, and as such both CC and GR. Hence, in a meta-population setting chemicals even in a non-preferred habitat may affect long term meta-population dynamics.

References

Levins, R. (1969). Some demographic and genetic consequences of environmental heterogeneity for biological control. Bulletin of the Entomological Society of America 15, 237-240

5.6. Question 1

What are drivers of recovery of local populations that are affected by a chemical stressor in a meta-population setting?

5.6. Question 2

In what type of meta-population would a local population be less affected, with smaller number of local populations which are relatively large, or a setup with lot of small local populations?
