# Spatial Ecology

*"Populační ekologie živočichů"*

Stano Pekár

**Spatial ecology** - describes changes in spatial pattern over time

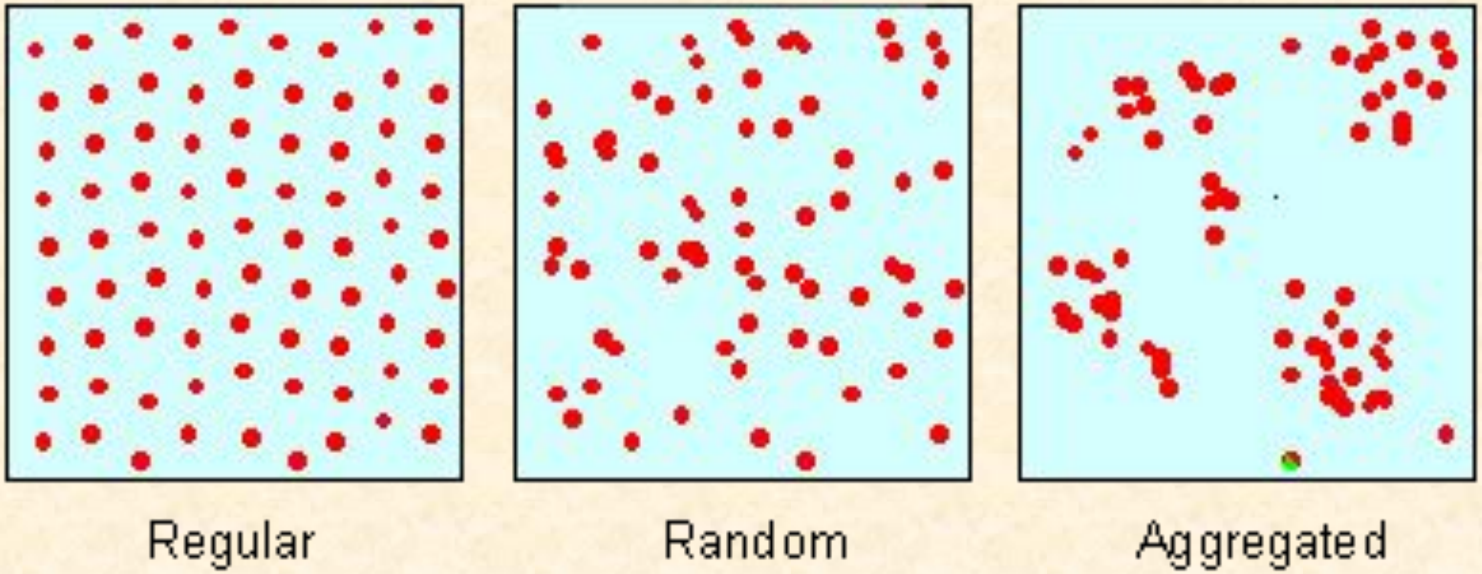
- processes - colonisation / immigration and local extinction / emigration

- local populations are subject to continuous colonisation and extinction
- wildlife populations are fragmented

**Metapopulation** - a population consisting of many local populations (sub-populations) connected by migrating individuals with discrete breeding opportunities (not patchy populations)

# Distribution of individuals

- population density changes also in space
- for migratory animals (salmon) seasonal movement is the dominant cause of population change
- movement of individuals between patches can be density-dependent
- distribution of individuals have three basic models:




- most populations in nature are aggregated (clumped)

# Regular distribution

- described by hypothetical discrete uniform distribution

$$P(x) = \frac{1}{n}$$

$n$ .. is number of samples
$x$ .. is category of counts (0, 1, 2, 3, 4, ...)

- all categories have similar probability
- mean: $\mu = \frac{1}{2}(n+1)$
- variance: $\sigma^2 = \frac{1}{12}(n^2 - 1)$
- for regular distribution: $\mu > \sigma^2$

# Random distribution

- described by hypothetical Poisson distribution

$$P(x) = \frac{\mu^x e^{-\mu}}{x!}$$

$\mu$ .. is expected value of individuals
$x$ .. is category of counts (0, 1, 2, 3, 4, ...)

- probability of $x$ individuals at a given area usually decreases with $x$

- observed and expected frequencies are compared using $\chi^2$ statistics

- for random distribution: $\mu = \sigma^2$

# Aggregated distribution

- described by hypothetical negative binomial distribution

$$P(x) = \left(1 - \frac{\mu}{k}\right)^{-k} \frac{(k+x-1)!}{x!(k-1)!} \left(\frac{\mu}{\mu+k}\right)^{x}$$

$\mu$ .. is expected value of individuals
$x$ .. is category of counts (0, 1, 2, 3, 4, ...)
$k$ .. degree of clumping, the smaller $k$ ($\rightarrow 0$) the greater degree of clumping

- approximate value of $k$: $$k \approx \frac{\mu^2}{\sigma^2 - \mu}$$

- for aggregated: $\mu < \sigma^2$

**Coefficient of dispersion (CD)**

$$CD = \frac{s^2}{\bar{x}}$$

CD < 1 … uniform distribution
CD = 1 … random distribution
CD > 1 … aggregated distribution

# Dispersal

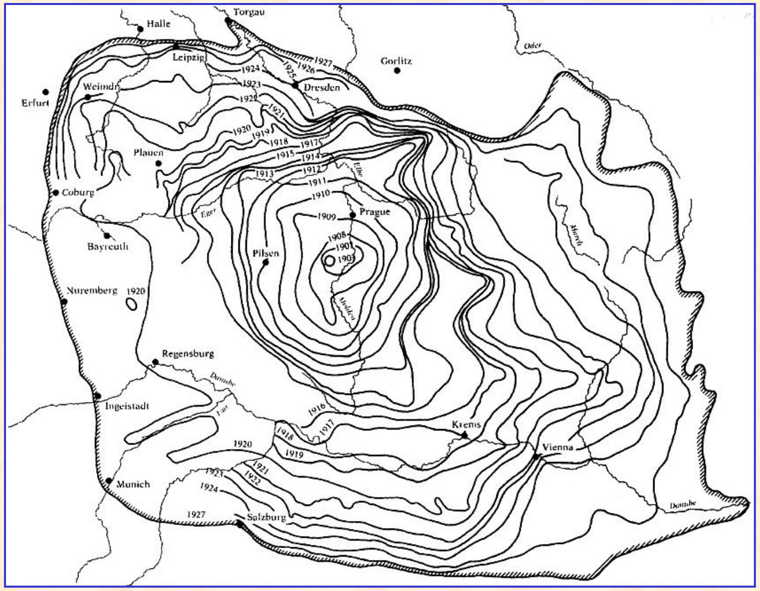
- **Geographic range** - radius of space containing 95% of individuals
- **expansion** – increase in geographic range
- individual makes blind **random walk**
- random walk of a population undergoes **diffusion** in space
- diffusion (Brownian motion)  model in 2dimensional space:

$$\frac{\partial N}{\partial t} = D\left(\frac{\partial^2 N}{\partial x^2} + \frac{\partial^2 N}{\partial y^2}\right)$$

\- radial distance moved in a random walk is related to $\sqrt{time}$

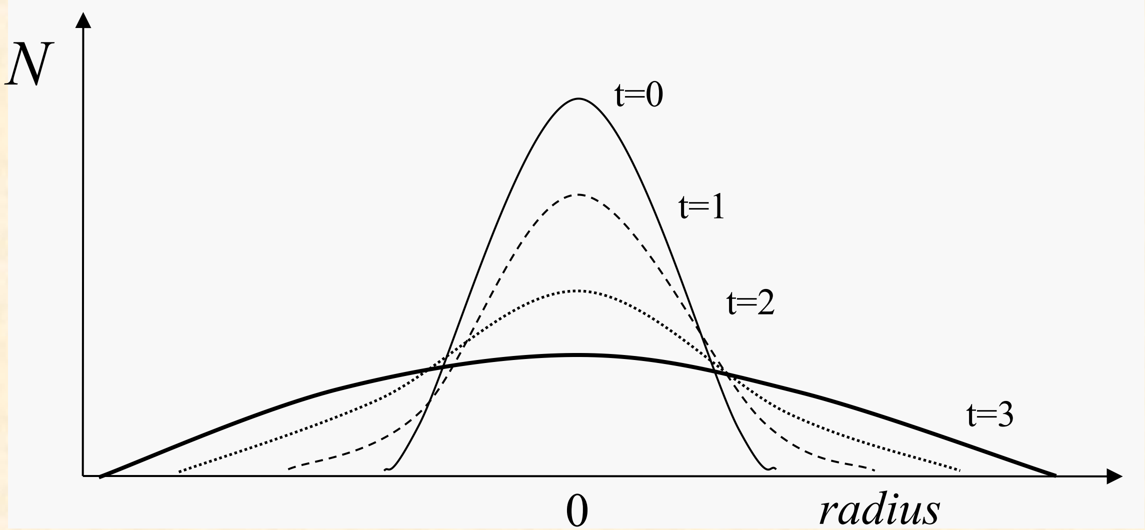
*D* .. diffusion coefficient (distance²/time)

Elton 1958




Spread of muskart in Europe

# Pure dispersal




- Diffusion model
- solved to 2dimensional Gaussian distribution

$$N(\rho,t)=\frac{N_0}{4\pi Dt}\exp\left(\frac{-\rho^2}{4Dt}\right)$$

$$\rho=\sqrt{4Dt}$$

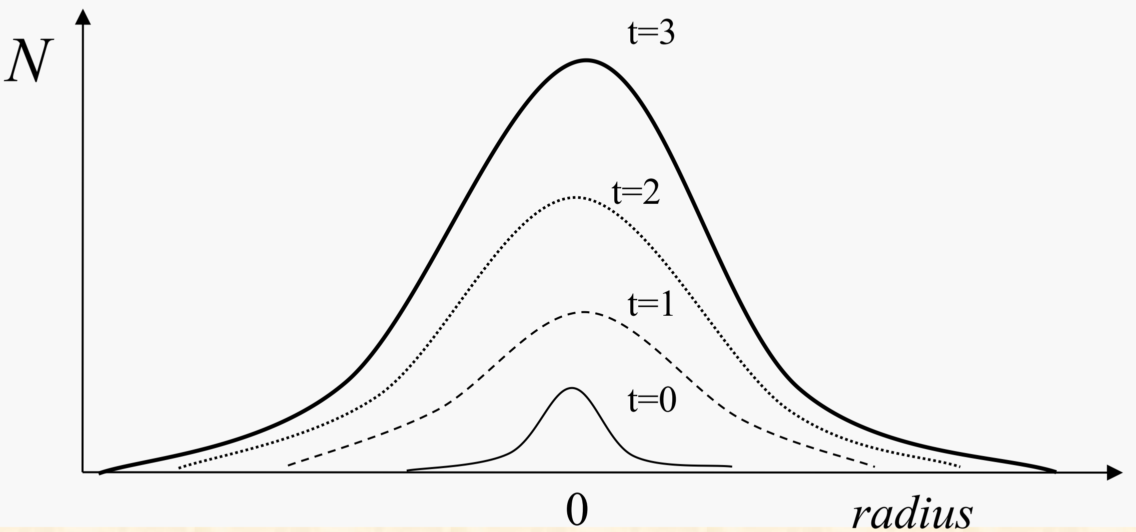
$$D=\frac{\rho^2}{4t}$$

- assuming all individuals are dispersers
- range expanses linearly with time
- no reproduction

$N_0$ .. initial density

$\rho$ .. radial distance from point of release (range)

# Dispersal + population growth




• Skellam‘s model
- includes diffusion and exponential population growth

*r* .. intrinsic rate of increase

$$N(\rho,t) = \frac{N_0}{4\pi Dt}\exp\left(rt - \frac{\rho^2}{4Dt}\right)$$

*c* - expansion rate [distance/time]

$$c = 2\sqrt{rD}$$

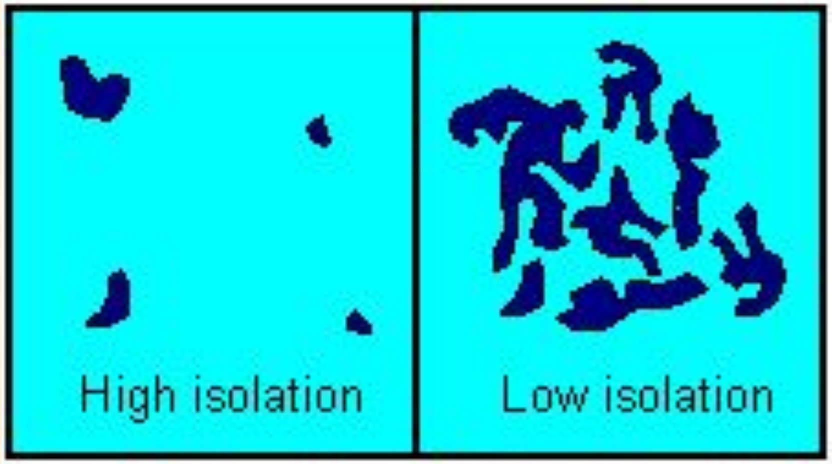
Skellam 1951

# Metapopulation ecology

- Levins (1969) distinguished between dynamics of a single population and a set of local populations which interact via individuals moving among populations

- Hanski (1997) developed the theory - suggested *core-satellite* model

- the degree of isolation may vary depending on the distance among patches




- unlike growth models that focus on population size, metapopulation models concern persistence of a population - ignore fate of a single sub-population and focus on fraction of sub-population sites occupied

# Levin's model

- assumptions

- sub-populations are identical in size, distance, resources, etc.
- extinction and colonisation are independent of *p*
- many patches are available
- natality and mortality is ignored

*p* .. proportion of patches occupied
*m* .. colonisation (immigration) rate - proportion of open sites colonised per unit time
*e* .. extinction (emigration) rate - proportion of sites that become unoccupied per unit time

$$\frac{\mathrm{d}p}{\mathrm{d}t} = mp(1-p) - ep$$

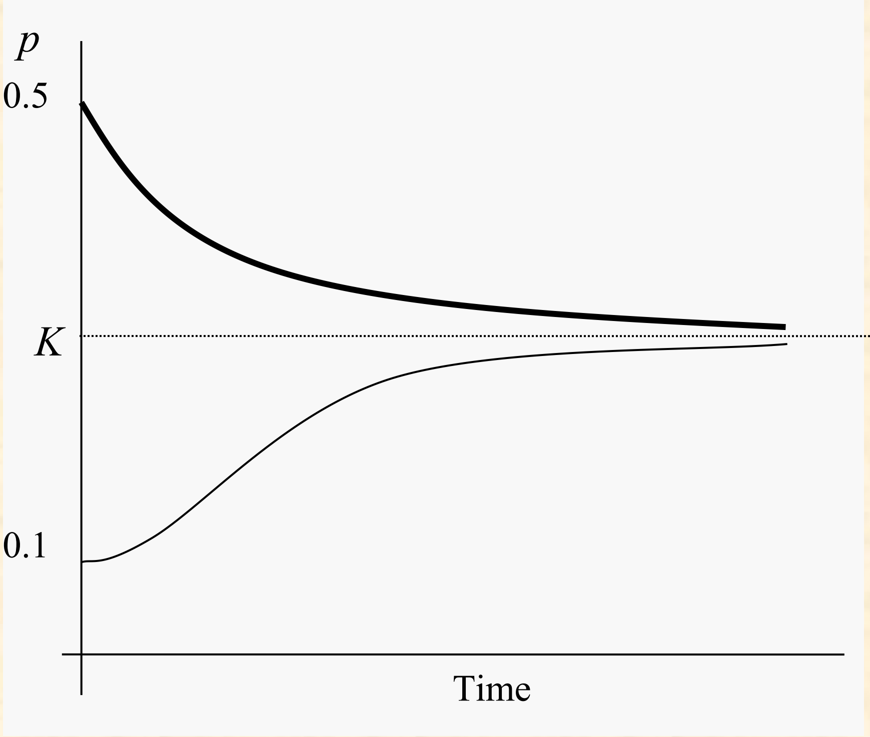
Levin (1969)

- equilibrium is found for $\frac{\mathrm{d}p}{\mathrm{d}t} = 0$

$$p^* = \frac{m - e}{m} = 1 - \frac{e}{m}$$

- sub-populations will persist ($p^* > 0$) only if colonisation is larger than extinction ($m > e$)
- all patches can be occupied only if $e = 0$

- $K$ ..is fraction of patches
- defined by balance between $m$ and $e$




- metapopulations are found in insects, *Daphnia*, frogs, birds

- rescue-effect model, incidence model