Let \( p(t) \) be the fraction of suitable habitat patches that are occupied at time \( t \) (\( p(t) \) is a measure of the size of the metapopulation).

- \( e \): rate of local extinction (i.e., rate at which occupied patches go extinct)
- \( m \): rate of (re)colonization of empty patches (rate per occupied patch and per available patch)

It follows (from the definitions) that the rate at which empty patches are colonized is \( mp(1-p) \) and the rate at which patch go extinct is \( ep(1-p) \), therefore:

\[
\frac{dp}{dt} = mp(1-p) - ep
\]

Original LEVINS Model (1969): Model of an "ideal" metapopulation consisting of a very large number of identical patches, each of which might be occupied or unoccupied at any given point in time.

Differential equation predicting rate of change in proportion of patches occupied.

Analogy to population models: rate of change depends on "birth" of patches (colonization) minus "death" of patches (local extinction).

This basic equation is analogous to the logistic equation \( \frac{dn}{dt} = rn(1-n/k) \) except that it gives rate of change in number of occupied patches instead of rate of change in number of individuals:

\[
\frac{dp}{dt} = mp(1-p) - ep = mp(1-p) - ep(1-p/(1-e/m))
\]

\( m-e \) is metapopulation equivalent of \( b-d \) and \( 1-e/m \) is equivalent of \( K \) (carrying capacity) because \( \frac{dp}{dt} = 0 \) when:

\[
p = 1 - e/m
\]

Equilibrial solution to number of patches occupied:

Metapopulation persists if colonization rate exceeds extinction rate.

Characteristics of a “classic” metapopulation (Hanski 1997)

1. Suitable habitat occurs in discrete patches that may or may not be occupied by local reproducing populations
2. Even the largest local populations have a measurable risk of extinction (unless the largest population is the source of a source-sink system)
3. Habitat patches must not be too isolated to prevent recolonization following extinctions. The regional metapopulation persists in the face of local extinctions precisely because of sufficient dispersal among populations.
4. Local populations do not have completely synchronous dynamics (i.e., “rescue effect”).

Prediction: a threshold number or density of suitable patches is required for large-scale metapopulation persistence. The larger scale processes of migration and colonization, as well as the regional distribution of patches, determine population dynamics. [More than just a patchy, subdivided population]

Synchrony among populations increases metapopulation extinction risk.

Spatial Population Structures

(from Harrison and Taylor 1997)
(from Harrison and Taylor 1997)