BIOL 410 Population and Community Ecology

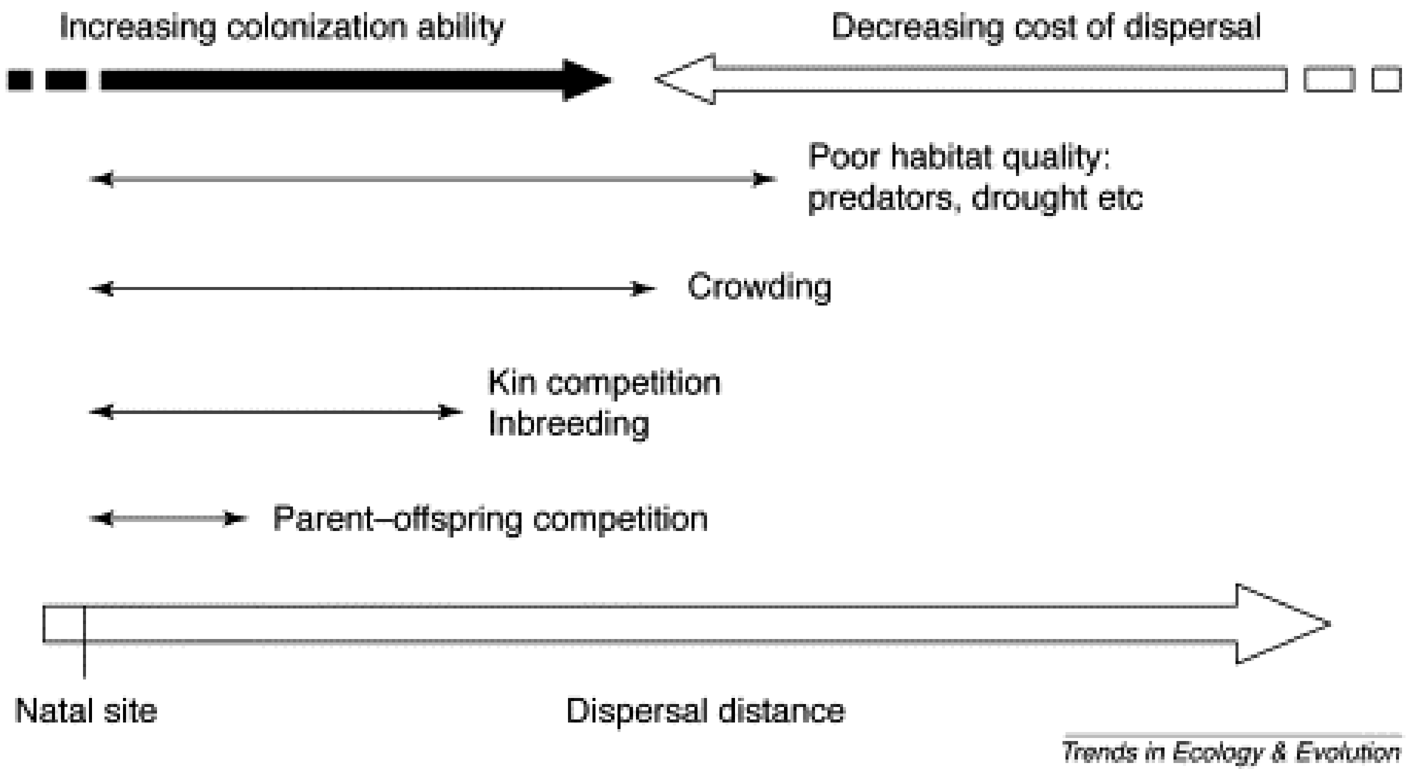
Dispersal
Source-sink populations
Metapopulations

Dispersal

- Movement away from breeding site
  - Natal dispersal
    - Movement of individuals from their site of birth to their breeding site
  - Breeding dispersal
    - Movement from one breeding site to another
- Three stages (leaving, travelling, settling)

Dispersal

- Means of escape (competition (kin), environmental conditions)



(Ferriere et al. 2000)

Who disperses?

- Stage dependent?
- Sex dependent?
- Genetic dependent?
- Phenotype dependent (dispersal polymorphism)

Who disperses?

- Stage dependent
  - Egg, seed
  - Juvenile
  - Adult

    - Investment
    - Costs (survival, reproductin)
    - Competition

- Disperser size and number
  - Mortality during dispersal
  - Energetic cost
  - Competitive ability following dispersal

Who disperses?

- Sex dependent
  - In birds, females are predominantly the dispersing sex
  - In mammals, males are more likely to disperse

  - Dispersal may be more costly for female mammals:
    - **Female** reproductive success is **limited primarily by nutritional constraints**, while males are limited by number of females they can inseminate. So, females may benefit more than males from familiarity with food resources, denning sites, & neighbours.
    - **Male** reproductive success depends more on **access to mates**, they may benefit by moving to areas or groups where there are larger numbers of mates (e.g., lions & some primates)

  - Contrast with birds?
    - Avian mating systems are largely based on **resource defence**. So, males might be more successful in establishing territories in their natal area because familiarity may permit higher feeding rates & reduced predation rates.
    - Females might benefit from the potential to choose between the resources of different mates &, if **inbreeding** is costly, females rather than males should disperse

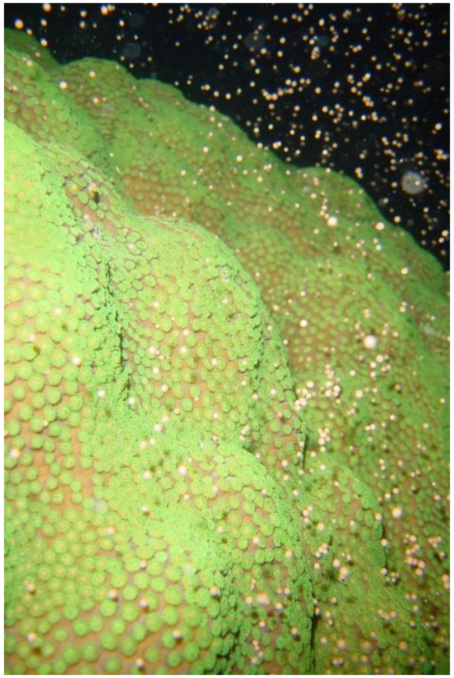
Who disperses?

- Genetic dependent
  - Propensity to disperse genetically dependent

- Phenotype dependent (dispersal polymorphism)

Is dispersal passive or active

- Passive dispersal
  - Dispersal distance random (somewhat)
  - Habitat selection minimum



Who disperses?

- Active dispersal
  - Influence dispersal distance
  - Habitat selection
    - Best of “n”
    - State or experience dependent

When dispersal occurs

- Density independent?
- Density dependent?
  - Resource dependent?
  - Competition dependent?

Measuring movement and dispersal

- Landscape connectivity
- Dispersal kernels

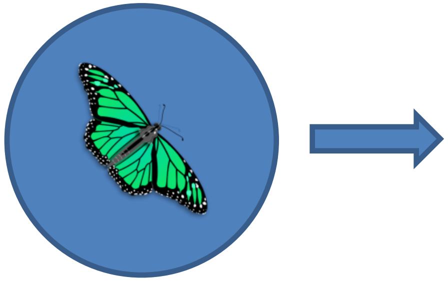
- Tracking individuals
- Tracking dispersal, migration impacts
  – Population genetics

Incorporating immigration and emigration in population models

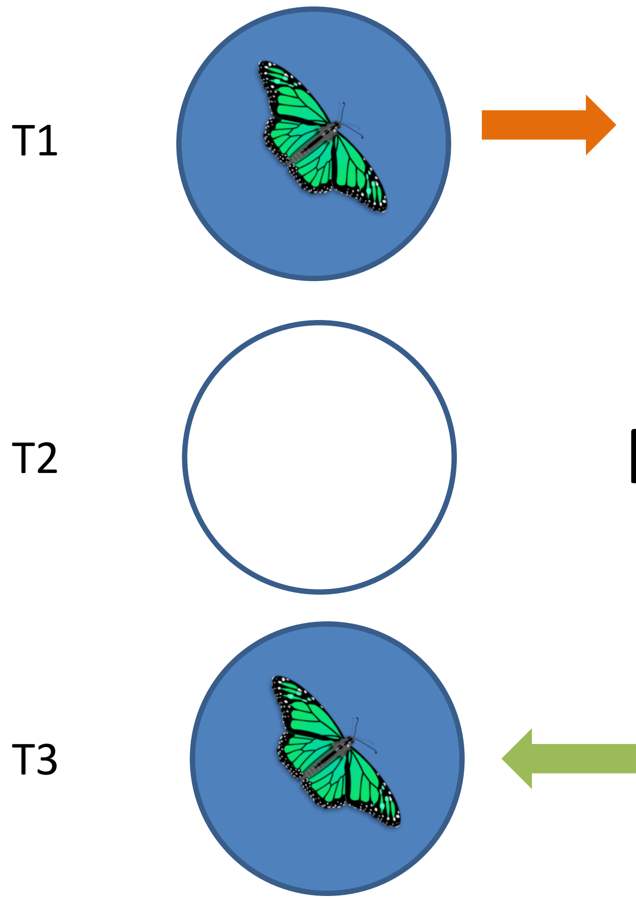
$$N_{t+1} = N_t + B - D + I - E$$

Exponentially growing populations

- Build in emigration, either as a constant rate of loss (c), or as a per capita rate of emigration (density dependent loss) – g.
  - $\frac{dN}{dt} = rN - c$ or $\frac{dN}{dt} = rN - gN$



$$\frac{dN}{dt} = rN - gN$$



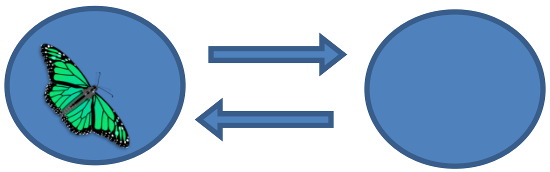
Patch occupancy?

- Relevant biological scale?
  - Population?
  - Patch?

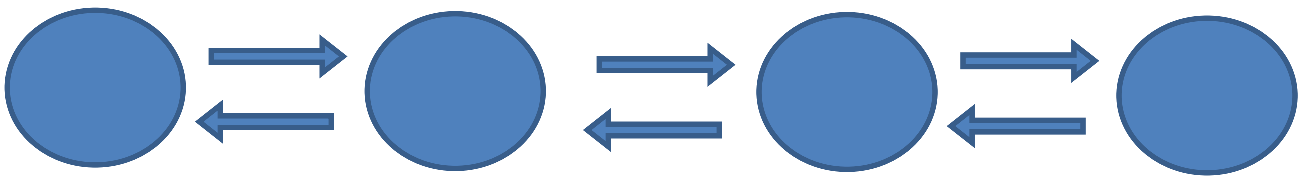
Habitat patches

- Patch is a general term
- Definition of “patch” varies according to context
- Patch may equate with a terrestrial or aquatic ‘island’
- A patch can be any size

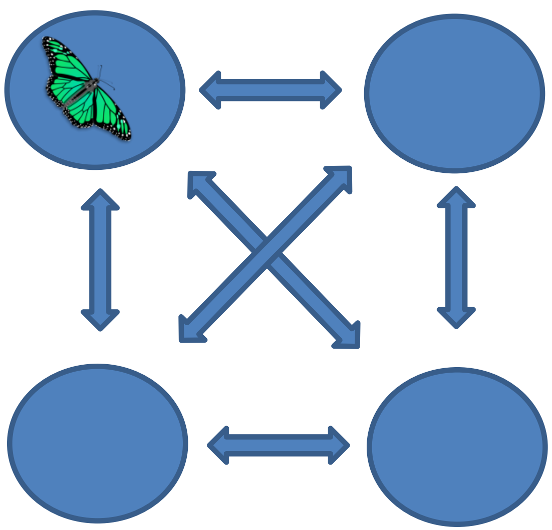
Patch occupancy in space



Two patch



One-dimensional
Stepping stone



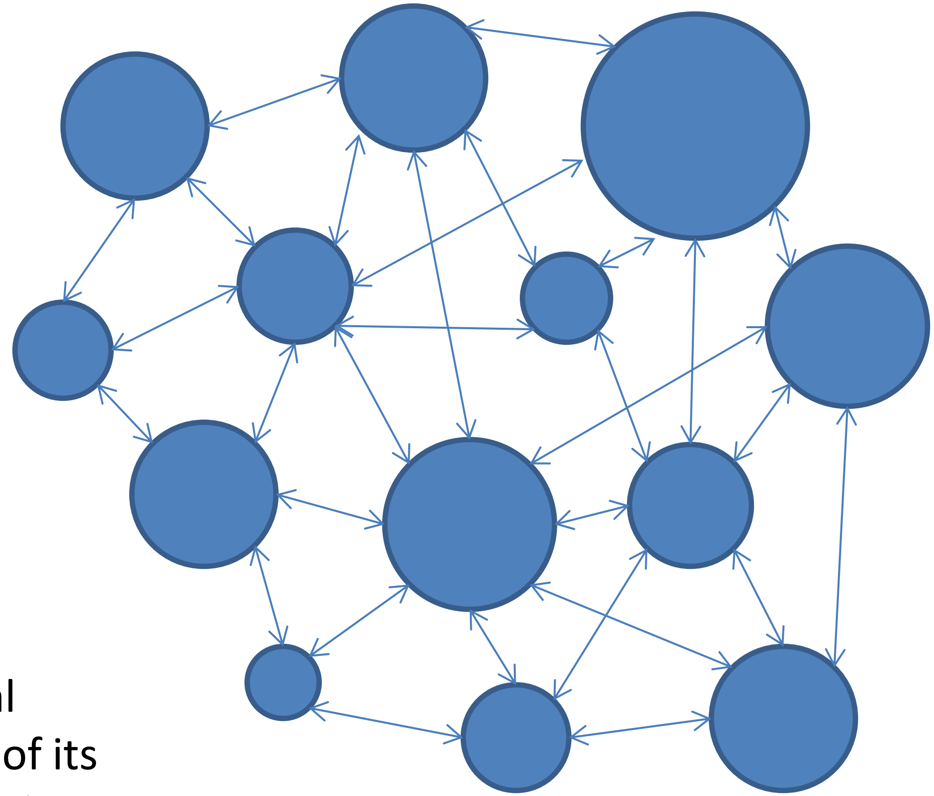
Metapopulation

Metapopulation
persistence
vs.
Patch occupancy

Metapopulations

Metapopulations

- Comprised of subpopulations occupying individual patches
- interconnected by immigration/emigration



Local extinctions

- loss of individual subpopulations.

Regional extinctions

- loss of all subpopulations in a metapopulation

Dynamics of a metapopulation is a continual cycle of **local extinction** and **recolonization** of its collective subpopulations, rather than the gain and loss of individuals

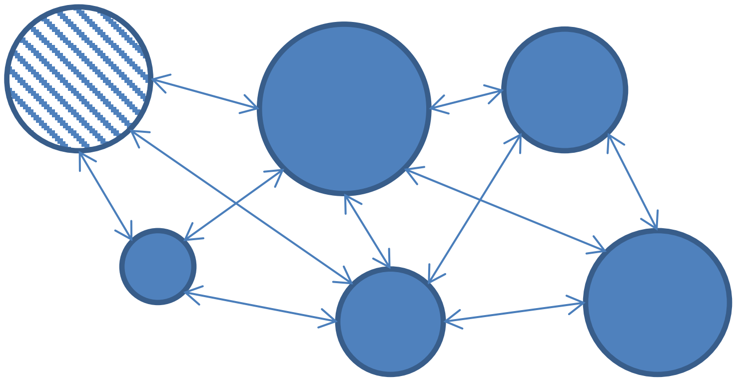
Metapopulations

- Occupancy models
  - Patch state: occupied, unoccupied
  - Patch processes: extinction, colonization

- Classic Levin's metapopulation model (1970)
  1. Assume that density of individuals in patch is not important
  2. Patches may experience colonization or extinction events
     - In basic model not landscape or habitat dependent
  3. Consider occupation as patches containing one or more individual
  4. Population measure: fraction of patches occupied by a species (regardless of density within the patches)

Extinction vs Persistence

- **Within a subpopulation**
- **Probability of extinction within fixed time period (*p_e*)**
- **Probability that subpopulation will persist during the same period (1- *p_e*)**



Probability (P) that the population will persist for a number (n) of time periods (years or decades):

$$P_n = (1 - p_e)^n$$

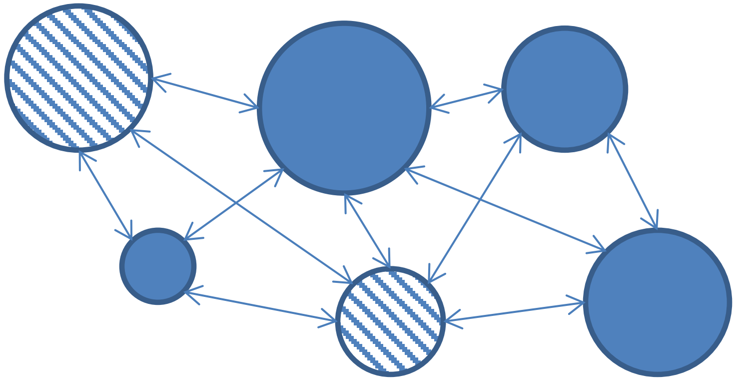
Regional Extinction Risk

- **Probability that two subpopulations (or patches - *x*) will go extinct within a single time period -** $(p_{e1} \times \ p_{e2})$

- **Probability that at least ONE subpopulation will persist is one minus the probability that ALL patches will go extinct simultaneously**

- $P_x = 1 - (p_e)^x$

- **Where P_x is probability of regional persistence**



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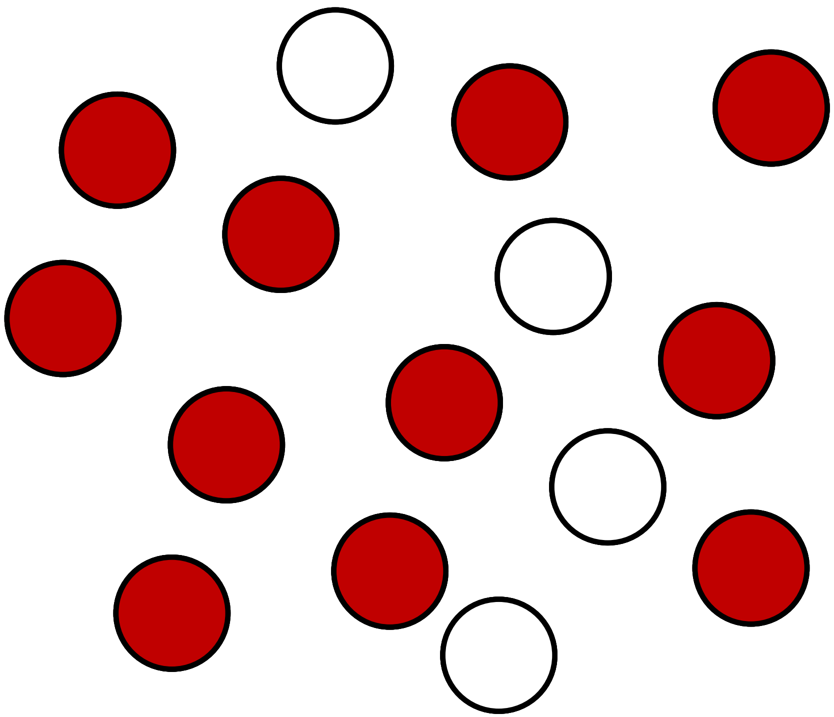
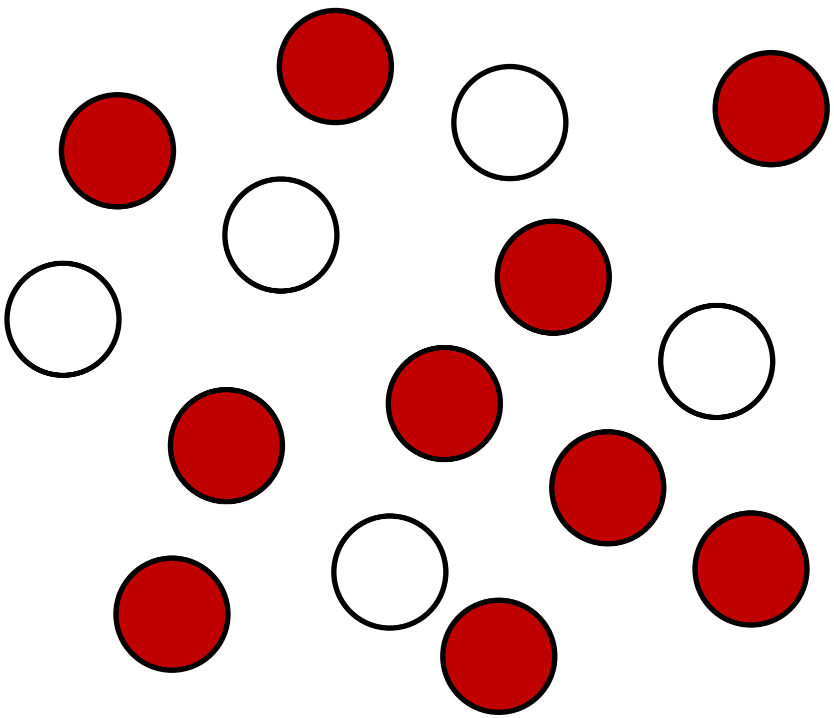
Site Occupancy

- **Assume a set of homogenous patches that can hold or be colonized by subpopulations:**



Site Occupancy

- **fraction of the sites occupied (*f*) over time (t) is the interplay between immigration rates (I) and extinction rates (E)**



$$\frac{df}{dt} = I - E$$

Basic Metapopulation Model

- **Probability of local colonization (p_i) – Chance that an unoccupied patch will be colonized over the next time step.**
- **influenced by patch size, resources, proximity to other patches etc.**
- **Can be dependent or independent of the fraction of sites occupied (f)**

- **Immigration rate (I) is dependent on probability of local colonization (p_i) and availability of unoccupied sites (1-f).**

$$I = p_i(1 - f)$$

Basic Metapopulation Model

- **Probability of local extinction (p_e) – Chance that a subpopulation in a patch will go extinct over the next time step.**

- **Extinction rate (E) is the product of local exinction probability (p_e) and the fraction of sites occupied (f).**

$$E = p_e f$$

Basic Metapopulation Model

- **Thus, the change in the fraction of sites occupied over time (*df/dt*) is the probability of local colonization of available sites [$p_i(1-f)$] minus the number of occupied sites that are likely to go extinct over that time step ($p_e f$).**

$$\frac{df}{dt} = p_i(1-f) - p_e f$$

Model Assumptions

1. **Homogenous Patches**
2. **No spatial structure**
3. **No time lags**
4. **Constant p_e and p_i**
5. **Regional occurrence (f) affects local colonization (p_i) and extinction (p_e)**
6. **Large number of patches**

Island-Mainland Model

- **Colonization of patches (p_i) does not depend upon immigration among patches, but occurs via a continuous source of migrants from a large source population (*propagule rain*).**

Island-Mainland Model

- **Stable rate for fraction of sites occupied over time (df/dt = 0)**
- $\frac{df}{dt} = p_i(1-f) - p_e f$
- $0 = p_i(1-f) - p_e f$
- $0 = p_i - p_i f - p_e f$
- $0 = p_i - p_i f - p_e f$
- $p_i f + p_e f = p_i$

- $estimated\ freq\ of\ sites\ occupied\ \hat{f} = \frac{p_i}{p_i + p_e}$

Internal Colonization

- **internal colonization effect (*i*) -** constant within a population, reflects how much the colonization of empty patches increases with each additional patch occupied

$$\boldsymbol{p_i = i\,f}$$

Internal Colonization

- **Determine fraction of sites occupied (f) where rate of site occupancy (df/ft) is stable, or zero**

Basic metapopulation model

$$\frac{df}{dt} = p_i(1-f) - p_e f \quad \longrightarrow \quad \frac{df}{dt} = if(1-f) - p_e f$$

$$\hat{f} = 1 - \frac{p_e}{i}$$

Internal Colonization

- **In contrast to Island-Mainland model, persistence (*f*>0) is no longer guaranteed.**

- **Persistence (*f*>0) in Internal Colonization Model occurs if the internal colonization effect (*i*) is greater than the probability of local extinction (p_e).**

Sources and Sinks and the Rescue Effect

- **What if patches vary in quality?**
- **If some subpopulations have positive intrinsic growth rates ($r>0$), they could produce surplus individuals than the local carrying-capacity that emigrate from the patch (SOURCE POPULATIONS)**
- **These migrants may colonize subpopulations that are in decline ($r<0$) and prevent local extinctions (SINK POPULATIONS)**
- **This is termed the *Rescue Effect***

Rescue Effect

- **The extinction parameter (e) – measure of the strength of the rescue effect**

- $p_e = e(1 - f)$

Rescue Effect with propagule rain

- **Determine fraction of sites occupied (f) where rate of site occupancy (df/ft) is stable, or zero**

Basic metapopulation model

$$\frac{df}{dt} = p_i(1-f) - p_e f \longrightarrow \frac{df}{dt} = p_i(1-f) - ef(1-f)$$

$$\hat{f} = \frac{p_i}{e}$$

Rescue Effects and Internal Colonization

- $\frac{df}{dt} = if(1-f) - ef(1-f)$

COLONIZATION **EXTINCTION**

(internal colonization) (rescue effect)

- **Equilibrium depends on the relative sizes of *i* and *e.***
- ***If i>e,* immigration rate exceeds extinction rate, and metapopulation grows to landscape saturation (*f=1*)**
- ***If i<e*, extinct exceeds immigration and the metapopulation contracts to regional extinction (*f=0*)**
- ***If i=e*, then *f* does not change (neutral equilibrium)**
- ***If i and e vary stochastically,* metapopulation may flucuate between two equilibrium points**