Simulation Model of Mating Behavior in Flies

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Outline

(1) The role of mating behavior in natural populations

(2) The model
   (2.1) the aim and applicability of the model
   (2.2) fundamental components of the model
   (2.3) quantification of parameters

(3) Simulation
   (3.1) simulation experiments and results

(4) What is next?
Mating Behavior

*Species are groups of actually or potentially interbreeding natural populations, which are reproductively isolated from other such groups.*

*...behavior differences are among animals the most important factor in restricting random mating between closely related forms.*

E. Mayr, 1942
Mating Behavior

- Flies as model system
- Courtship before copulation (duration varies for both)
- Courtship is composed of signals (visual, olfactory, auditory, chemosensory, chemosensory)

The signals should come from both male and female

Female → threshold level → copulation
The Model
the aim of the model

- Characterizing the effect of mating behavior in speciation
- Quantification of isolation
- How ethological isolation increases over time?
- Kence-Bryant Model
- Applicable to many species of flies
The Model
fundamental components of the model

*Duration of Courtship*
- vigor values
  Assumption1: distribution of vigor within genotypes is Gaussian
  Assumption2: both sexes are identically distributed (*coevolution*)

*Duration of Copulation*
- average copulation time (*e.g.* 15 min)
- \( N(\mu, s) \)

*Positive Assortative Mating*
- isolation angle \([\theta]\) (*e.g.* 0° \(\Rightarrow\) no isolation)
Vigor

- Male and female vigor represent the intensity of courtship signals of the courting male and female.
- **Assumption:** every single individual of a population has a unique vigor value (variation among individual flies \( \Rightarrow N(\mu, s) \))
- **MALES** \( \Rightarrow \) increased activity results in increased mating success
  
  \[
  \text{vigor} \quad \underset{\downarrow}{\text{courtship time}} \quad \underset{\uparrow}{\text{mating success}}
  \]

- **FEMALES** \( \Rightarrow \) increased reluctance to mate
- Linear differential of the signals \( \Rightarrow \) “effective excitation”
  
  \[
  \text{courtship time} = \frac{H}{a_m - a_f}
  \]

\( H \) initial threshold level
Vigor

- Assumption: All females in a population exhibit a constant Initial Threshold Level (H).

\[
\text{courtship time} = \frac{H}{a_m - a_f} = \frac{1}{A_m - A_f}
\]
• Basic model of the simple hyperbolic relationship between average effective excitation, \( A_m - A_f \), and mating speed.
Duration of Copulation

- $A_m$ and $A_f$ are not correlated with copulation time
- Copulation time is independent from mating time
- Not all copulations of a given genotype exhibit identical durations (laboratory observations)

\[
\begin{align*}
\mu & \quad \text{(Randomly assigned)} \\
\sigma &
\end{align*}
\]
Positive assortative mating

- **Assortative mating** (or **assortative pairing**); sexually reproducing organisms **tend to mate** with individuals that are
  
  - like themselves in some respect (**positive assortative mating**) or
  
  - dissimilar (**negative assortative mating**)

Vigor of $A_m$ and $B_m$ are equal

- Some courtship signals may be inappropriate btw distinct genotypes due to genetic differentiation.
- An isolation based on quantitative differences.
Positive assortative mating

- Isolation angle separates the vigor signals of distinct genotypes (partial)

**Effective excitation**

\[ \text{mating time} = \frac{1}{(A_m \cos(\theta) - A_f)} \]

\[ \theta = 0^\circ \]

\[ A_m = V \]

\[ B_m = V \]

\[ \theta > 0^\circ \]  (for \( 0 < \theta \leq 90 \))

\[ B_m' < V \]
**Positive assortative mating**

- Complete reproductive isolation

Matings are possible only when $A_m > A_f$

\[ B_m \cos(\theta) = A_f \]

\[ \text{mating time} = \frac{1}{(B_m \cos(\theta) - A_f)} \]

$B_{m'} < V \Rightarrow \text{effective excitation} = 0 \Rightarrow \text{no mating!}$
The Model

Additional components of the model

Offsprings

– observing changes (distribution of mating times, genetic diversity..etc.) among generations \( \rightarrow \) speciation
– Poisson distribution, \( \lambda = 2 \)

Progeny sex

• uniform numb.

Inheritance of alleles

– Diploid; 2 alleles
– Uniform
The Model

Additional components of the model

Non-overlapping generations

More than one mating

– Males are free to court other females and mate upon completion of a copulation
– Females do not accept another male → female receptivity to other males is reduced by the transfer of sperm and seminal fluids
Simulation
Sim. Experiments & Results

SD for vigor of males and females

Percent Mating

Time (min)

International Hybrid Systems Workshop, 2008, Koç University, İstanbul
Why are we interested in mating times and distributions?
-- unbalanced inheritance of alleles to the next generation (fitness)
Simulation

Sim. Experiments & Results

- n genotypes $\rightarrow$ $n^2$ matings
- $A_m - A_f$, $B_m - B_f$
- $A_m - B_f$, $B_m - A_f$
- Keeping other variables constant, increasing the isolation angle between genotypes decreases matings among different genotypes ($A_m - B_f$ or $A_f - B_m$).
- $f(\text{IntraG}) + f(\text{InterG}) = 1$
Simulation

Sim. Experiments & Results

Ethological Isolation Index

\[ I = \frac{(M_{AA} + M_{BB} - M_{AB} - M_{BA})}{N} \]

- Possible to quantify reproductive isolation
Simulation

Sim. Experiments & Results

Exp. 1

- *Rare Male Advantage* is thought to be one of the most important factors that maintain genetic variation in natural populations.
- In experiments investigating this effect one wing of the males of one strain was clipped and clipping was alternated between rare and common strains.
- When we sum the results of these exp. an advantage favoring rare strain occurs. This is not because of any behavioral change in the rare strains but the result of clipping of wings.

Exp. 2
Simulation

Sim. Experiments & Results

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<th>genotypes</th>
<th>percentage</th>
<th>vigor</th>
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<td>rare</td>
<td>11.7</td>
<td>10</td>
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<tr>
<td>18</td>
<td>common</td>
<td>88.3</td>
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<table>
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<th>Sim. Exp.</th>
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<th>percentage</th>
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</table>

- Instead of 11.7% - 90% (~1/9)
  27.85% - 72.15% (~4/9) → shown as a proof for rare male advantage
New features

– **Overlapping generations**
  
  - Fly populations show very little overlapping of generations

– **Isolation angles** btw the ind. of the same genotype
New features

- Initial threshold level (H) is not the same for all females in a population.
Thank you for your attention...

References: