Competition

Problem and Theory
GxG Interactions
Problem

• Competition (Fighting)
  – Dominance
  – Limited Space
  – Limited Food Supply
  – Peck Order
Results of Competition

• Reduced Gain
• Increased Mortality
  – Direct
  • Injuries
  – Indirect
  • Immune response
  • Diseases susceptibility
• Reduced Feed Efficiency
  – Energy lost in fighting
  – Increased Fat deposition

Animal Well being concerns
Effects of Group Size on Pig Growth and Composition

• Group Size:
  1, 4, 8, 16 or 32 pigs per pen

• Similar Pen and Feeder Space Per Pig

• Average Initial and Final Pig Weights
  25.7 and 108.5 kg

Average Daily Gain


Group Size

Lecture 15
Fat Depth

They May Look Happy, But Competition is a Real Problem in Swine and Poultry
Animal Well-being

• Animal Welfare Issues Are Becoming a Major Concern.
  – Egg Producers Are Asking for a Different Type of Hen, Specifically Adapted to ‘Animal Friendly’ Production Systems Preisinger (1998).
The Cause of the Problem

• Environment of Selection
  – Natural
    Unlimited Territory
    Limited Food
    Must Attract Mates

• Environment of Production
  – Domestic
    • Limited Territory
    • Food Provided
    • Mates Provided
Examples Of Behavioral Problems

- Susceptibility To Hysteria In Large Groups
- Pacing Before Laying,
- Feather Pecking
- Cannibalistic Deaths
- Fearful Or Panic Responses
- Cannibalism
- Inter-individual Aggression
Contributing to The Problem

• Individual Selection
  – Group Setting
  – Non Group Setting
Individual Selection In a Group Setting
Selects for the Most Aggressive Animals
Domestication

• Method To Adapt An Animal To A Production Environments

• Stress Is A Manifestation Of How Well The Bird Is Adapted To That Environment
Adaptation

Birds in Diverse Ecosystems Evolved from a Common Ancestor

Each Would be Stressed in the Other Environment Because they are Not Adapted to it (GxE Interaction).
Can Genetic Selection Improve Adaptability and Well-being of Birds?

• Appleby and Hughes (1991)
  – Welfare Problems In Cages Are Less Likely To Be Alleviated By Genetic Selection Than Those In Alternative Systems
  – Welfare Is Compromised If Freedom To Exercise Normal Behavior Is Absent
Genetic Selection Can Change “Normal Behavior”

• A Bird Can Evolve Through Selection
  – Prefers To Be In Close Proximity To A Large Number Of Cage Mates
  – By This Definition, Its Natural Behavior Is Not Compromised
Breeding Cabbages

- Blind Chickens
- Ethics
Solutions?

• Management
  – Well-being issues
  – Costly

• Genetics
  – Continue the Domestication Process
  – Get Rid of Unwanted and Undesirable Characteristics Which Were Needed In Natural Environments (Peck Order, Dominance)
Direct Selection on Behavior?

- What Traits Needs to Be Measured
  - Biting
  - Fighting
  - Other?
- At What Cost?
- Diverted Selection Intensity
Link Between Behavior And Stress Can Be Misinterpreted

- Duncan and Filshie (1979)
  - Flighty Strain Of Birds
    - Exhibited Avoidance And Panic Behavior Following Stimulation
    - Returned To A Normal Heart Beat Sooner Than A Line Of More Docile Birds
    - Docile Birds May Be Too Frightened To Move.
  - Is Flightiness Good Or Bad For Well-being
Indirect Selection To Reduce Undesirable Behaviors

• Group Selection
  – Based On The Hypothesis That When Productivity Of The Group Is High, Behavioral Stresses Of The Group Must Be Reduced Or Absent (GxG interaction reduced)
  – Does Not
    • Increase Costs
    • Divert Selection Intensity
    • Require Measurement Of Behaviour Traits
Among Group Selection

• Foundation Established By Griffing (1967)
• Extend Usual Gene Model
  – Direct Effects Of Its Own Genes
  – Associate Contributions From Other Genotypes In The Group (GxG interactions)
Group Selection

• Not to be confuse with individual selection for the betterment of the group
  – Wayne Edwards (1962), Hamilton (1964)
  – Controversial Evolutionary Theory
  – Appears to have a number of theoretical problems
  – Even for the case of related individual (usual kin selection)

• Group selection as applied here is among group selection
  – The entire group live or dies depending on the behavior of the group as a whole (pack behavior)
Pigs in Individual Pens

GxG Interactions Not Possible
Example Performance in Individual Pens

$Y_1 = 19$

$Y_2 = 16$

$Y_3 = 17$
Pigs in a Common Pen

GxG Interactions Possible
Interacting Effects

\[ Y_1 = \mu + D_1 + A_2 + A_3 + \varepsilon \]

\[ Y_1 = 10 + 9 + 0 + (-4) + 0 = 15 \]

\[ Y_2 = \mu + D_2 + A_1 + A_3 + \varepsilon \]

\[ Y_2 = 10 + 6 + (-7) + (-4) + 0 = 5 \]

\[ Y_3 = \mu + D_3 + A_1 + A_2 + \varepsilon \]

\[ Y_3 = 10 + 7 + (-7) + 0 + 0 = 10 \]

Lecture 15
Clone Top Pig

\[ Y_1 = \mu + D_1 + A_2 + A_3 + \varepsilon \]

\[ Y_2 = \mu + D_2 + A_1 + A_3 + \varepsilon \]

\[ Y_3 = \mu + D_3 + A_1 + A_2 + \varepsilon \]

\[ Y_1 = 10 + 9 - 7 - 7 + 0 = 5 \]

\[ Y_2 = 10 + 9 - 7 - 7 + 0 = 5 \]

\[ Y_3 = 10 + 9 - 7 - 7 + 0 = 5 \]
Clone Worst Pig

\[ Y_1 = \mu + D_1 + A_2 + A_3 + \varepsilon \]
\[ Y_2 = \mu + D_2 + A_1 + A_3 + \varepsilon \]
\[ Y_3 = \mu + D_3 + A_1 + A_2 + \varepsilon \]

\[ Y_1 = 10 + 6 + 0 + 0 + 0 = 16 \]
\[ Y_2 = 10 + 6 + 0 + 0 + 0 = 16 \]
\[ Y_3 = 10 + 6 + 0 + 0 + 0 = 16 \]
Cloning the Best Pig Gave Worst Performance and vice versa

GxG Interaction
Individual Selection in a Non Group Setting

- Selection For Aggression May Still Result Due to Genetic Correlation Between Direct and Associative Effects
Individual Selection

$$\Delta \mu = \left( \frac{i}{\sigma} \right) \left[ d \sigma^2_A + (da) \sigma_A \right]$$

$d \sigma^2_A$  Additive Genetic Variance of Direct Effects

$(da) \sigma_A$  Covariance between Direct and Associative Effects
Group Selection

\[ \Delta \mu = \left( \frac{i}{\sigma} \right) \left[ d \sigma_A^2 + 2 (da) \sigma_A^2 + a \sigma_A^2 \right] \]

\[ a \sigma_A^2 \] Variance of Associative Effects

This quantity is always positive
To Optimize Productivity In Competitive Environments

• Do Not Select Those Individuals That Perform The Best
• Select The Groups That Produces The Best
Group Selection

N=26 (6.5)

N=19 (6.3)

N=15 (15)

N=23 (5.7)
A Positive Response To Selection Is Ensured

• If Selection Is Transferred From The Individual To That Of The Group
• Group Selection Operates On Both Direct And Associate Components
Kin Selection
(Not The Usual Definition)

- If the group is composed of related individuals the efficiency is greatly increased, particularly as group size increases. Griffing (1976)
Group Selection
Applications
Application
<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Year</th>
<th>Species</th>
<th>Trait(s)</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>Wade</td>
<td>1977</td>
<td><em>Tribolium castaneum</em></td>
<td>Population size</td>
<td>First experimental study of group selection</td>
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<tr>
<td>Wade</td>
<td>1980</td>
<td><em>T. castaneum</em></td>
<td>Population size, cannibalism rate</td>
<td>Investigated the role of population structure in the response to selection</td>
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<tr>
<td>Wade and McCauley</td>
<td>1980</td>
<td><em>T. castaneum</em></td>
<td>Population size</td>
<td>Effects of propagule size and random extinction on population differentiation</td>
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<tr>
<td>Craig</td>
<td>1982</td>
<td><em>T. castaneum</em></td>
<td>Emigration rate</td>
<td>Replicated group selection treatments; explicit individual selection treatment</td>
</tr>
<tr>
<td>Wade</td>
<td>1982</td>
<td><em>T. castaneum</em></td>
<td>Population size</td>
<td>Effects of migration on population differentiation</td>
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<tr>
<td>McClintock</td>
<td>1984</td>
<td>Domestic rat</td>
<td>Male mating behavior</td>
<td>Documents probable group selection in male cooperation in mating</td>
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<tr>
<td>Goodnight</td>
<td>1985</td>
<td><em>Arabidopsis thaliana</em></td>
<td>Leaf area</td>
<td>First group selection in plants; factorially combined group and individual selection treatments</td>
</tr>
<tr>
<td>Wade</td>
<td>1987</td>
<td><em>T. castaneum</em></td>
<td>Competitive ability</td>
<td>Interdemic selection for competitive ability</td>
</tr>
<tr>
<td>Goodnight</td>
<td>1990a, 1990b</td>
<td><em>T. castaneum</em>, <em>Tribolium confusum</em></td>
<td>Population size, emigration rate</td>
<td>Selection on two species communities; demonstration of contribution of genetic interactions among individuals</td>
</tr>
<tr>
<td>Wade and Goodnight</td>
<td>1991</td>
<td><em>T. castaneum</em></td>
<td>Population size</td>
<td>Group selection by differential migration</td>
</tr>
<tr>
<td>Muir</td>
<td>1996</td>
<td>Chickens</td>
<td>Egg production</td>
<td>Group selection in vertebrates; first commercial use of group selection in animals</td>
</tr>
</tbody>
</table>

Eggs per Hen Housed

Generation

1  2  3  4  5

50  70  90  110  130  150  170  190  210  230  250

91  195  219  225  237

Lecture 15
Percent Mortality

<table>
<thead>
<tr>
<th>Generations</th>
<th>% Mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>67.9</td>
</tr>
<tr>
<td>2</td>
<td>13</td>
</tr>
<tr>
<td>3</td>
<td>15.2</td>
</tr>
<tr>
<td>4</td>
<td>14.9</td>
</tr>
<tr>
<td>5</td>
<td>8.8</td>
</tr>
</tbody>
</table>
Survival After Mechanical Failure in First Month

Colony Cage
- Selected: 48
- Control: 38

Single Cage
- Selected: 85
- Control: 79
Survival For Month 2-12

- Colony Cage: Selected 89, Control 82
- Single Cage: Selected 95, Control 93

Lecture 15
7th Generation

- Selected (KBG), Control (C), and Commercial (DXL) Lines Were Compared
- All Stocks Housed In Both Single- or 12-Bird Cages
Cumulative Mortality

- CONTROL
- KGB
- COMMERCIAL
TOTAL EGGS PER CAGE/12

- SINGLE: 251, 295, 266
- STOCK: 198, 193
- COLONY: 217

Categories:
- CONTROL
- COMMERCIAL
- SELECTED

Lecture 15
RATE OF LAY

- CONTROL
- KGB
- COMMERCIAL

COLONY
- Lecture 15

SINGLE
CONCLUSIONS

• Group Selection Is Effective In Improving Well-being Of Layers In A Relatively Short Period Of Time Without Sacrificing Productivity

• Individual Selection Makes the Problem Worse
Incorporation of Competitive Effects in Breeding Programs Without Group Selection

Mixed Model Theory
Problems With Group Selection

- Group Selection
  - Requires
    - Families Be Housed Together
    - Selected As a Group.
  - Rate of Inbreeding Increases Rapidly
Incorporation of Competitive Effects In The Mixed Model Equations (MME)
Example

Pen 1

Pen 2

Pen 3
Usual Animal Model

\[ Y = X\beta + Z_d \mu_d + \varepsilon \]

\[
\begin{bmatrix}
    y_1 \\
    y_2 \\
    y_3 \\
    y_4 \\
    y_5 \\
    y_6 \\
    y_7 \\
    y_8 \\
    y_9
\end{bmatrix}
= 
\begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \end{bmatrix}
[\beta] + 
\begin{bmatrix}
    1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
    0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
    0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
    0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
    0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
    0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\
    0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
    0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
    0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1
\end{bmatrix}
[\mu_1, \mu_2, \mu_3, \mu_4, \mu_5, \mu_6, \mu_7, \mu_8, \mu_9] + 
\begin{bmatrix}
    \varepsilon_1 \\
    \varepsilon_2 \\
    \varepsilon_3 \\
    \varepsilon_4 \\
    \varepsilon_5 \\
    \varepsilon_6 \\
    \varepsilon_7 \\
    \varepsilon_8 \\
    \varepsilon_9
\end{bmatrix}
\]
Interacting Effects

\[ Y_1 = \mu + D_1 + A_2 + A_3 + \varepsilon \]

\[ Y_2 = \mu + D_2 + A_1 + A_3 + \varepsilon \]

\[ Y_3 = \mu + D_3 + A_1 + A_2 + \varepsilon \]
Expand Mixed Model Equations

\[ Y = X\beta + Z_d\mu_d + Z_a\mu_a + \varepsilon \]
Associative Effects Incidence Matrix

\[ Y = X\beta + Z_d\mu_d + Z_a\mu_a + \varepsilon \]

**Animal 1**

\[
Z_a = \begin{bmatrix}
0 & 0 & 0 & 1 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 \\
1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
1 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 1 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 & 1 & 0 & 0
\end{bmatrix}
\]

Pigs 4 and 5 in Same pen
MME with Competitive Effects

\[
\begin{bmatrix}
XX & XZ_d & XZ_a \\
Z_dX' & Z_dZ_d + k_1A^{-1} & Z_dZ_a + k_2A^{-1} \\
Z_aX' & Z_aZ_d + k_2A^{-1} & Z_aZ_a + k_3A^{-1}
\end{bmatrix}
\begin{bmatrix}
\beta \\
\mu_d \\
\mu_a
\end{bmatrix}
=
\begin{bmatrix}
XX \\
XZ_d \\
XZ_a
\end{bmatrix}
\]

\[
\begin{bmatrix}
k_1 & k_2 \\
k_2 & k_3
\end{bmatrix}
= \sigma^2 \varepsilon
\begin{bmatrix}
\sigma_d^2 & \sigma_{ad} \\
\sigma_{ad} & \sigma_a^2
\end{bmatrix}^{-1}
\]
Genetic Parameters

\[ \sigma_d^2 \quad \text{Direct Effect} \]

\[ \sigma_a^2 \quad \text{Associate Effect} \]

\[ \sigma_{ad} \quad \text{Covariance Between Direct and Associative Effect} \]
Maximum Likelihood Estimates of Genetic Parameters

\[ L = -0.5 \ln |R| - 0.5 \ln |G| - 0.5 \ln |C| - 0.5 Y'PY \]

\[ \ln |R| = \ln |I \sigma_e^2| \]
\[ = \ln(\sigma_e^2)^N + \ln |I| \]
\[ = N \ln(\sigma_e^2) \]

\[ G = \begin{bmatrix} A \sigma_D^2 & A \sigma_{AD} \\ A \sigma_{AD} & A \sigma_A^2 \end{bmatrix} \]

\[ C = \begin{bmatrix} X'X & X'Z \\ Z'X & Z'Z + G^{-1} \sigma_e^2 \end{bmatrix} \]

\[ \ln |C| = \sum_{i=1}^{M+N+R} \ln \lambda_i \]
Optimal Selection

\[ I = b_1 \mu_d + b_2 \mu_a \]

The optimal weights are found as the partial regression coefficients of mean pen performance on estimated direct and associative effects.
### Example Pedigree

<table>
<thead>
<tr>
<th>Sire</th>
<th>Dam</th>
<th>Ani</th>
<th>Pen</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>5</td>
<td>8</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>9</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>6</td>
<td>7</td>
<td>10</td>
<td>1</td>
<td>20</td>
</tr>
<tr>
<td>6</td>
<td>7</td>
<td>11</td>
<td>2</td>
<td>10</td>
</tr>
</tbody>
</table>

![Pedigree Diagram]

\[ X = \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \end{bmatrix} \quad \quad \quad B = [\mu] \quad \quad \quad \quad Y = \begin{bmatrix} 5 \\ 6 \\ 20 \\ 10 \end{bmatrix} \]
<table>
<thead>
<tr>
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<th>Ani</th>
<th>Pen</th>
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</tr>
<tr>
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<td>5</td>
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<td>2</td>
<td>6</td>
</tr>
<tr>
<td>6</td>
<td>7</td>
<td>10</td>
<td>1</td>
<td>20</td>
</tr>
<tr>
<td>6</td>
<td>7</td>
<td>11</td>
<td>2</td>
<td>10</td>
</tr>
</tbody>
</table>

$Z_1 = \begin{bmatrix}
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\
\end{bmatrix}$

$Z_2 = \begin{bmatrix}
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
\end{bmatrix}$

10 is with 8  
11 is with 9  
8 is with 10
\[
\begin{bmatrix}
X'X & X'Z_1 & X'Z_2 \\
Z_1'X & Z_1'Z_1 + A^{-1}k_{11} & Z_1'Z_2 + A^{-1}k_{12} \\
Z_2'X & Z_2'Z_1 + A^{-1}k_{21} & Z_2'Z_2 + A^{-1}k_{22}
\end{bmatrix}
\begin{bmatrix}
\hat{b} \\
\hat{d} \\
\hat{a}
\end{bmatrix}
= 
\begin{bmatrix}
X'y \\
Z_1'y \\
Z_2'y
\end{bmatrix}
\]

\[
\begin{bmatrix}
k_{11} & k_{12} \\
k_{21} & k_{22}
\end{bmatrix}
= 
\begin{bmatrix}
\sigma_d^2 & \sigma_{da} \\
\sigma_{da} & \sigma_a^2
\end{bmatrix}^{-1}
\sigma_e^2
\]

\[
\begin{bmatrix}
k_{11} & k_{12} \\
k_{21} & k_{22}
\end{bmatrix}
= 
\begin{bmatrix}
50 & -5 \\
-5 & 10
\end{bmatrix}^{-1}
\begin{bmatrix}
50
\end{bmatrix}
\]

Lecture 15
```plaintext
proc iml;
start main;

y={5,
  20,
  6,
  10};

X={1,
  1,
  1,
  1};

A={1 0 0 0 .5 .5 0 0,
  0 1 0 0 .5 .5 0 0,
  0 0 1 0 0 0 .5 .5,
  0 0 0 1 0 0 0 .5 .5,
  .5 .5 0 0 1 .5 0 0,
  .5 .5 0 0 0 .5 1 0,
  0 0 .5 .5 0 0 1 .5,
  0 0 .5 .5 0 0 .5 1};

AINV=INV(A);

Z1={0 0 0 0 1 0 0 0,
    0 0 0 0 1 0 0 0,
    0 0 0 0 0 0 1 0,
    0 0 0 0 0 0 0 1};

Z2={0 0 0 0 0 0 1 0,
    0 0 0 0 0 0 0 1,
    0 0 0 0 1 0 0 0,
    0 0 0 0 0 1 0 0};

P={50 -5,
   -5 10};
K=inv(P)#50;
LHS=((X`*X)||(X`*Z1)||(X`*Z2))
   //((Z1`*X)||(Z1`*Z1+AINV#K[1,1])||(Z1`*Z2+AINV#K[1,2]))
   //((Z2`*X)||(Z2`*Z1+AINV#K[2,1])||(Z2`*Z2+AINV#K[2,2]));
RHS=(X`*Y)||(Z1`*Y)||(Z2`*Y);
C=INV(LHS);
BU=C*RHS;
RMSE=(Y`*Y-BU`*RHS)#(1/3);
print BU RMSE;
finish main;
run;
quit;
```

Lecture 15
Estimates

\( \hat{u} = 10.25 \)

<table>
<thead>
<tr>
<th>Animal</th>
<th>Direct</th>
<th>Associate</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>.798</td>
<td>-.217</td>
</tr>
<tr>
<td>5</td>
<td>.798</td>
<td>-.217</td>
</tr>
<tr>
<td>6</td>
<td>-.798</td>
<td>.217</td>
</tr>
<tr>
<td>7</td>
<td>-.798</td>
<td>.217</td>
</tr>
<tr>
<td>8</td>
<td>-1.117</td>
<td>-.242</td>
</tr>
<tr>
<td>9</td>
<td>3.512</td>
<td>-.410</td>
</tr>
<tr>
<td>10</td>
<td>-1.732</td>
<td>-.074</td>
</tr>
<tr>
<td>11</td>
<td>-.662</td>
<td>.727</td>
</tr>
</tbody>
</table>

Note animal with best direct effect has worst associative effect

Vice vesra
Lab Problem 1  Competition

Assume animals are in pens as indicated by the rectangles above. Fit an animal model with competitive effects, assume

$$\frac{\sigma^2_e}{\sigma^2_a} = 1 \quad \frac{\sigma^2_e}{\sigma^2_p} = .1 \quad \frac{\sigma^2_e}{\sigma^2_p} = 15$$

Lecture 15
Assume animals are in pens as indicated.

a) Fit an animal model with and without competitive effects

b) Rank Individuals for breeding using the following indexes

c) Discuss results relative to breeding program

Without Competitive Effects

$$I = \frac{1}{\sigma^2_e} \left( \begin{array}{cc} \sigma^2_d & \sigma_{da} \\ \sigma_{da} & \sigma^2_a \end{array} \right)^{-1} \left( \begin{array}{c} \mu_d \\ \mu_a \end{array} \right)$$

With Competitive Effects

$$I = \frac{1}{\sigma^2_e} \left( \begin{array}{cc} 30 & -4 \\ -4 & 10 \end{array} \right)^{-1} \left( \begin{array}{c} \mu_d \\ \mu_a \end{array} \right) + \frac{3}{60}$$
Experimental Testing

• Experimental Model
  – Quail
  – Trait: 6 Week Weight (wt)

• Methods tested:
  – Control: Animal Model BLUP (AM-BLUP)
  – Competitive Model BLUP: (CE-BLUP)

• Selected for 25 Hatches
Estimates of Genetic Parameters

\[
\mathbf{G} = \begin{bmatrix}
\sigma_D^2 & \sigma_{AD} \\
\sigma_{AD} & \sigma_A^2
\end{bmatrix} = \begin{bmatrix}
33.7 & -5.5 \\
-5.5 & 2.8
\end{bmatrix}
\]

\[
\sigma_e^2 = 124.5
\]
Initial Experiment
Group Size and Feed Restriction

Quail Mortality (%)
Initial Experiment
Group Size and Feed Restriction

6 Week Weight (g)
Results

25 Hatches of Selection
6 Week Weight

Lecture 15
Associative Effects

- AM-BLUP
- CE-BLUP
Direct Effects
Mortality At Termination of Experiment (Hatch 25)
Feed Efficiency Trial

Full Fed
No Feed Restriction
2-6 Weeks of Age
Feed Conversion (Feed per Gain)

Feed/Gain

CE-BLUP
AM-BLUP
Conclusions

• Estimation of Direct and Associative Effects Allows
  – Mapping of QTL of Unseen But Important Traits
  – Increased Efficiency of Utilization of Limited Resources
  – Increased Yield Without Increasing Inputs
  – Does Not Increase Cost of Program
Conclusions

• Traditional BLUP Selection
  – Is Not Optimal
  – Ignores Competitive Effects
  – Assumes No Genotypes x Genotype Interactions
Conclusions

- BLUP Incorporating Associative Effects
  - Almost As Good As Group Selection
  - Far Superior to Traditional BLUP
  - Does Not Increase Rate of Inbreeding As Fast As Group Selection