Does altruism exist?
If so, why?

SOCIAL EVOLUTION

I. SOCIAL BEHAVIOR

A. SOCIAL INTERACTIONS

1. COOPERATE
2. SELFISH
3. ALTRUISTIC
4. SPITEFUL

<table>
<thead>
<tr>
<th></th>
<th>ACTOR +</th>
<th>ACTOR -</th>
</tr>
</thead>
<tbody>
<tr>
<td>RECIPIENT +</td>
<td>COOPERATIVE</td>
<td>ALTRUISTIC</td>
</tr>
<tr>
<td>RECIPIENT -</td>
<td>SELFISH</td>
<td>SPITEFUL</td>
</tr>
</tbody>
</table>
II. EVOLUTION OF SOCIAL BEHAVIOR

A. SELECTION FOR SOCIAL AND EUSOCIAL BEHAVIOR

1. GROUP SELECTION
   - COOPERATION FAVORS THE ENTIRE GROUP (GROUP IS UNIT OF SELECTION)

2. NATURAL SELECTION AT GENIC (individual) LEVEL
   a. Mutualism
   b. Parental Manipulation
   c. Kin Selection. Hamilton 1963

**INCLUSIVE FITNESS**

\[ w_i = a_i + \sum r_{ij}b_{ij} \]

- \( w_i \) = inclusive fitness of \( i \)
- \( a_i \) = direct effect of trait on individual with
- \( r_{ij} \) = relatedness between \( i \) and \( j \) individuals; proportion of genome shared
- \( b_{ij} \) = benefits of \( i \)'s trait on \( j \) individual fitness
FOR ALTRUISM TO EVOLVE: HAMILTON’S RULE

\[ rb - c > 0 \text{ or } \frac{b}{c} > \frac{1}{r} \]

- \( b \): benefits of action
- \( r \): relatedness
- \( c \): costs of action

THINK OF \( b \) AND \( c \) IN UNITS OF OFFSPRING SURVIVING

SO IF \( r \) IS HIGH, THEN \( \frac{b}{c} \) NEED NOT BE TOO LARGE
SO IF \( r \) IS LOW, THEN \( c \) NEEDS TO BE LOWER AND/OR \( b \) MUST BE LARGE

- e.g., \( r = 0.5 \) (like full sibling)

\[ \frac{b}{c} > \frac{1}{0.5} \text{ or } \frac{b}{c} > 2; \text{ SO SACRIFICE ONE OFFSPRING, YOU HAVE TO HELP} \]

- \( > 2 \)

IF ONLY 1 IS SAVED PER UNIT OFFSPRING (1/1), ALTRUISM CANNOT EVOLVE (e.g., \( 1 < 2 \))

SO 3 FACTORS INFLUENCE THE EVOL OF ALTRUISM: \( r \), \( b \) and \( c \)

---

Test of Hamilton’s Rule in Bee-eaters by S. Emlen, P. Wrege and colleagues

- > 50% mortality of nestling
- cooperative breeders: “colony” of nests
- about 50% of nests have helpers: non-reproductive adults that feed and guard nestling
- helpers increase the fledging success of a nest:

<table>
<thead>
<tr>
<th>Group Size</th>
<th>Mean Number of Nestling Fledged</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
</tr>
</tbody>
</table>

- colonies have mixed relatedness
Questions:

1. Does kinship affect the likelihood of becoming a helper?

![Bar graph showing likelihood of becoming a helper with coefficient of relatedness as x-axis.]

2. Does kinship influence whom to help?

![Bar graph showing frequency of kinship as x-axis with coefficient of relatedness.

OBSERVED

EXPECTED]
Test of Hamilton’s Rule in Pied-kingfishers by Reyer

-explicit measurements of the costs and benefits of helping
-communal breeders = tunnels in banks
-male biased sex ratio of population (more males)
-primary helpers: forego mating for first year and stay at natal nest to help sibling
-secondary helpers: help unrelated pairs
-delayers: do nothing and wait until next year

-costly to primary helpers

-return rates:
  primary helpers = 54%
  secondary helpers = 74%
  delayers = 70%

-breeding the following year:
  primary helpers = 60%
  secondary helpers = 91%
  delayer = 33%

---

Test of Hamilton’s Rule in Pied-kingfishers by Reyer

-calculate costs and benefits
-track individuals across two mating seasons
-primary helper = from natal nest

---

<table>
<thead>
<tr>
<th>Behavioral tactic</th>
<th>First year</th>
<th>Second year</th>
<th>Inclusive fitness</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$y$ $r$ $f_1$</td>
<td>$o$ $r$ $s$ $m$ $f_2$</td>
<td>$f_1 + f_2$</td>
</tr>
<tr>
<td>Primary helper</td>
<td>$1.8 \times 0.32 = 0.58$</td>
<td>$2.5 \times 0.50 \times 0.54 \times 0.60 = 0.41$</td>
<td>0.99</td>
</tr>
<tr>
<td>Secondary helper</td>
<td>$1.3 \times 0.00 = 0.00$</td>
<td>$2.5 \times 0.50 \times 0.74 \times 0.91 = 0.84$</td>
<td>0.84</td>
</tr>
<tr>
<td>Delayer</td>
<td>$0.0 \times 0.00 = 0.00$</td>
<td>$2.5 \times 0.50 \times 0.70 \times 0.33 = 0.29$</td>
<td>0.29</td>
</tr>
</tbody>
</table>

*Note: Symbols: $y$ = extra young produced by helped parents; $o$ = offspring produced by breeding birds; $r$ = coefficient of relatedness between the male and $y$ or $o$; $f_1$ = fitness in year 1, $f_2$ = fitness in year 2, $s$ = probability of surviving from year 1 to year 2, $m$ = probability of finding a mate in year 2. 
*Source: Reyer [1985].*
TEST OF KIN SELECTION IN BABOONS
BY BUCHAN AND COLLEAGUES
-BABOONS LIVE IN GROUPS
-OFTEN, JUVENILE MALES FIGHT
-ADULT MALES OFTEN INTERVENE AND TYPICALLY HELP ONE OF JUVENILES
-DOES MALE PREFERENTIALLY HELP HIS OWN OFFSPRING?

EUSOCIALITY

COOPER BROOD CARE + REPROD CASTES + GEN OVERLAP
SOCIAL EVOLUTION

II. EVOLUTION OF SOCIAL BEHAVIOR

EUSOCIALITY

COOPER BROOD CARE + REPROD CASTES + GEN OVERLAP

IN HAPLODIPLOID SYSTEMS:
11 TIMES IN HYMENOPTERANS
1 IN THRIPS
1 TERMITES

IN DIPLOIDS:
1 MOLE RATS

NAKED MOLE RAT

- ONLY GROUP OF EUSOCIAL MAMMALS
- QUEEN WITH MANY WORKERS
- HIGHLY INBRED (HIGH RELATEDNESS)
- ARID ENVIRONMENT WHERE ESTABLISHING NEW COLONIES IS EXTREMELY HARD (LOW SUCCESS RATE)
- XENOPHOBIC
- COOPERATE IN DEFENSE, FOOD GATHERING AND TUNNEL DIGGING
SOCIAL EVOLUTION

II. EVOLUTION OF SOCIAL BEHAVIOR

C. HOW DO YOU TELL KIN?

1. INDIRECTLY: ASSOCIATION (e.g., in nest)

2. DIRECTLY: CUES

   e.g., NAKED MOLE RATS BY ORIAIN AND JARVIS
   - REJECTED FOREIGNERS BASED ON ODOR

D. GENERALIZATION ACROSS TAXA

- EXTENT OF BENEFITS OF HELPING INFLUENCES DEGREE OF KIN DISCRIMINATION
- ANALYSIS BY GRIFFIN AND WEST 2003

Help = correlation between help given and benefit to recipient

Kin = correlation between amount of help and relatedness
   (so + are species that show preferential help to kin, while – show opposite preferential help)
SOCIAL EVOLUTION

III. COOPERATION AMONG NON-KIN

A. RECIPROCAL ALTRUISM (TRIVERS 1971)

-PRISONER’S DILEMMA

PLAYER A ACTION

<table>
<thead>
<tr>
<th>PLAYER B ACTION</th>
<th>COOPERATE : C</th>
<th>DEFECT: D</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>R (both light sentence)</td>
<td>S (sucker gets longer sentence)</td>
</tr>
<tr>
<td>D</td>
<td>T (temptation, defector's sentence reduced)</td>
<td>P (punishment for both)</td>
</tr>
</tbody>
</table>

PAYOFFS ARE: T > R > P > S, AND R > (S+T)

BOTH SHOULD COOPERATE, BUT A DOES BEST TO DEFECT WHEN B COOPERATES

ONE TIME INTERACTION: BOTH D
MULTIPLE INTERACTIONS: TIT FOR TAT

---

SOCIAL EVOLUTION

III. COOPERATION AMONG NON-KIN

A. TEST OF RECIPROCAL ALTRUISM – TIT FOR TAT

Vampire Bats
by G.S. Wilkinson

• individuals feed on blood from mammals
• will starve to death after 60 hours of no feeding
  33% young bats fail to feed at night
  7% of adults fail to feed at night
• others regurgitate blood meals
• social system: 8-12 adult females + offspring roost in hollow trees
• roost make-up changes daily, so interactions with kin and non-kin

What factor determines who to regurgitate to?

PREDICTIONS:

KIN SELECTION – REGURGITATE TO KIN

RECIPROCAL ALTRUISM – REGURGITATE TO RECIPROCAL BAT
SOCIAL EVOLUTION

III. COOPERATION AMONG NON-KIN

A. TEST OF RECIPROCAL ALTRUISM

Vampire Bats
by G.S. Wilkinson

RESULTS: GENETIC RELATEDNESS AND DEGREE OF ASSOCIATION IMPORTANT IN WHO GETS REGURGITATED BLOOD

---

SOCIAL EVOLUTION

III. COOPERATION AMONG NON-KIN

A. TEST OF RECIPROCAL ALTRUISM – TIT FOR TAT

Additional Prediction of Model: Costs of regurgitating cannot outweigh the benefits to the recipient

RESULTS: Loss of 5 ml of blood from donor (pink) results in about 4 hours towards starvation, but the same amount of blood results in about 17 hours away from starvation
SOCIAL EVOLUTION

III. COOPERATION AMONG NON-KIN

A. TEST OF RECIPROCAL ALTRUISM – TIT FOR TAT

Vampire Bats
by G.S. Wilkinson

Additional Prediction: Individuals should recognize roost mates

EXPERIMENT:

In one cage put --
3 adult females from roost 1
4 adult females, 1 infant and 1 adult male from roost 2 (> 50 km away)
Unrelated individuals
Starve individuals, then return them to cage to see who feeds it

RESULTS:

12 of 13 blood regurgitations occurred between bats from same population.
Also, probability of donating directly related to being fed before

III. COOPERATION

B. MUTUALISM

Work on Taï Chimpanzees by C. Boesch

- Groups of about 8 individuals, that join and break from larger communities of 30-80 individuals
- Feed on fruits and leaves, but also meat: Colobus monkeys
- 84% of hunts involve > 2 chimpanzees
- Hunt in groups of 4-5 individuals
- 42% of the group do not participate in the hunt, but eat the prey - cheaters
- LOW RELATEDNESS among chimpanzees

IS THERE AN ADVANTAGE TO EVERYONE BY COOPERATING?
III. EVOLUTION OF COOPERATION

B. MUTUALISM

Work on Tai Chimpanzees by C. Boesch

PREDICTION: INDIVIDUALS BENEFITS WHEN COOPERATING

RESULTS: INDIVIDUALS GAIN MORE WHEN HUNTING COOPERATIVELY – HIGHER SUCCESS RATE, MORE MEAT

BUT...

THERE ARE CHEATERS WHO DO NOT HUNT

CHEATERS GAIN LESS THAN HUNTERS, SO COSTS OF BEING CHEATED IS LIKELY OFFSET BY THE BENEFITS OF COOPERATION
III. EVOLUTION OF COOPERATION
B. MUTUALISM

Work on African wild dogs by S. Creel

INDIVIDUALS GAIN MORE MEAT WHEN HUNTING COOPERATIVELY & HAVE HIGHER REPRODUCTIVE SUCCESS IN BIGGER GROUPS

DILUTION EFFECT: GROUPING

- LARGER GROUP, LESS LIKELY (PER CAPITA) INDIVIDUAL WILL BE CAPTURED

REDSHANK BY CRESSWELL

- MORE INDIVIDUALS IN A FLOCK, LESS LIKELY EACH INDIVIDUAL IS ATTACKED
III. EVOLUTION OF COOPERATION

B. MUTUALISM

DILUTION EFFECT

EXTENSION: SELFISH HERD

- nest in colonies, and males defend nests
- older and larger males are dominant and typically win central spots
- why try to be in the center??

Cooperative Defense

-in many mammals, adults will surround young when predators are a threat

Musk ox surrounding young (circular defensive formation) in the presence of predators (like wolves)
Only social species of cats
Fission-fussion social units of multiple females and cubs, with coalition of adult males
-ranges from 1 to 18 adult females
-group foraging/hunt
-defend territory from other prides
-defend young from infanticide males

What factors favor social behavior in lions?
How is this social interaction maintained?

What factors favor social behavior in lions?
Hypothesis 1: Foraging success of larger groups is higher than smaller groups or solitary individuals

-no advantage during time of prey abundance
-some advantage during prey scarcity
-NOT true for groups of 2-4
-solitary does as well as large groups
What factors favor social behavior in lions?

Hypothesis 2: Defense against infanticide males

- males often take over pride and carry out infanticide to induce females into estrus
- females associated in large groups when raising cubs
- larger groups defended cubs against males

<table>
<thead>
<tr>
<th>NO. OF DEFENDING FEMALES</th>
<th>AGGRESSIVE ENCOUNTERS BETWEEN FEMALES AND EXTRA-PRIDE MALES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Some Cubs Survive</td>
</tr>
<tr>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>≥2</td>
<td>1</td>
</tr>
</tbody>
</table>

Note. — Data were collected from 1978 to 1988. Note that no defending males were present in any of these encounters. Fisher test, P < .05.

SUMMARY:

FOOD, CUB DEFENSE AND TERRITORY DEFENSE ALL EXPLAIN GROUPING IN LIONS

Why did it evolve in lions?
1. High density — lead to shared defense of resources or territories
2. Large prey pattern of resource renewal — deplete one spot and forage in another spot, then previous spot eventually gets renewed in the territory
III. EVOLUTION OF COOPERATION

C. DELAYED BENEFITS

-long-tailed manakin work by McDonald and Potts
-males form stable coalition and cooperate in displaying to females
-females prefer unison songs

why pair up?

1. direct benefits? No

-259 of 263 observed mating across 33 pairs were received by alpha male.

2. kin selection? No

$r$ of pairs: -0.14 (-.35 to 0.07, 95% confidence interval)
17 of 33 pairs had negative $r$

III. EVOLUTION OF COOPERATION

C. DELAYED BENEFITS

-when alpha dies, beta takes over
(11 of 11 cases of alpha male death)

-because females typically return to the same court, beta reaps benefits
IV. COST OF SOCIAL BEHAVIOR/LIVING

A. INCREASED COMPETITION FOR RESOURCES
Fieldfares (a song bird) nest in loose colonies in woodlands
As colony size increases, the probability of nest survival increases
However, as colony size increases the probability of survival for specific nestlings decreases

B. PARASITES
- increased parasite transmission
- cliff swallow work by Brown and Brown
- cliff swallows nest in colonies
- prevalence of swallow bugs is higher in larger colonies
IV. COST OF SOCIAL BEHAVIOR/LIVING

B. PARASITES

- Parasite infestation negatively correlated with body size
  (at day 10)

C. Increased risk of exploitation by other members of group

- Acorn woodpeckers in CA live in large social groups
- Females can cheat by removing the existing eggs from and laying their
  own eggs in another females nest.

### Table 2

<table>
<thead>
<tr>
<th>Colony size (no. active nests)</th>
<th>Nestling body mass (g)</th>
<th>F</th>
<th>N†</th>
<th>P‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 10 F</td>
<td>22.9</td>
<td>0.9</td>
<td>7</td>
<td>.19</td>
</tr>
<tr>
<td>NF</td>
<td>20.3</td>
<td>1.1</td>
<td>4</td>
<td>.38*</td>
</tr>
<tr>
<td>43 F</td>
<td>22.9</td>
<td>0.5</td>
<td>21</td>
<td>.052</td>
</tr>
<tr>
<td>NF</td>
<td>22.1</td>
<td>0.8</td>
<td>19</td>
<td>.001*</td>
</tr>
<tr>
<td>56 F</td>
<td>24.0</td>
<td>0.5</td>
<td>16</td>
<td>.001*</td>
</tr>
<tr>
<td>NF</td>
<td>21.5</td>
<td>1.1</td>
<td>7</td>
<td>.001*</td>
</tr>
<tr>
<td>75 F</td>
<td>23.8</td>
<td>0.3</td>
<td>16</td>
<td>.001*</td>
</tr>
<tr>
<td>NF</td>
<td>21.1</td>
<td>0.5</td>
<td>15</td>
<td>.001*</td>
</tr>
<tr>
<td>125 F</td>
<td>24.2</td>
<td>0.3</td>
<td>33</td>
<td>.001*</td>
</tr>
<tr>
<td>NF</td>
<td>21.0</td>
<td>0.7</td>
<td>40</td>
<td>.001*</td>
</tr>
<tr>
<td>345 F</td>
<td>23.7</td>
<td>0.2</td>
<td>86</td>
<td>.001*</td>
</tr>
<tr>
<td>NF</td>
<td>20.3</td>
<td>0.3</td>
<td>69</td>
<td>.001*</td>
</tr>
</tbody>
</table>

† Sample size (number of nests). For the colony size listed as < 10 nests, the total sample size (F + NF nests) is > 10 because data from several colonies were pooled.
‡ From Mann-Whitney U tests comparing F and NF nests. Since body masses of nestlings within a nest were not statistically independent, analyses were based on average nestling body mass for each nest. Significant differences indicated by *.
IV. SUMMARY

BENEFITS OF SOCIAL LIVING
1. DILUTION EFFECT OR ACTIVE DEFENSE
2. IMPROVED FORAGING/PREY ACQUISITION
3. IMPROVED CARE OF OFFSPRING (COMMUNAL BREEDERS)

COSTS OF SOCIAL LIVING
1. INCREASED COMPETITION WITHIN GROUPS FOR RESOURCES
2. INCREASED RISK OF INFECTION
3. INCREASED RISK OF EXPLOITATION OR INTERFERENCE OF PARENTAL CARE

CONSERVATION IN VERTEBRATES

I. MAJOR THREATS

II. BREAK-DOWN OF DANGERS ACCORDING TO THE WORLD CONSERVATION UNION RED LIST

<table>
<thead>
<tr>
<th>TAXA</th>
<th># SPECIES</th>
<th># SP STUDIED</th>
<th>#THREATENED</th>
<th>%THREATENED</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAMMALS</td>
<td>4842</td>
<td>4789</td>
<td>1130</td>
<td>23% [24%]</td>
</tr>
<tr>
<td>BIRDS</td>
<td>9932</td>
<td>9932</td>
<td>1194</td>
<td>12% [12%]</td>
</tr>
<tr>
<td>REPTILES</td>
<td>8134</td>
<td>473</td>
<td>293</td>
<td>4% [62%]</td>
</tr>
<tr>
<td>AMPHIBIANS</td>
<td>5578</td>
<td>401</td>
<td>157</td>
<td>3% [39%]</td>
</tr>
<tr>
<td>FISHES</td>
<td>28100</td>
<td>1532</td>
<td>750</td>
<td>3% [49%]</td>
</tr>
<tr>
<td>TOTAL</td>
<td>56586</td>
<td>17127</td>
<td>3524</td>
<td>6% [21%]</td>
</tr>
</tbody>
</table>
III. CASE STUDIES

A. INTRODUCTION OF NOVEL PREDATORS OR COMPETITORS

e.g., brown tree snake in Guam

- naturally found in Australia, New Guinea and Melanesia
- likely introduced from New Guinea by a ship (stow-away) in 1960s
- no snakes on island and endemic species never been exposed to this predator
- eat eggs, birds and small mammals

Vertebrates in Guam evolved in the absence of snake

- introduction of the brown tree snake dessimated local fauna:
  - Birds: 9 of 11 forest dwelling species are extinct in the wild
  - Lizards: 4 of 10 natives extirpated (2 more are rare)

Slevin’s skink
Micronesian kingfisher
Guam flycatcher
Guam rail
III. CASE STUDIES

A. INTRODUCTION OF NOVEL PREDATORS OR COMPETITORS

Solution?
1. Snake-detector dogs to check cargo for snakes
2. Traps with live baits
3. Habitat modification – removal of attractive sites for nesting

Other introduction problems: Rabbits in Australia, Starlings in the U.S.

III. CASE STUDIES

B. LOSS OF HABITAT AND LOSS OF GENETIC VARIATION

99% OF THREATED BIRD SPECIES IS DUE TO HUMAN ACTIVITIES

Decline of the greater prairie chicken in Illinois
- prairies abundant ca. 200 years ago
- 1837, steel plows allowed farmers to farm prairies, converting them to farms
- range shrank, and so numbers shrank

http://www.audubon.org
Decline of the greater prairie chicken in Illinois
-range shrank, and so numbers shrank
-1933, hunting was banned
-1962 and 1967, reserves established to help populations rebound
-so 60s to 70s, populations increased
-BUT by mid 70s pops crashed, to the point that only 5-6 males were observed displaying in leks

WHY?

WORK BY Westenmeier and colleagues
1. reduction of population size
2. fragmentation of populations

INBREEDING
-loss of variation and increase of homozygosity
-also, no choice but to mate with related individuals

Is there inbreeding depression (problems)?
1. survey data indicates that egg hatching success rate declined in time.
CONSERVATION IN VERTEBRATES

III. CASE STUDIES
B. LOSS OF HABITAT AND LOSS OF GENETIC VARIATION

WORK BY Bouzat and colleagues

Is this due to increased levels of homozygosity?
1. Yes, other larger populations outside Illinois and pre-bottleneck population of Illinois show more genetic variation

<table>
<thead>
<tr>
<th>Locus</th>
<th>Illinois</th>
<th>Kansas</th>
<th>Minnesota</th>
<th>Nebraska</th>
<th>Illinois pre-bottleneck*</th>
</tr>
</thead>
<tbody>
<tr>
<td>AD142</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>AD123</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>AD144</td>
<td>4</td>
<td>7</td>
<td>8</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>AD1140</td>
<td>3</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>AD1162</td>
<td>2</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>AD1230</td>
<td>6</td>
<td>9</td>
<td>8</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>Mean</td>
<td>3.67</td>
<td>5.82</td>
<td>5.33</td>
<td>5.83</td>
<td>5.12</td>
</tr>
<tr>
<td>SE</td>
<td>0.56</td>
<td>0.75</td>
<td>0.94</td>
<td>1.05</td>
<td>0.87</td>
</tr>
<tr>
<td>Sample size</td>
<td>32</td>
<td>37</td>
<td>48</td>
<td>90</td>
<td>79</td>
</tr>
</tbody>
</table>

Note: SD indicates standard deviation of mean number of alleles per locus. The Illinois population in column 1 shows significantly less allelic diversity than the rest of the populations (P = 0.05).

*Number of alleles in the Illinois pre-bottleneck population include both extinct alleles that are shared with the other populations and alleles detected in the museum collection.

Source: From Bouzat et al. (1998).

WORK BY Westenmeier and colleagues

If it is lack of genetic variation, gene flow should help...introduce individuals from other populations

Yes, population in Illinois is now rebounding!
III. CASE STUDIES

C. San Francisco Garter Snake *Thamnophis sirtalis tetrataenia*
- a subspecies of the common garter snake
- destruction of habitat in the East Bay has lead to the decline of this species, and currently, since 1967, it is listed as an endangered species and is protected by law
- 1940’s survey down Skyline Blvd indicated that this subspecies is very common near ponds and water sources
- 1950’s, habitat turned to housing developments. All habitat turned to housing by 1960’s
- Recent surveys indicate populations near Skyline are extinct
- Now 65 populations are found in the Peninsula
- Estimated number is about 1500 individuals across these populations.

D. The California Condor *Gymnogyps californianus*
- One of the largest North American birds: 22 lbs, 9.5 ft wingspan
- Early 1900’s population started declining due to hunting and lead poisoning (from bullets that kill mammals) + low reproductive rate (1 egg every other year)
- By 1940, only about 100 left in CA
- 1985, only nine left in the wild (all of NA)
- 1987, last wild condor was captured for captive breeding, joined with 26 others
- Only populations left were in San Diego and LA Zoos.
- 1992 first individuals released in the wild in Ventura County
- 2002: total population back to 202, with 73 released in the wild